INTELLIGENT USE OF MARITIME INFO-COMMUNICATION SYSTEMS IN DEVELOPING ENVIRONMENTS

Submitted in fulfilment of the requirements for the Doctor of Engineering degree: Electrical Power Engineering in the Faculty of Engineering and Built Environment at the Durban University of Technology

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Declaration by the student

Intelligent use of maritime info-communication systems in developing environments

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l confirm that this thesis is composed of my original work and contains no material previously submitted to the Durban University of Technology or any other institution for academic qualifications. The content of my thesis consists of work I have carried out since the commencement of my DEng studies.

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I hereby approve the final submission of the following thesis.

Prof Sanja Bauk **Prof Innocent E. Davidson**

This __11__ day _____May_____ of 2023 at the Durban University of Technology.

Abstract

The doctoral dissertation entitled "**Intelligent use of maritime info-communication systems in developing environments**" examines to which extent some maritime entities in developing countries use rationally (intelligently or smartly) Information Communication Technology and Systems (ICT&S). In addition, the dissertation examines readiness of considered maritime entities to introduce and adopt novel, sophisticated ICT&S in the future. In this regard, the explorative, comparative and causal studies have been carried out in several maritime companies in Albania, Bosnia and Herzegovina, Croatia, Greece, Italia, Montenegro, Serbia, Slovenia, and South Africa. The objectives of these studies were contemporary maritime ICT&S like Electronic Data Interchange (EDI), Port Community System (PCS), Enterprise Resource Planning (ERP), Customer Relationship Management (CRM), Electronic Logistics Marketplace (ELM), Blockchain Technology (BCT), Vessel Traffic Monitoring Information System (VTMIS), THETIS System as a part of Port State Control (PSC), SafeSeaNet (SSN), European Common Information Sharing Environment (CISE), Sea Traffic Management (STM), e-Navigation, e-Maritime, Maritime Cloud, Common Maritime Communication Platform (CMCP), (Satellite) Automatic Identification System ((S)AIS), Electronic Chart Display and Information System (ECDIS), Long Range Identification and Tracking (LRIT), Maritime Surveillance Service (MSS), Earth Observation Services (EOS), Satellite-based Oil Spill Detection System (SOSDS), Oil Spill Prediction Modeling System (OSPMS), Maritime Single Window (MSW) or Maritime Single Environment (MSE), Digital Twins (DT), and Autonomous aerial/sea surface/underwater Vehicles (AxV). The number and capacities of these complex, contemporary ICT&S speak in favor of rapid and huge digital changes in maritime. Developing countries, with generally vertically integrated administration and transitional economy, challenging operating environments, along with fragile social freedom, face numerous impediments in implementing these ICT&S. Therefore, the goal of this dissertation is to identify challenges in new digital technologies adoption and in achieving related innovation success in the emerging countries, including South Africa and proper solution options to addressing these challenges, using the best international practice.

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Abbreviations

(S)AIS	(Satellite) Automatic Identification System
4IR	4^{th} Industrial Revolution
AC	Autonomic Computing
AGV	Automatic Guided Vehicle
AI	Artificial Intelligence
AISA	Autonomous Intelligent Software Agents
AMSPM	Administration for Marine Safety and Port Management
AMV	Autonomous Maritime Vehicles
API	Application Programming Interface
APMEN	Asia-Pacific Model Electronic Port Network
ATA	Approximate Time of Arrival
ATD	Approximate Time of Departure
AUV	Autonomous Underwater Vehicle
AxV	Autonomous aerial/sea surface/underwater Vehicles
B&H	Bosnia and Herzegovina
BC	Blockchain
BCO	Beneficiary Cargo Owners
BCT	Blockchain Technology
BLoS	Beyond Line of Sight
BMSCS	Blockchain-based Maritime Supply Chain System
C2	Command & Control
CCC	Container Crypto Coin
CISE	European Common Information Sharing Environment
CMCP	Common Maritime Communication Platform
CNN	Convolutional Neural Network
COMPASS	Coordination Of Maritime assets for Persistent And Systematic Surveillance
COP	Common Operation Platform

CPT	Container Platform Token
CR	Collision Risk
CRM	Customer Relationship Management
CSF	Critical Success Factors
CTD	Conductivity, Temperature and Depth
dApps	distributed Apps
DCSA	Digital Container Shipping Association
DF	Data Fusion
DL	Deep Learning
DS	Decision Support
DT	Digital Twins
EC	European Commission
ECDIS	Electronic Chart Display and Information System
ECRE	Empty Container Repository Engine
EDI	Electronic Data Interchange
EEA	European Economic Area
ELM	Electronic Logistics Marketplace
EMSA	European Maritime Safety Agency
ENC	Electronic Navigation Charts
EO/IR	Electro-Optical/Infra-Red
EOS	Earth Observation Services
ePIcenter	Enhanced Physical Internet-Compatible Earth-frieNdly freight Transportation answER
EPIRB	Emergency Position Indicating Radio Beacon
ERP	Enterprise Resource Planning
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
EU	European Union
FEU	Forty Equivalent Unit
FIS	Fuzzy Inference System
GDP	Gross Domestic Product
GMDSS	Global Maritime Distress and Safety System
GPS	Global Positioning System

GSCP	Global Shared Container Platform
GSCR	Global Shipping Container Registry
ICO	Initial Coin Offering
IBM	International Business Machines (Corporation)
ICT&S	Information Communication Technology and Systems
IHO	International Hydrographic Organization
II	Industrial Internet
IMO	International Maritime Organization
INS	Inertial Navigation System
INUS	Intelligent UxV Surveillance
IoE	Internet of Everything
IOS	Inter-organizational information systems
IoT	Internet of Things
ISTAR	Intelligence, Surveillance, Target acquisition And Reconnaissance
IT	Information Technology
ITAR	International Traffic in Arms Regulations
IVEF	Intra-VTS Exchange Format
JDL	Joint Directors of Laboratories
LARS	Launch and Recovery System
LBL	Long Baseline
LRIT	Long Range Identification and Tracking
LoS	Line of Sight
LR	Lloyd's Register
LRIT	Long Range Identification and Tracking
LSTM	Long Short-Term Memory model
MAD	Mean Absolute Deviation
MAPE	Mean Absolute Percent Error
MBL	Maritime Blockchain Labs
MC	Maritime Cloud
MIT	Massachusetts Institute of Technology
ML	Machine Learning
MO	Marine Operations

MOC	Maritime Operations Center
MS	Mission System
MSDA	Maritime Situational and Domain Awareness
MSDBN	Multi-Source Dynamic Bayesian Network
MSE	Maritime Single Environment
MSE	Mean Square Error
MSS	Maritime Surveillance Services
MSW	Maritime Single Window
MTOW	Maximum Take-Off Weight
NAVDAT	Navigation Data
NavTex	Navigation Telex
NBDP	Narrow-Band Digital Printing
NMSW	National Maritime Single Window
non-SOLAS	non-International Convention on Safety of Lives at Sea
OC	Operations Centre
ODADS	Open Data Anomaly Detection System
OPV	Oceanic Patrol Vessel
OSPMS	Oil Spill Prediction Modelling System
OWL	Ontology Web Language
PCS	Port Community System
PESTEL	Political, Economic, Social, Technological, Environmental, Legal impacts
PSC	Port State Control
PSF	Prime Shipping Foundation
RFID	Radio Frequency IDentification
RMP	Recognized Maritime Picture
ROV	Remotely Operated (underwater) Vehicle
SAIS	Satellite Automatic Identification System
SAR	Search and Rescue
SAS	Synthetic Aperture Sonar
SBL	Short Baseline
SC	Smart Contract
SE	Standard Error

SEE	South-East Europe
SLAM	Simultaneous Localization and Sampling
SLoS	Short Line of Sight
SOLAS	Safety of Life at Sea
SOSDS	Satellite-based Oil Spill Detection System
SSN	Safe Sea Net
STM	Sea Traffic Management
SWOT	Strengths Weakness Opportunities Threats
TEU	Twenty Equivalent Unit
UAV	Unmanned Aerial Vehicles
UML	Unified Modelling Language
USA	United States of America
USB	Ultra-Short Baseline
USD	United States Dollar
USV/UUV	Unmanned Sea/Underwater Vessels
UxV	Unmanned (aerial/sea/underwater) Vehicle
VDES	Very High Frequency Data Exchange Service
VGM	Verified Gross Mass
VHF	Very High Frequency
VLF	Very Low Frequency
VTMIS	Vessel Traffic Monitoring Information System
VTS	Vessel Traffic Service
VTSMIS	Vessel Traffic Service Management Information System

CHAPTER I: Introduction

1. Introduction

1.1 Background

Maritime is an important industry. Over 80% of the total transport of all goods takes place by sea [1], since it is the most efficient and massive mode of transportation. The world's seas provide free waterways. These are the largest absorbers of carbon dioxide and the largest producers of oxygen. The seas are the main source of food for one third of the world's population [2]. Furthermore, oil and diamonds are extracted from the seabed.

Despite these, the seas are exposed to the pollution caused by both natural disasters and human factors. An additional paradox related to the world's ocean is that maritime lags significantly behind other industries and businesses in terms of digitalization. Among the main reasons is a large number of non-International Convention on Safety of Lives at Sea (non-SOLAS) ships. In 2016, it was estimated that 60 000 non-SOLAS ships are going to use Electronic Navigation Charts (ENC) and its up-to-date services [3]. This means, that until 2016, these vessels did not use neither ENC nor Electronic Chart Display and Information Systems (ECDIS), which is obligatory due to both International Maritime Organization (IMO) and International Hydrographic Organization (IHO) regulations for the majority of vessels sailing through international waters. Since concept of smart or e-Navigation aims reducing number of accidents for SOLAS ships for 65%, non-SOLAS ships cannot be neglected, especially in confined waters and those with heavy traffic. Some research analysis in this respect were done in South Korea. Within the accidents of more than 3000 vessels encountered, only 13% of SOLAS ships were involved, while the rest, i.e., 87%, were non-SOLAS ships [4]. Hereof, numerous ships, which do not comply with SOLAS regulations, will slow down the process of e-Navigation and common communication maritime platform implementation. Besides, some ships do not have modern electronic navigation aids as (Satellite) Automatic Identification System ((S)AIS), chart radar, and the like. Analyzes of some severe accidents at sea have shown that the crew usually is not familiar with advanced electronic navigational devices onboard ship [5], [6].

The inter-organizational information systems (IOS) are used 75% in hinterland and only 25% offshore [7]. Internet of Things (IoT), Internet of Everything (IoE) or Industrial Internet (II) in the context of the 4th Industrial Revolution (4IR), is used considerably less at sea than at land. In road and rail transport, it is possible to track cargo at the level of a single unit or a container, while in maritime transport this is still not achieved [8], [9], [10], [11], [12]. The research of networks at sea is much more complex in comparison to land due to sea surface movements, wave occlusions, multipath feeding, urban canyon effect, poor coverage, etc. [13]. Having in mind all these impediments, different communication channels such as Very High Frequency Data Exchange Service (VDES) and Navigation Data (NAVDAT) are developed with the aim of overcoming the connectivity issues and/or low stability of internet at vast seas [14].

In addition to the afore stated, there are thousands of autonomous vehicles on roads and millions of registered drones, but only one autonomous ship ("Falco"), and another one, which is currently under construction ("Yara Birkeland") [15]. In addition to this, blockchain technology is not widely accepted yet, e.g., since there are various impediments like the lack of trust between stakeholders, the lack of governmental support, legislation regulations, stakeholders' readiness for risky investments in emerging technology, and the like. An extensive desktop study of academies writings in maritime [16] shows that very small percentage of articles deals with advanced marine info-communication concepts such as big data, virtual intelligence, robotics, 3D printing, virtual and/or augmented reality, digital security, etc. There is no clear strategy for further development of Info-Communication Technologies and Systems (ICT&S) in maritime. This complicates maritime digitization in developed countries, and even more in developing or emerging ones.

Regardless of the fact that maritime industry and business are more conservative than other industries and businesses in general, and in terms of digitalization as well, we will refer to some important digitalization achievements in maritime so far. For instance, ECDIS revolutionary changed traditional way of navigation in the second half of the 1990s, and there is tendency for its full implementation at the global scale [17], [18], [19]. The ECDIS became obligatory for newly built ships. The concepts of Sea Traffic Management (STM), e-Navigation and common maritime communication platform are steps further in comparison to the ECDIS well established navigation decision support system onboard and ashore. These advanced systems should provide smooth communication at bidirectional relations between ships, ports, and on shore based safety, legal, business, industry and other relevant entities. These should reduce risks of accidents, environmental impacts and costs [20], [21]. The Maritime Cloud or common maritime communication platform is conceived to support STM and e-Navigation concepts by means of well-known communication channel such s as Very High Frequency (VHF) radio, Navigation Telex (NavTex), Automatic Identification System (AIS), etc. Newer communication channels as VHF Data Exchange (VDES), Navigation Data (NavDat), Narrow-Band Digital Printing (NBDP), Satellite Automatic Identification System (SAIS) are deployed now-a-days more intensively [22]. Some pioneer steps in deploying remotely controlled and unmanned underwater and sea surface vessels have been recently undertaken [23], as well. Seaports as enablers of berth-to-berth navigation and key nodes of sea-land transportation use different ICT&S solutions like Electronic Data Interchange (EDI), Vessel Traffic Service (VTS), Vessel Traffic Monitoring Information System (VTMIS), Port Community System (PCS), Enterprise Resource Planning (ERP), Customer Relationship Management (CRM), access to the Electronic Logistics Marketplace (ELM), Blockchain (BC), etc. Furthermore, the concepts of e-Maritime, Maritime Single Window/Environment (MSW/E), Common Information Sharing Environment (CISE) and the like [24], [25]. Contemporary ICT&S support multimodal, intermodal, co-modal, and/or synchro modal transportation chains bringing multiple benefits to all involved parties, by providing real-time visibility, efficient data exchange, and higher flexibility in the context of unexpected changes during the shipments [26], [27]. There has been a debate about ICT&S being the major technological and organizational facilitator of economic globalization by creating 'death of distance' [28] and 'flat world' [29]. However, it is not possible to exclude the role of containerization [30]. The combination of both containerization and ICT&S allowed the reduction of shipping costs and uplift logistics and supply chain management [31]. Ships, seaports and ICT&S play important roles in the world trade. Apart from this, they are still insufficiently present among research trends, particularly in developing counties, which usually function in transitional conditions.

In general, we are witnessing massive progress in the field of ICT&S. The question is do we really need all these innovations and do they always make our lives easier and better. In order to grasp the best of ICT&S, we need to know which of these technologies we actually need and how to use them purposely. When it comes to a business environment, it is very important that higher management structures are aware of these needs and discuss them with employees. This is especially important in maritime business, bearing in mind that stakeholders in maritime are usually conservative and not 'early new technology adopters'.

Throughout the publications on which this dissertation is based we explored to which extent some stakeholders in maritime, in developing countries as Albania, Bosnia and Herzegovina, Croatia, Greece, Italia, Montenegro, Serbia, and Slovenia intelligently use available ICT&S resources. Additionally, we indirectly assessed their readiness to adopt new technologies. As a methodological framework, we used Holtham's & Courtney's model [32], [33], [34], [35], [36], [37], [38], which encompasses the following key constructs: information and knowledge, ICT&S management of roles and skills, internal and external communication, organizational culture, ICT&S strategy and manager's mindset, which has to bind all other components intelligently. The hypothetical-deductive approach, which includes identifying a broad problem area, defining the problem statement, hypothesizing, determining measures, data collection, data analysis, and the interpretation of results, has been used, firstly. Then, an inductive approach was applied [39]. After a comprehensive study in the field, we noticed some similarities and differences in European Union (EU) and non-EU countries, which were subject of the research. Through this study, we developed a multiple linear regression model, which depicts dependence between intelligent use of existing ICT&S, employees' knowledge about the technology, ICT&S management, maritime business systems' effectiveness and related organizational culture [40]. The proposed model fits well in the considered sample of collected data, but it should be uplifted at the level of theory through further more rigor and extensive research in this area.

Regarding actual Blockchain Technology (BCT) and its deployment in maritime, we tested the level of stakeholders' awareness and knowledge about BCT and their readiness to adopt it [41], [42]. The research was based on exploratory sequential mixed method design, where we began with the qualitative research and ended up with quantitative one. Analysis was done upon the pool of experienced maritime stakeholders in maritime from South Africa and Montenegro. The findings are presented in the form of PESTEL (Political, Economic, Social, Technological, Environmental, Legal impacts) or 'fishbone' diagram and through discussion of the collected qualitative and quantitative data, including the limitations and clear proposal for further studies in this sphere.

The set of studies and publications within the scope of the dissertation encompasses, as well, developing a cost-benefit model for emerging countries assessment to the European Common Information Sharing Environment (CISE). This advanced digital platform enhances maritime border security, primarily when it comes to prevention of illegal migrations. The model, which we proposed offers novel perspectives and insights that can be universally useful experiences to different CISE implementation initiatives, especially for developing countries [43].

Advanced autonomous aerial, sea, and underwater vehicles' (AxV) performances were also investigated through the prism of the Strengths Weakness Opportunities Threats (SWOT) approach. Different types of autonomous assets were analyzed at high level of abstraction, including the requirements for data and information integration into common communication platform, with the purpose of enhancing safety and security of maritime borders regarding illegal migrations and drug smuggling. Upon the analysis, we found out a strong argument in favor of increasing initiatives for testing, validating and integrating unmanned systems within current surveillance infrastructures, both at land and sea, since these assets can enhance actual surveillance and monitoring in a cost-effective way. However, the so-called 'blind-belief in technology', including the analyzed AxVs, should be interrogated. The readiness of the stakeholders in maritime to implement and adopt these advantageous systems should be further investigated, with the aim of justifying the innovation implementation success in both military and civil marine traffic and surveillance missions [44], [45], [46], [47], [48], [49].

Let us conclude this general introduction with two citations, highlighting the need for serious consideration of smart implementation and exploitation of highly sophisticated, super-complex ICT&Ss. Oxford's Michael Wooldridge says: "It takes time for the technology to become really embedded and for people to find the right way of using it" [50, p.42]. If we assume that this component of rational ICT&S application is fulfilled, then we should not forget that "the basic attitude should be that technology has to improve the human condition, and not replace humans" [50, p.165].

1.2 Problem statement

There is no clear ICT&S development strategy in maritime. Innovations and their success in this field are limited to the level of different research projects implemented fragmentally in the developed parts of the world. On the other side, the whole continents or parts of the continents are excluded from the plans for digital transformation in maritime; for instance: Africa, Latin America, South-East Europe and Central Asia. Developing or emerging countries suffer the lack of awareness and knowledge regarding rational implementation and adoption of advanced ICT&C in maritime. Consequently, the goal of this study is to examine challenges of digital transformation, in particular within the developing maritime economies of South Africa and Montenegro. Not only revealing out these challenges, but also pathing the way towards smart adoption and exploitation of new disruptive ICT&S in emerging maritime sector is the goal of this research work. This will be done through collecting relevant information and drawing recommendations for rational digital transformation in maritime by including all stakeholders. Through uprising the level of awareness and knowledge in maritime digital transformation, dissipation of scarce human and monetary resources in developing countries (South Africa and Montenegro) can be avoid, while efficiency, effectiveness and productivity can be increased across the maritime cluster. Seafarers and employees on land side, should attain higher level of productivity and satisfaction by using rationally sophisticated ICT&S within their working environment off and on shore in the future. This will lead to the digital innovation success and prosperity in maritime, with emphasize on emerging coastal regions.

1.3 Aim and objectives

Digitalization in maritime is lagging behind other industries. Additionally, the level of intelligent exploitation of the available maritime info-communication systems, especially in developing countries is rather low. This is a problem, especially if we bear in mind the need of making quick adoption to the forthcoming considerably more complex, sophisticated and demanding, disruptive ICT&S in terms of their usage, maintenance, and upgrading their functions and applications in the actual digital era.

Aim:

The aim of the dissertation is to examine the level of rationality, intelligence or smartness at which maritime entities in selected South-East Europe (SEE) developing countries (Albania, Bosnia and Herzegovina, Croatia, Greece, Italia, Montenegro, Serbia, and Slovenia) and in South Africa adopt available maritime business and sea-traffic management systems, including those for marine surveillance. This is done with the ultimate goal of optimal deployment of scarce human and monetary resources in digital transformation in emerging maritime environments, along with enhancing innovation success and common socio-economic prosperity and growth in selected regions.

Objectives:

1. Assessing the level of rationality in deploying advanced ICT&S in some selected maritime entities in emerging economies with accent on knowledge, management skills, IT strategy, system efficiency, and organizational culture as key constructs for smart implementation and adoption of novel ICT&S.
2. Evaluation of the selected maritime entities readiness to implement and adopt disruptive blockchain technology in maritime supply chain management and logistics due to specific political, economic, social, technological, environmental, and legal conditions in South Africa and Montenegro.
3. Appraisal of the advantages and disadvantages of the advanced unmanned aerial vehicles like medium altitude aircrafts (AR3 and AR5) and high altitude pseudo satellite (Zephyr) for maritime surveillance across the borders of the coastal regions.

1.4 Key research questions

The research objective and questions are strongly related. It would be impossible to adequately detail the research questions if the research objective had been unclear, unspecified, or ambiguous. What's more, the research questions have been clarified to the extent that it is possible to relate them to existing literature in the area of digital transformation in maritime, with emphasis on developing littoral zones. The purpose of this research study is to identify the level of rational implementation of advanced ICT&S in maritime and to draw recommendations for smarter digital transformation in the future, with the ultimate goal of enhancing growth and prosperity of emerging coastal regions, while the focus is on South Africa and Montenegro. Research objective is twofold: (1) to assess the level of rationality in implementing and adopting advanced maritime ICT&S by selected maritime entities in developing countries, and (2) to upraise the level of awareness and common knowledge regarding new, disruptive technologies like blockchain based maritime supply chain systems and unmanned (autonomous) underwater and aerial vehicles in maritime surveillance and safety missions at sea borders.

Key research questions:

1. What is the level of intelligent implementation of contemporary, advanced ICT&S in maritime in developing countries like South Africa and Montenegro?
2. What are the challenges in implementing blockchain technology in shipping and port logistics, with accent on South Africa and Montenegro as emerging maritime countries?
3. What are advantages and disadvantages of novel, advanced unmanned (autonomous) underwater and aerial vehicles used in maritime surveillance and safety missions across the sea boarders?

Transition from research problem towards problem statement, which encompasses both research objective and research questions is presented in Table 1.

Table 1. Research problem translated into problem statement (Sources: Own).

	Problem statement	
Problem	**Research objective**	**Research questions**
The absence of a clear development strategy regarding digital transformation in maritime, which is accompanied with the lack of awareness and knowledge regarding rational deployment of new, disruptive ICT&S, in particular in developing coastal countries as South Africa and Montenegro.	Research objective is twofold: (1) to assess readiness of selected maritime entities in developing countries, to implement and adopt advanced maritime ICT&S, and (2) to upraise the level of awareness and common knowledge regarding new, disruptive technologies like blockchain based maritime supply chain systems and unmanned (autonomous) underwater and aerial vehicles in maritime surveillance and safety missions over sea borders.	1. What is the level of rationality in the implementation of the contemporary, advanced ICT&S in maritime, with accent on developing countries? 2. What are the challenges in implementing blockchain technology in shipping and port logistics, with emphasize on South Africa and Montenegro as developing coastal countries? 3. What are the advantages and disadvantages of novel, sophisticated unmanned (autonomous) underwater and aerial vehicles in surveillance and safety missions across sea borders?

This research problem is relevant since it relates to the topic of advanced ICT&S in which much is known fragmentary, while the knowledge is scattered and not integrated, in particular when it comes to developing countries like South Africa and Montenegro. Consequently, the aim of this research is to present an integrated overview of the topic along with the suggestions for ICT&S intelligent adoption in developing countries, at the examples of South Africa and Montenegro. Since a good problem statement is relevant and feasible at the same time, we try to answer research questions within the restrictions related to time and money, but also availability of respondents.

1.5 Limitations and delimitations

Research studies are usually limited in terms of time and money, while the availability of respondents might be the problem, as well. Regarding limitations of this study, it is to be noted that in some segments of our work, descriptive and exploitative approaches were used. What's more we dealt with new, disruptive technologies, so-called "game changers", e.g. blockchain in maritime and unmanned underwater and aerial vehicles in maritime surveillance and safety missions across the sea borders. Only in one part of the study a causal approach has been used and the relations among the variables in the model are tested through multiple linear regression analysis. The research is focused on case studies with a limited number of respondents. Restricted number of individuals, who are employed in maritime institutions "served" as a key data collection units. Regarding the time horizon in which this research project has been carried out, only one shot or cross sectional studies were conducted. In the future research work in this domain, longitudinal studies with larger number of the respondents from different organizational levels across various maritime business and administrative bodies should be conducted. Instead of descriptive and explorative approaches, causal one should be used in the domains of blockchain and autonomous vehicles adoption in developing maritime environments, as well; while mixed quantitative and qualitative techniques should be used in verifying the hypothesis and justifying causal relations among the variables in the framework of a smart adoption of sophisticated and complex ICT&S in maritime. Additionally, besides multiple linear regression analysis, experiments with dynamic programing and stochastic models might be involved. However, within presented study, we did our best to collect, put into the right context, analyze and present the obtained results in an acceptable manner; useful for researchers, IT and maritime professionals at the current moment, and as a sound foundation for further investigation in the field. We do believe that this research will serve as an inspiration for upcoming, more rigor investigations in this domain, including related areas.

1.6 Significance of the study

This study covers a wide range of advanced ICT&S in maritime. It acquaints readers with the key features and utilities of these systems, as well as with the directions for their rational use in developing environments, with a focus on South Africa and Montenegro. The study points to the advantages but also the challenges of the new digital technology in maritime. Additionally, it establishes causal relationships between key factors for advanced ICT&S successful implementation. The study opens door for further research work in the field and facilitates communication between IT architects (designers), managers and customers (end users) in maritime. It introduces for the first time, due to the best of our knowledge, multiple linear regression analysis into the models for intelligent ICT&S adoption in emerging countries like South Africa and Montenegro. Besides, it brings these countries as usually marginalized ones onto the larger map of geographic, political, economic, social, and digital transformation dynamic research.

1.7 Project contribution

This reserach study emanated into several research articles published in journals and conference proceedings, which are indexed in the referential data basis. The list of selected publications, which arose from this research project is as follows:

Journal papers

1. Kapidani, N.; Bauk, S.; Davidson, I.E.A. "Developing Countries' Concerns Regarding Blockchain Adoption", *Journal of Marine Science and Engineering*, 2021, 9(12), 1326, DOI: https://doi.org/10.3390/jmse9121326 (ISSN: 2077-1312); indexed in SCIE & Scopus (Impact factor 2021: 2.458).
2. Kapidani, N.; Bauk, S.; Davidson, I.E. "Digitalization in Developing Maritime Business Environments towards Ensuring Sustainability", *Sustainability* (Switzerland), 2020, 12(21), pp. 1–17, 9235, DOI: https://doi.org/10.3390/su12219235 (ISSN: 2071-1050); indexed in SCIE, SSCI & Scopus (Impact factor 2021: 3.251).
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Book Chapters

5. Kapidani, N.; Belojević, A.; Haçkaj, A.; Otašević, Đ.; Metaj, E.; Kardović, E. "South Adriatic Connectivity Governance as One of the SAGOV Project Concerns", Chapter 28, pp. 315-332, In: Bauk, S.; Dimov, S.I. (Eds.), *The 1st International Conference on Maritime Education and Development ICMED*, Springer, Boston, USA (ISBN: 978-3-030-64087-3; eISBN: 978-3-030-64088-0), 2021, p. 452, DOI: https://doi.org/10.1007/978-3-030-64088-0
6. Bauk, S.; Kapidani, N.; Boisgard, J-P.; Lukšić, Ž. "Key Features of the Autonomous Underwater Vehicles for Marine Surveillance Missions", Chapter 7, pp. 69-82, In: Bauk, S.; Dimov, S.I. (Eds.), *The 1st International Conference on Maritime Education and Development ICMED*, Springer, Boston, USA (ISBN: 978-3-030-64087-3; eISBN: 978-3-030-64088-0), 2021, p. 452, DOI: https://doi.org/10.1007/978-3-030-64088-0

Conference papers

7. Mihajlović, A.; Kapidani, N.; Lukšić, Ž.; Tournier, R.; Vella, G.S.; Moutzouris, M.; Souse, B.; Blum, A.; Paladin, Ž. "Planning a Case for Shared Data Retrieval across the European Maritime Common Information Sharing Environment", *The 26th International Conference on Information Technology (IT'22)*, 2022, 21684653, DOI: 10.1109/IT54280.2022.9743531 (ISBN: 978-9940-8707-2-0); indexed in Scopus & IEEE Xplore.
8. Mihailovic, A.; Kapidani, N.; Kočan, E.; Antonopoulos, S.; Moutzouris, M. "A Framework for Incorporating a National Maritime Surveillance System into the European Common Information Sharing Environment", *The 25th International Conference on Information Technology (IT'2021)*, 2021, 9390138, DOI:

https://doi.org/10.1109/IT51528.2021.9390138 (ISBN: 978-172819103-4); indexed in Scopus & IEEE Xplore.

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1.8 Outline of the study

The rest of the study is organized into the following chapters:

Chapter 2: It contains literature review, which reveals scarcity of literature resources in the following fields: maritime ICT&S; blockchain as a disruptive digital technology, blockchain in maritime, including shipping and port logistics, i.e. blockchain based supply chain management, TradeLens platform, smart contracts, crypto-currency payment mechanisms, blockshipping; Big Data; autonomous (unmanned) underwater and aerial vehicles for maritime surveillance and safety actions; and, multimodal containers emerging technology as a novel approach in handling marine transportation.

Chapter 3: This describes applied research methodology, used mathematical models, experimental setup and components, while descriptive, explorative and causal research approaches were used. As a key research strategy, case studies were applied, with minimal extent of the researcher interference in non-contrived study settings. The individuals with high education and high level of logical thinking, employed at the selected maritime organizations for couple of years, represent the "units" of analysis, while time horizon for the studies was one shot, cross sectional one.

Chapter 4: This chapter presents experimental and simulation results along with the data analysis – qualitative, quantitative, and mixed ones. Data were collected through questionnaires and semi-structured interviews over a fixed sample size, while measurements were done via the appropriate data testing, categorizing and coding. Basic statistics and multiple linear regression analysis were applied. In one case, SWOT analysis has been used. The results are presented in the form of tables and graphs.

Chapter 5: It includes discussions and inferences, which follows data analysis based on quantitative, qualitative and mixed data collecting and processing methods. The discussions follow each segment of the study and include limitations and directions for further, more extensive and rigorous investigations in the field.

Chapter 6: This chapter contains conclusions and recommendations drawn from the study. These can be used as a reference point by both researchers and professionals in maritime sector, with emphasize on developing economies of littoral regions.

Chapter 7: At the end of the study, the extensive list of references in the field of investigation is given. The references can serve further, more extensive, and deeper research in ICT&S smart adoption across maritime business and industry sectors in developing environments.

CHAPTER II: Literature Review

2. Literature review

2.1 Scarcity of literature sources

Literature resources on smart adoption of ICT&S in maritime in developing countries are scarce. The lack of research outcomes is a result of these countries unstable economies and rigid administrations, which increases digital divide and put them at risk of being further marginalized [51]. In an extensive survey of research papers on ICT&S-related topics within transitional economies (including countries of former Eastern-Soviet Block and Yugoslavia) published between 1993 and 2012 [52] there are several papers which explicitly concerned ICT&S role in the domain of transportation including maritime. These papers are the results of projects, and deal mainly with different organizational issues within national level(s). It is to be mention that there is a several papers published in this field, although from their titles it is not obvious that these consider in fact ICT&S. For instance, the presence of contemporary ICT&S solutions at eight seaports of developing countries (Bar, Durrës, Constanza, Koper, Piraeus, Ploče, Rijeka, and Thessaloniki) was explored in [53]. The results, unfortunately, were not encouraging. All the ports, except one (Durrës), had EDI (Electronic Data Interchange) service, while five ports, except Bar, Durrës, and Ploče, had VTS (Vessel Traffic Service) system. However, neither of the considered ports had (at the time of the survey) contemporary ICT&S solutions such as Enterprise Resource Planning (ERP), Customer Relationship Management (CRM), Vessel Traffic Monitoring Information System (VTMIS), Port Community System (PCS), nor access to Electronic Logistics Marketplace (ELM). Considered ports did not use Cloud computing services nor IoT. Furthermore, the authors of [54] have found that the Port of Kotor, as an emerging cruising destination under UNESCO protection at the South Adriatic Sea, suffers the lack of transactional and added-value e-services on its web site, whereas these services are notably present on the official web sites of some recognized European cruising ports like Southampton, Venice, Dover, Genoa, Civitavecchia, and Helsingborg. In addition, the authors of [55] offered a novel model of logistics, based on real data collected on site over several years, developed for the coastal tourist destinations in Montenegro, i.e., Bar, Budva, Kotor, Tivat, and Herceg Novi. This model logically includes the ICT&S component. Besides these research works, which are more or less concerned with seaports, sea-land transportation, passenger traffic, and corresponding ICT&S solutions, research works in the domain of PCS and ICT integration in Croatian seaports [56], [57], [58] are also worth mentioning. It might be of interest to point out that in [57] among others has been concluded: "Croatian seaports are currently in the phase of transition from isolated seaports to communicated ones". It is also important to mention, that [59] gave an original seven-pillar regional model of ports' development within a single port system of the Balkans. The uniform IT (Information Technology) platform at the port and logistics level was proposed as one of the pillars. The authors suggested a regional approach to develop standardized IT tools and platforms. They also pointed out: "Anyhow, the main issue remains on how to motivate all transport and logistics entities to accede to this important project. Certainly, a top down model is needed, where governments and transport ministries should achieve wider agreements for the region".

The authors of [32], [33] in their research works in the domain of intelligent exploitation of contemporary ICT&S solutions have dealt with the problems of conceiving and designing a tailored-made ICT&S adoption models for developing environments, which function in transitional economies. With same adaptions, these could be applied to the South African context as emerging one. In addition, Stace et al. [60], Keszey [61], Sabi et al. [62], and Sislian & Jaegler [63] developed similar theoretical frameworks for rational ICT&S adoption in developing environments. These theories arose upon the classical theories of ICT&S adoption and implementation developed earlier by Rockart [64], Davis [65], and Rogers [66].

2.2 Blockchain as a disruptive technology

Besides considerations in the domain of rational deployment of advanced ICT&S in maritime sector in developing countries, the dissertation considers Blockchain technology (BCT) and its early adoption. This technology records and saves a file of every single transaction from the time the first transaction was made. It is based on distributed ledger, which records and shares all transactions that occur within the blockchain network [67]. Blockchain technology allows transfer of funds and any other digital information fast and securely anywhere in the world. This novel technology enables trusted transactions among 'untrusted' participants in the entire chain of the network [68]. In other words, blockchain is a shared, circulated electronic ledger technology that can record transactions as they materialize between parties in secure and temper resistant way [69].

It is accepted that the invention and implementation of blockchain came by Satoshi Sakamoto back in 2008, as he published the paper "Bitcoin: A Peer to Peer electronic Cash System" [70]. This paper described a peer to peer version of the electronic cash that would allow online payments to be made directly from one party to another without going through a financial institution. According to Sarmah [71], a few months later after the introduction of blockchain an open source program to implement blockchain system was released and the first bitcoin network was begun in 2009. During the first five years after the creation of Bitcoin, the history of blockchain remained nearly synonymous with that of Bitcoin [72]. It was only in 2013 that blockchain technology started finding its place in other cryptocurrencies, such as Ethereum. The creation of Ethereum marked the second milestone in the history of Blockchain. In 2013, a nineteen-years-old programmer, Vitalik Buterin, published a white paper that laid out his plan for a blockchain system that could also facilitate "decentralised applications" [73]. Wallet software enabled users to electronically transfer bitcoins using a computer, mobile or a web application. Ethereum platform made it possible and realistic for blockchain to work with contracts and loans. It is based on an algorithm called smart contracts ensuring the implementation of an action between the two parties. Due to Ethereum's ability to offer a faster, safer and efficient environment, the technology became largely popular.

Blockchain for the enterprise is solving previously unsolvable problems [74]. Vast new efficiencies are now prevalent in global trade and similar effects are being visible across the food industry, mining, trade, finance, banking, and other industries where the value of block chain is more apparent than ever before. In the maritime industry, in 2017, Maersk shipping company and American multinational technology corporation IBM have together developed a blockchain solution named TradeLens, improving visibility and efficiency across the supply chain [75].

Blockchain in maritime, enhances supply chain management, which involves designing, engineering, manufacturing, and distributing products or services from manufacturers to consumers [76]. In the blockchain-based maritime supply chain system (BMSCS) [77], the blockchain itself brings together a wide range of logistics partners. These include manufacturers, retailers, consignees, shippers, freight forwarders, terminal operators, port authorities, customs, ocean carriers, or shipping lines, land transporters, insurance agencies, brokers, agents, beneficiary cargo owners, and the like, making it possible to track and trace cargo thoroughly and to provide access to information relating to shipments delivery timeframes. The involved parties are usually from different departments, countries with different regulations, business practices and cultures. For instance, thirty to forty different organizations might be involved, and hundreds of documents can be exchanged within only one single shipment. In its essence, it is blockchain is a distributed database supported by complex cryptography, i.e. encryption algorithms, hashes, time-stamps, consensus mechanisms, and the like, to ensure maritime data exchange in close to real-time with high level of traceability, transparency, verifiability, audibility, and immutability. The key benefit behind the blockchain is that it can systematically store big data and make it visible to all relevant actors in the global trade chains. This has significant advantages in comparison to time consuming and error prone manual work, which is still dominant in maritime.

This study investigates how blockchain technology can potentially change things in shipping industry for the better. According to Sharma [78], blockchain technology can remove the excessive paper work, reduce bureaucracy and decrease overall transportation costs, which mainly occur due to documentation, while simultaneously offering other intelligent and efficient solutions. Shipping companies on a daily basis have to deal with a plethora of operational and logistics processes in order to complete transportation, such as the network design, which involves the selection of transshipment stations and harbors, through which routing and scheduling are planned, along with and fleet planning [79].

The four specific advantages to using BCT in the shipping industry have been identified as the document exchange, container utilization efficiency, intelligent transportation and container reporting [80]. However, there are some barriers of blockchain implementation in the maritime industry. Firstly, cost is one of the barriers of blockchain implementation. Companies would incur much more expenses if they need to switch the systems and train their employees to acquire the knowledge of blockchain. Zhou [81] outlines that the main disadvantage of blockchain is the high energy consumption. The reliability of the blockchain technology is doubted by some professionals. Blockchain is currently immature and needs further development. The problem with the blockchain is that the note, which is operating on old software, will not accept the transactions in the new chain. The limitation of knowledge and expertise of blockchain technology also prohibits the maritime industry from adopting this new technology [82]. Gaining industry adoption is the most critical and this will determine the success of blockchain technology in both the supply chain and logistics. As more and more supply chain stakeholders participate, blockchain becomes more valuable, evolving into an industry practice. However, it will quick a challenge at first to obtain stakeholder commitment because of different levels of digital readiness and the initial requirement to recognize the mutual benefits of blockchain based collaboration. While studies argue that blockchain provides hacking-free high-level security, a quiet a few hacking instances significantly deteriorated the reputation of the blockchain [83]. Also, according to Munim [83] one of the major obstacles when it comes to implementation of blockchain in the maritime industry is the lack of standardization in data elements and the like. Both benefits and challenges of BCT implementation in maritime, with focus on developing countries are considered with an aim to enhance conceiving and designing a model for smart (rational, intelligent) adoption of BCT in an emerging environment.

2.2.1 Blockchain in maritime

Supply chains are some of the largest, most complex ecosystems in the business world today. It is common, for instance, to have up to 30 or 35 independent actors involved, over a hundred people and 200 separate exchanges of information and documents across an end-to-end supply chain. As extremely complex systems, current supply chains are inherently inefficient [75]. Due to the World Economic Forum by reducing barriers within the international supply chain, which includes shipping and port management, global trade could increase by nearly 15%, boosting economics and creating jobs. More precisely, reducing barriers in global trade for 5–20%, can increase worldwide trade volume by 10–15% and affect global GDPs by 3–5%, specifically for individual, developing countries GDPs by up to 15% [84].

Today information is exchanged in bilateral manner between shippers and either their suppliers or the transport providers. The information is often trapped in organizational silos, which means that there are two or more versions of what is going on. Consequently, cargo is often delayed and certainly, this is inefficient because cargo information is available at one part of the supply chain, but not at the other. This leads to challenges like both inefficiency and blind spots, which lead to gaps; gaps lead to delays; delays lead to increased costs for everybody involved. Additionally, the processes today are predominantly manual in nature. A lot of information is keyed, re-keyed, and all these is time consuming, inefficient, and it creates a lot of anomalies, exceptions, and each one of those have to be dealt with a timely fashion to keep the cargo fluidly moving from end to end.

Custom's clearance is a crucial issue. Custom's authorities around the world are trying to find better ways to assess risk at early stage and to look at shipments that are of concern to them or potential customer to avoid impeding global commerce. Obviously, current processes are time consuming and costly. Customs are also trying to prevent identity and other frauds. Therefore, early risk assessment is a key component.

Due to the current processes being so manual in nature and because of the information silos, shipping and port management operations take time; time costs and can lead to delays, and ultimately cargo delay, custom's clearance delay, and additional costs. The operations in shipping and port management are by nature complex and this restricts the ability for companies involved in supply chains to understand adequately when the cargo is going to be delivered. The companies have to have buffers in their supply chains. The costs and inefficiency are born by everybody in the supply chain, but most importantly by the shippers who ultimately pay the costs of inefficiency.

2.2.2 Blockchain in supply chain management

A blockchain is based on distributed ledger, which records and shares all transactions that occur within the blockchain network [67]. The blockchain in maritime enhances supply chain management, which involves designing, engineering, manufacturing, and distributing products or services from manufacturers to consumers [76]. In the blockchain-based maritime supply chain system (BMSCS) [77], the blockchain itself brings together a wide range of logistics partners. These include manufacturers, retailers, consignees, shippers, freight forwarders, terminal operators, port authorities, customs, ocean carriers, or shipping lines, land transporters, insurance agencies, brokers, agents, beneficiary cargo owners, and the like, making it possible to track and trace cargo thoroughly and to provide access to information relating to shipments delivery timeframes. The involved parties are usually from different departments, countries with different regulations, business practices and cultures. For instance, thirty to forty different organizations might be involved, and hundreds of documents can be exchanged within only one single shipment. In order to reduce paper work, inefficiency and limited data captured capacities BMSCS is developing. In its essence, it is a distributed database supported by complex cryptography, i.e., encryption algorithms, hashes, time-stamps, consensus mechanisms, and the like, to ensure maritime data exchange in close to real-time with high level of traceability, transparency, verifiability, audibility, and immutability. The key benefit behind the blockchain is that it can systematically store big data and make it visible to all relevant actors in the global trade chains. This has significant advantages in comparison to time consuming and error prone manual work, which is still dominant in maritime.

Due to low-cost and high-efficiency, maritime logistics becomes the main mode of trade and transportation around the globe. In addition, due to the diverse demands and oversupply of shipping market, the competition for shipping services increased. Maritime transport services include numerous stakeholders and deal with plenty of transportation documents, which cause delays in delivering goods. To deal with this efficiently and effectively blockchain technology has been gradually deployed in maritime supply chains [85]. Blockchain, i.e., BMSCS in this context, enhances service efficiency through smart contracts and cryptocurrency based payment mechanisms; tracking and tracing the status of cargo via RFID, GPS and IoT; empty containers placement; early risk assessment; and, possibilities for new value added services development, since some BMSCS are established on open platforms (Figure 1).

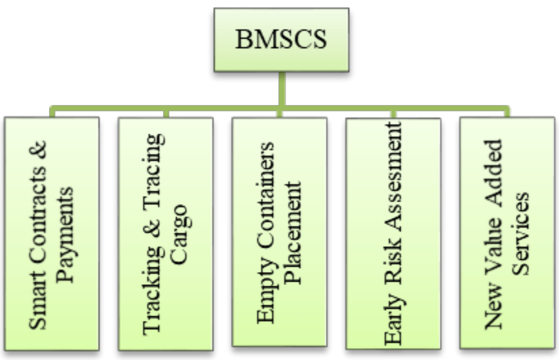


Figure 1. BMSCS key constructs (Source: Own).

Today, there is a plenty of projects and initiatives to deploy BMSCS in shipping and ports logistics. The BMSCS market leader is TradeLens solution developed as a result of collaboration between Maersk and IBM in 2018 [41], [75]. Besides TradeLens, there is many similar high-tech initiatives in maritime. For instance, DP World Company started integration with TradeLens [86], while the Port Authority of Algeciras Bay also signed the contract with TradeLens. Danish Maritime Authority started to work on implementing blockchain in custom clearance. IT Company Ideanomics works with Asia-Pacific Model Electronic Port Network (APMEN) on blockchain for the biggest Chinese ports like Port of Shanghai and Port of Guangdong. The APMEN has numerous members including ports in Shanghai, Xiamen, South Wales, Vancouver, etc. The Port of Rotterdam started to investigate blockchain implementation in reducing turnaround time of vessels. Maritime Blockchain Labs (MBL) developed a prototype of blockchain to address the declaration, tracking and tracing, online auditing, and processing of dangerous goods to increase visibility and reduce risks [12]. Cargosmart and IBM are working together on improving customs clearance, logistics trusts and transparency [87]. CargoLedger, which is Rotterdam Port Authority and Dutch blockchain start-up, works on ship tracking [88]. CargoX provides the services related to the first smart bill of lading and other maritime documents transactions [89].

The BMSCS is a complex, distributed relational database, which enables participants' easy communication and permissioned information share in near-real time. It allows cargo track and tracing along the entire supply chain in near-real time. It is a base for smart contracts in maritime like letter of credit and bill of loading. The BMSCS can incorporate smart payment mechanisms based on crypto-currency as 300Cubits, ShipChain, and Prime Shipping Foundation (PSF) instant payment systems [90]. It enables early risk assessment and efficient interventions across supply chain when planned activities unexpectedly turned into unplanned ones. Since it is dominantly based on open platform, new added-value services can be developed in the future.

Table 2 presents some of the major BMSCS developments in maritime industry [77], [91]. Regarding safety, semi-private blockchains are common. The consortium companies' reputation speaks in favor of safety. Maritime, as conservative, assesses and recognizes quality of operation in long run. Namely, stakeholders in maritime are not early adopters. However, trust between network participants is bigger problem than safety. The BMSCS as an unorthodox technology and cryptocurrencies are still highly volatile. In such a setting, maritime stakeholders do not like to disclose essential business information about customers, suppliers and cargo. Many freight forwarders and intermediaries, e.g., earn their profit thanks to information asymmetry [92]. Interoperability will be smaller problem in terms of technology (since standards have been intensively developing), than in terms of smooth processes flows at inter-organizational level.

Positional data might be used to track vessels by identifying port locations, fueling locations and routes. This is particularly the case with tracking dangerous and hazardous goods, pharmaceuticals, or food. The use of blockchain does not guarantee that the information recorded in ledgers is correct and does not prevent tampering data prior to entering it into blockchain ledger, e.g., the contents of a container, fuel production, testing or combustion, and the like. Due to huge amount of data and traffic generation, including data storage, blockchain requires a wideband channels like G5 or G6, while the internet speed can be low when the working stage is offshore. Further, it causes high-energy consumption.

Table 2. Some BMSCS applications (Sources: [77], [91]).

No.	BMSCS		
	Consortium	Platform	Ledger
1.	Port of Koper, Slovenia	CargoX	Public
2.	Malaysia's West Port & LPR - Brazilian textile importer	300cubits	Public
3.	Maersk & IBM	TradeLens	Consortium (permissioned)
4.	Abu Dhabi Ports and Port of Antwerp	Silsal	Consortium (permissioned)
5.	EY & Guardtime	Marine Insurance Blockchain	Public
6.	PIL, PSA & IBM	Proof of Concept (POC)	Consortium (permissioned)
7.	Port of Antwerp with Belfruco, Enzafruit, PortApp, 1-Stop and T&G Global	Smart Contracts	Consortium (permissioned)
8.	2021.AI Den Danske Maritime Fond, EUDP, INVICTA	Blockshipping	Public
9.	Port of Malmo & Port of Copenhagen	PortChain	Consortium (permissioned)
10.	AAT, FileVersion Health, CROP	CargoChain	Consortium, (permissioned)

Unlike proof-of-work blockchains as Bitcoin or Ethereum, Tezos' proof-of-stake requires significantly less energy and cost to operate, making it an ideal alternative platform for building blockchain applications that are eco-friendly [93]. However, since this platform is the product of many organizations across the globe working currently together on an open-source product, due to the author's best knowledge, there is no evidence that this platform is up to now applied in maritime, which is rather conservative business and industry sector. The BMSCS indicates the potential to reduce transaction costs in a number of areas, including reducing the need for intermediaries such as brokers and courier services, and to reduce related financial expenses and energy costs. But, previously stated does not take into account the comparable costs of the overall investment and expenses associated with blockchain implementation and adoption, especially in developing environments. Present level of awareness, knowledge, and expertise about blockchain is scarce among the stakeholders. Therefore, educational, training or human capacity building programs are necessary at regulatory, administrative and operational levels. Higher level of standardization across the global supply chain is still necessary. The Digital Container Shipping Association (DCSA) conducts efforts in this respect, but further actions that are more extensive are unavoidable. In general, there is a hesitation by stakeholders in maritime sector to invest in blockchain systems in terms of technological integration, regulatory, organizational, and educational costs, since maritime sector traditionally relies on its legacy systems. There appears to be a gap between what practitioners in the blockchain area suggest and what has been a range of state-of-the-art approaches in the software engineering and information security research and practice. Further, the major liner shipping companies are the most likely parties to benefit from blockchain given the complexity of their blockchains, including diverse stakeholders' needs and huge requirement on financial resources. This can put other potential actors in the global supply chain at a disadvantage. The last but not the least, the basic attitude should be that technology, in this case blockchain on the top of global supply chain should improve the human condition, and not replace humans [50]. Therefore, human and ethical dimensions of blockchain technological development and more extensive deployment in maritime should not be neglected.

2.2.3 TradeLens platform

TradeLens is a new business model in shipping and port management. It enables one-to-many connections for all the actors, all individuals that are involved in a global supply chain instead of bilateral connections. Everybody come together in a maritime industry neutral, open platform for every participant [75]. Maersk, the world's largest international container shipping and logistics company and IBM the technology leader in blockchain came together to provide a new, open platform solution underpinned by blockchain to help unlock some of the opportunities for more efficient global supply chain. Maersk and IBM have a long history of working together, actually decades. In March 2017, these organizations collectively try to improve global trade through digitization. In January 2018, these organizations launched early adapter program; trials began, and in August 2018, these formally launched the TradeLens limited availability platform, shared among 92 participants. In December 2018, TradeLens is commercially realized, along with 1.5 million events per day published to the platform. Some of these events are presented in Table 3.

The platform can track 120+ unique consignment shipments, while 60+ network members are onboard or in a process of accessing. TradeLens supports 18+ unique, standardized, trade document types. Some of these documents are shown in Table 4. In February 2019, enhanced document sharing, permissions and notifications were released. The platform includes half a billion events on annual basis and this number grows with more and more network members.

Twenty million containers of cargo information is in the system today, which is roughly 1/5 of global trade and it is growing. The platform involves numerous parties and systems: ocean carriers, ports and terminal operators, inland carriers, shippers, consignees, beneficiary cargo owners, freight forwarders, 3PLs, custom authorities, government agencies, financial and insurance services, transportation management systems, Port Community Systems (PCSs), supply chain validity systems, supply chain, manufacturers, retailers, etc. They all collaborate and share information. TradeLens provides them with comprehensive, real-time visibility and immutability across the end-to-end journey of shipment. In other words, data is available immediately, along with the single simplified view across all shipments. For instance, as a terminal operator publishes a piece of information about the fact that a container has been loaded onto a ship that becomes immediately available to everybody else in the supply chain. The idea is to build workflow based on smart contracts using chain code to derive cross-organizational workflow by excluding manual work.

Blockchain on which the platform is based, enables the trust in data that are available on the platform. It is an open and censorship-resistant distributed database model, secured by encryption and decentralization. Blockchain records information in blocks on a shared ledger, storing a synchronized copy of it on all the systems participating in the network, hence assuring its immutability [94]. The trust anchors, which are the blockchain nodes, ensure through consensus algorithms that the information should be written on the platform as approved like valid. All information are auditable, verifiably and temper proof; so, as soon as a piece of data is published to the blockchain it cannot be edited. The only way to edit a document is to create a new version of the document. Consequently, all the documents are fully auditable. Additionally, cryptographic hash of the data is written to the blockchain, and this is a part of the supply chain. It is important to say that private data remain private. TradeLens as information sharing model allows ecosystem partners to have access to the information they should access and vice versa. The platform offers a high level of flexibility through application of RESTful APIs (Application Programming Interfaces), back-end ERP (Enterprise Resource Planning) and secured front-end Web services.

Table 3. TradeLens standardized events (Source: [75]).

Actual	Estimated	Planned
Start container tracking	Documentation cutoff: Vessel ETD	Import documents approval
Start shipment tracking	VGM (Verified Gross Mass): Vessel ETD	Discharged from truck
Booking confirmation	Cargo cutoff: Vessel ETD	Loaded on vessel
Stuffing started	Rail ETD	Stuffing started
Vessel ATA	Rail ETA	Stuffing completed
Vessel ATD	Bill of Lading Available	Loading on vessel
Loaded on rail	Vessel ETD	Gate in
Rail ATD	Vessel ETA	Gate out
Rail ATA	Discharged from vessel	Packed container selected for inspection
Loaded on truck	Load on vessel	Packed container passed inspection
+Add more	Custom release	Cargo specific certificate approved
	+Add more	+Add more

In the middle or in the very core of TradeLens solution there is the platform and blockchain behind it. Below the platform is the network. The network is not a physical network. It is set of entities that provide the data, including the data itself. The ocean carriers, ports, terminal operators, customs, shippers, inland transporters, etc., provide the data. On the top, above the platform are applications and services, i.e., RESTful APIs, back-end ERP, and secured Web that enable people to exchange the information. These are based on open published industrial UN/CEFACT standards that are defined at the platform level, so that third parties are allowed to build new value-added services and applications. This is the basic kind of model, through which TradeLens is moving forward as a paradigm shift in information sharing across the whole ecosystem. A conceptual framework of TradeLens as a blockchain based solution in global supply chain is presented in Figure 2.

Which kind of information are shared across the platform, i.e., over the entire supply chain? - This information are mostly shipping milestones. Things as: has a container be staffed; has the container be gated; what is the estimated time of arrival (ETA) of the container at the destination, and so on, are in fact shipping milestones. However, it is more than that. It is also the documents in maritime, both structured and unstructured (like PDFs, scans, images, etc.), by making them available to the participants along the supply chain. The documents need to change 'hands'. They need to be approved, updated, and available to build workflow using smart contracts like bill of lading, clearance, insurance, etc. This is powerful in terms of driving cross-organizational dataflow in maritime.

Within TradeLens, there is sensor data and Internet of Things (IoT) for referring to the container number, electronic seal, and temperature inside it, for instance. All of that are part of the underlined data that is made available to the participants who need that data. There is a whole concept of seamless and permission data sharing model that is built on the base what your role is, i.e., are you terminal, ocean carrier, shipper, inland transporter, etc. The default permission model allows people to share information, so that information is made available to those who need it, but it is not available to those who should not see it.

Table 4. TradeLens standardized documents (Source: [75]).

Document	Party
Import documentation approved	Customs House Broker
Customs release	Customs Authority
Cargo geography specific certificate approved	Customs House Broker
Bill of lading available	Beneficiary Cargo Owner (BCO)
Certificate of origin available	Beneficiary Cargo Owner (BCO)
Packaging list available	Beneficiary Cargo Owner (BCO)
Commercial invoice available	Beneficiary Cargo Owner (BCO)

TradeLens is of upmost importance whenever planned actions turn into unplanned. For instance, the ocean carrier's decision has implications not just for them but for all stakeholders further down the supply chain from customs brokers, port authorities and terminal operators to inland transporters and consignees. With TradeLens, changes to the shipment are reflected immediately allowing supply chain participants to coordinate actions tightly, delivering the consignee's inventory in time. TradeLens allows near-instant logistics adjustments so the disruptions are kept to a minimum. Global trade is an incredibly complex system, but TradeLens and blockchain create an industry-wide and innovative solution to alleviate this complexity and related impediments.

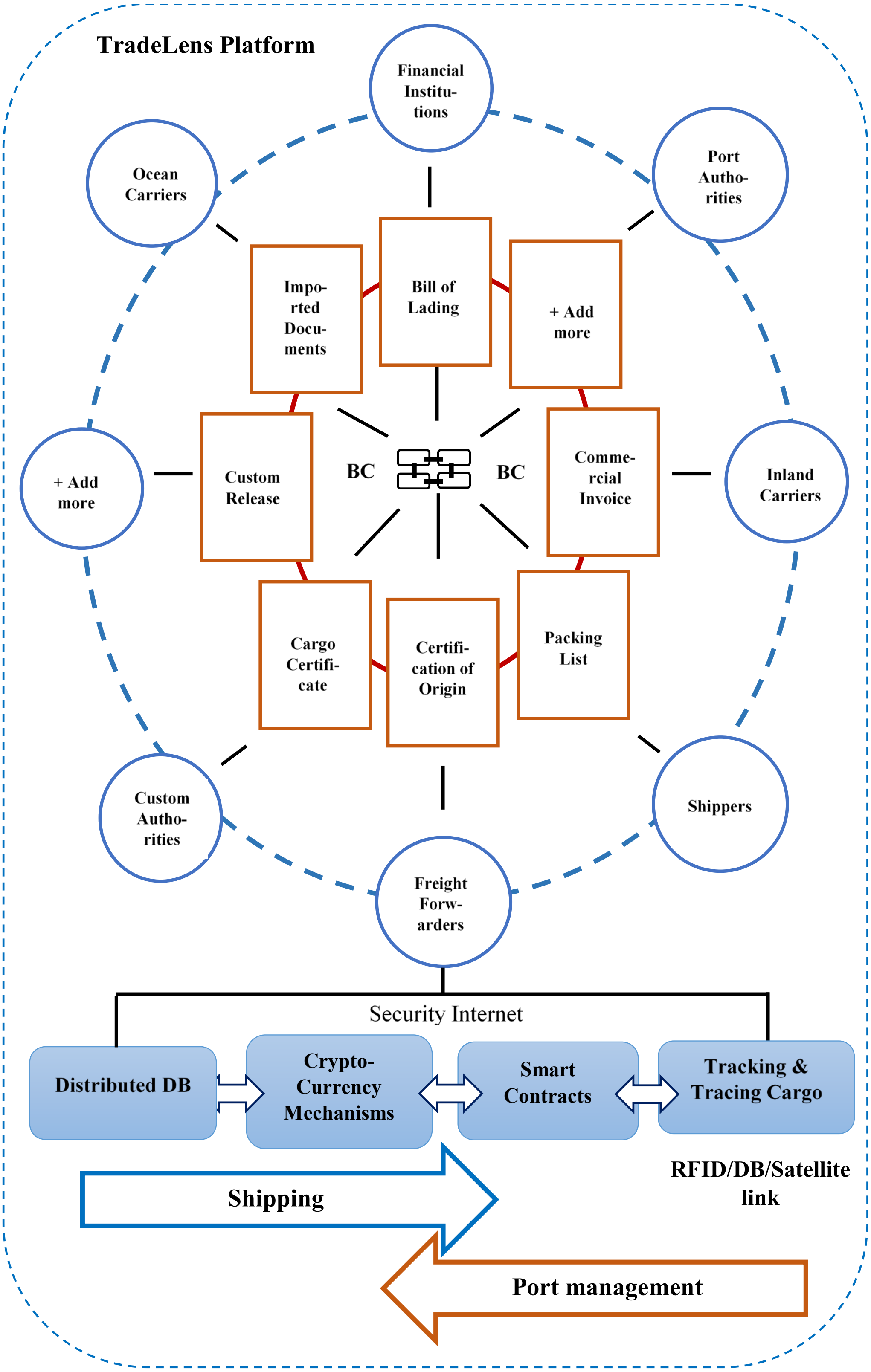


Figure 2. TradeLens conceptual framework (Source: Own).

2.2.4 Smart contracts

Smart contracts are programs stored on a blockchain that run when predetermined conditions are met. They are used to automate the execution of an agreement so that all participants can be immediately certain of the outcome, without any intermediary's involvement or time loss. They can also automate a workflow, triggering the next action when conditions are met [95]. Smart contracts work by following simple "if/when…then…" statements that are written into code on a blockchain. Or in other words, a smart contract presents the lines of code that are stored on a blockchain that automatically execute when predetermined terms and conditions are fulfilled [96]. A network of computers executes the actions when predetermined conditions have been met and verified. These actions could include releasing goods, funds, or confirmations in maritime supply chain. The blockchain is updated when the transaction is completed. That means the transaction cannot be changed, and only parties who have been granted permission can see the results. Blockchain network controls access. Within a smart contract, there can be as many stipulations as needed to satisfy the participants, so that the task will be completed correctly. To establish the terms, participants must determine how transactions and their data are represented on the blockchain, agree on the "if/when...then…" rules that govern those transactions, explore all possible exceptions, and define a framework for resolving disputes. Then the smart contract can be programmed by a developer, although organizations that use blockchain for business, provide templates, web interfaces, and other online tools to simplify structuring smart contracts. Key benefits of smart contracts are: speed, efficiency, accuracy, trust, transparency, and security (blockchain transaction records are encrypted, which makes them very hard to hack; plus, each record is connected to the previous and subsequent records on a distributed ledger, and hackers would have to alter the entire chain to change a single record). In maritime supply chain, sea waybill or bill of lading can be converted into a smart contract, while it requires an agreement between shipper and carrier, and/or any other relevant and permissioned parties to view the consignment, transport equipment, and documents, as permissions allow [97]. The benefits of such smart contract include: simplified transmission of shipping instructions; management of document status and versioning; faster submission of shipping instructions for creation of final bill of lading; quick sharing of documents with all permissioned parties; including immutability, traceability, and auditability of the documents involved [98].

2.2.5 Instant payments

While bitcoin is a digital coin, i.e. money that is digital, blockchain (BC) is the technology that enables moving digital coins or assets from one entity to another within the network [99]. This section of the paper explains how BC solves the problem of money transfer at conceptual level. If entity A is sending money to entity B, usually this is done by a third trusted party, i.e. bank. The A gives order to the third party (bank) to make money transfer to B. Trusted party identifies B account and transvers money after taking some fees. This takes three or more days, if the transfer is done internationally. Blockchain transfers money without a third party, faster (immediately), and cheaper than a third party. Let us dive in into money transfer between A and B via BC. Firstly, we have to introduce 'open ledger' term. An open ledger is a chain of transactions among the nodes of the network, which is public and open to all participants.

Everyone on the network can see where the money is, how much money each one has, and everyone can hypothetically decide whether an intended transaction is valid or not.

Example 1: Firstly, take a look to the concept of open ledger and how it can be implemented in BC. Let us assume that A has $15 and wants to move $5 to B. We are going to add this transaction to the ledger. Then, B wants to move $3 to C and we add this to the open ledger. The ledger is public and all nodes in the network can see and validate instantly the transactions if they are valid. Similarly, C can transfer $1 to D (Figure 3). However, if A wants now to move $15 to D, this transaction will not be approved, since A has only $10. Consequently, this transaction is unvalidated and it will not be added to the existing chain of valid transactions. This is simplified scenario with central, open ledger. If we assume that the ledger is distributed, it means that each node has a copy of the chain of synchronized transactions. This is more complex situation, and we are going to explain it through the following example.

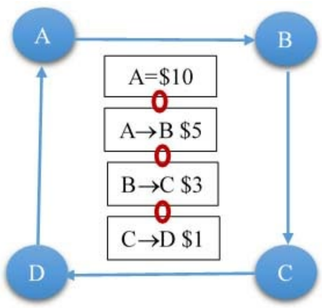


Figure 3. Centralized ledger (Source: Adapted from [99]).

Example 2: When ledger is distributed, each node holds the copy of the events that happened. In such a case, essentially we do not need centralized ledger. Now, we have to ensure that all copies of the ledger are synchronized and that all participants in the network see the same copy of the ledger, i.e., same version of the chain of validated transactions. The question, which follows is: how nodes make and synchronize the ledger? The simplest way to answer this question is through an example. Let us assume that B wants to move to C $5 (Figure 4). The B is going to publish and broadcast this intention to the network. Everyone on the network will see immediately that B wants to move $5 to C. This is an unvalidated transaction. Next question is, how this intended transaction can be validated? In order to answer the question, we have to introduce the concept of 'miners'. Miners are specific nodes in the network that have capacity to compete mutually, in terms, which one will be the first to declare a transaction valid or not valid, and to put it into the ledger if it is valid. The first miner that did this got a financial reward. In this case 'bitcoin'. This means wining the competition and validating a new transaction. The winner has to fulfil two tasks:

Task 1: To discover whether B has enough money to make transaction, and

Task 2: To find a 'special key' that will enable this miner to lock the new transaction (if it is feasible) to the previous event (validated transaction) in the chain. In order to find the key miner needs computational power and time, since the key is random. The miner is repeatedly guessing keys, until it found the key that matches. If we assume, in our example, that D found the key, it will publish the key, so that other nodes can see it is a public and consequently updated oven ledger copies with a new, now validated transaction 'B moved $5 to C'. This means, A, B, and C will add automatically this transaction to their distributed ledger copies. In such a way, all ledger copies will become synchronized.

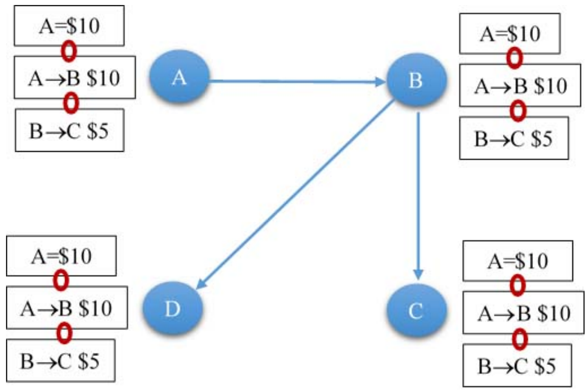


Figure 4. Distributed ledger (Source: Adapted from [99]).

At the operational level of blockchain-based maritime supply chain system, remains the question: who are the participants in such a network of financial transactions, and which nodes have the potential of miners? The answer depends on the particular case that might be analyzed in the particular setting and with a particular reason. Here is given just an idea or concept how blockchain based crypto-currency mechanism works in general. How it can be applied in a particular shipping or port management setting, within the blockchain-based supply chain, depends on a variety of conditions in which the observed system functions. The 300Cubits, ShipChain, and Prime Shipping Foundation (PSF) are initiatives that attempt to increase cryptocurrency deployment in maritime business [100]. However, there are still significant barriers and challenges to use blockchain and smart contracts in validating shipments and payments in maritime. The shipping industry increasingly faces cybersecurity threats, such as the NetPetya ransomware attack that affected Maersk in 2017, at a cost of over $200 million [101].

2.2.6 Blockshipping

Today the container shipping industry accounts for around 60% of all the world seaborne trade and 16% of total tonnage [1]. This valuable industry has been troubled for years by challenges like overcapacity, low freight rates, security threats and increasing environmental regulations. It is well-known fact in the industry that global shipping needs increased efficiency, improved processes and fundamental digital transformation to enhance profitability in the future and to comply with environmental regulations.

Currently, there is about twenty-seven million containers in the world, which are moved from one destination to another on trucks, container cars, ships, rail, or waiting in the port, container yard, railway station, and the like. About five million containers are uncontrolled and nobody knows their precise locations; if they are currently in transit or waiting for collection. Consequently, no one knows if they are empty or loaded, which means that no one knows if a truck or a train is wasting time and energy carrying an empty "metal box" instead of carrying

[1] OECD iLibrary

goods [102]. This is huge waste of energy; it produces additional costs and negatively affects the environment.

Therefore, the global shared container platform (GSCP) is currently under development. As the world's first blockchain based container registry, it will allow the industry to help real-time track of all containers worldwide. The platform will enable the industry players to manage efficiently all kinds of transactions related to container handling. The GSCP has several user groups like shipping lines, leasing companies, banks, financial institutions, blockchain container investment syndicates, transport service providers, beneficiary cargo owners (BCO), container terminals, container depots, repair shops, etc.

Through a secure login, each user group will have unique set of functionalities that matches their exact needs. For example, if you are a shipping line export user, you can use GSCP platform to find street turn matching opportunities for ensuring that empty containers meet export demands. You will see an inventory list of all export bookings, which require an empty container to the customer location for stuffing, rather than transporting an empty container from the port or the depo. For the convenience, the platform enables users to switch between list and map view. The user can apply one or more filters and inventory will update accordingly, for instance, only showing FEUs (40-feet units). Any set of applied filters can be saved in user's filter presets. This way they are quickly accessible whenever the user needs them. Matching export containers with import containers is easy and swift. This enables both importer and exporter to save an empty container haulage trip, plus gate in and gate out fees at the terminals. The system identifies possible matches based on container size, type, boarding date, previous commodities carried and availability. The platform also enables sending a request to the involved shipping line with the comment. The GSCP provides various ways to import booking and container data. The user can use EDI and API connection with the in-house booking or order platforms [103].

Blockshipping is, in fact, a share pool of containers, which enables 'just in time containers' situation. Today more than 40% of all containers in transport are empty. Therefore, resources are wasted and costs are increased. With Blockshipping saving potential for the shipping industry might be at least 5.7 billion USD and reduce of CO_2 emission can be 4.6 million tons yearly [104]. Blockshipping platform is a part of so-called programmable economy. In such economy, the interactions among different parties will not occur through mediation of a third trusted party, but automatically through autonomous intelligent software agents (AISA). These are also called dApps (distributed Apps) that run on blockchain and are authorized and instructed by the parties involved in the BMSCS to negotiate autonomously on their behalf [105].

Four key subsystems of Blockshipping are [106]:

- Global Shipping Container Registry (GSCR) – that holds real-time information about every container available through Blockshipping;
- Empty Container Repository Engine (ECRE) – that continuously calculates the next best-laden transport for each container. The engine also 'understands' the position of every truck available to transport the empty container;
- Autonomous Intelligent Software Agents (AISA) – that run on blockchain and negotiate all agreements;

- Smart Contracts (SC) – that can be treated as the rental contracts established through the autonomous negotiations, which persist on the blockchain and govern the rental through binding self-enforcing rental agreements.

Blockshipping has developed a unique revenue sharing model. Consequently, it issues two types of tokens:

- Internal utility token or Container Platform Token (CPT), and
- External revenue share coin or Container Crypto Coin (CCC).

The CPT will be used for clearing and settlement of transactions between the users of the platform. These transactions will relate to many different services and fees. A percentage of the revenue goes to a revenue share pool and is passed on to the owners of CCC tokens. Blockshipping exchanges the CPTs in the revenue share pool to Ether via USD. Then, it uses smart contracts to convert revenue Dutch auction on the Ethereum blockchain in which Blockshipping offers the owners of the CCC tokens price for their tokens. The offered price will increase until all available Ethers are spent. After the auction, Blockshipping distributes the acquired CCC tokens to all the owners of CCC tokens on a pro rata basis. In this way, token owners are rewarded regardless of their decision to sell or keep their CCC tokens (Figure 5) [107].

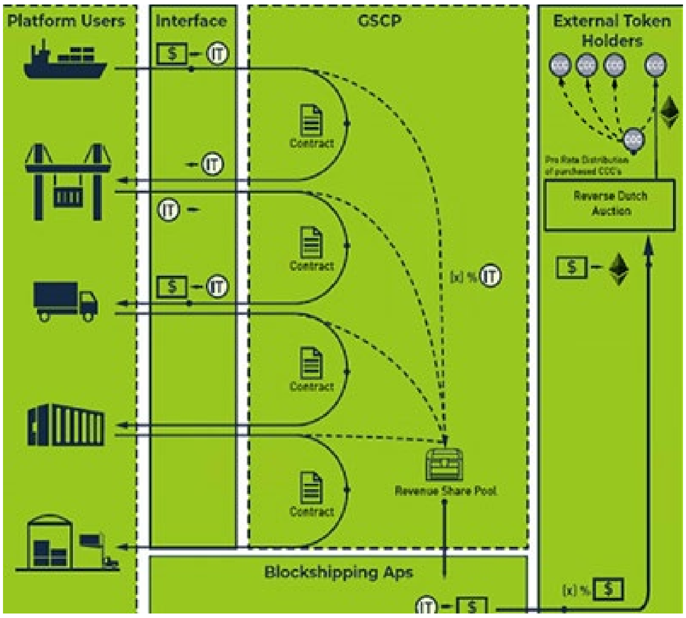


Figure 5. Blockshipping conceptual framework (Source: [107]).

The processes flow within Blockshipping is based on several simple and fully automated steps that will be explained shortly. The easiest way to make an explanation is to follow an example. Let us assume that shipping line needs to rent a container to transport goods from Nairobi (Kenya) to Rotterdam (Netherlands). Blockshipping empty container repository engine identifies the best-positioned empty container in Nairobi and informs the shipping line about the options. The shipping line informs its autonomous intelligent software agents (AISAs) about the containers. The rental negotiations then happen unsupervised between the shipping line and the container owner through their autonomous agents. The agreements established by AISAs are persisted on blockchain in smart contracts that govern the rental in binding self-enforcing rental agreement. Blockshipping container platform tokens CPT are used to pay rental fees, while the fees are transferred from the shipping line wallet, in accordance to the smart contract and reserved payment. The smart contracts can be changed if conditions change. For example, if rental period is extended when the container reaches its final destination in Rotterdam. Then, smart Oracle blockchain enforces the smart contract. The rental ends and releases CPTs to the container owner wallet [108].

2.3 Big Data concept

Some of the most important features of contemporary information systems applications in the maritime sector and industry are Big Data and Data Analytics. These concepts are consequentially related and are primarily derived from increased internet traffic of relevant data collected from various sources including heterogeneous surveillance assets and maritime coordination centers. Big Data generally involve two processes: data management and analytics. The first one is composed of acquisition and recording of raw data, extraction, annotation, integration, aggregation of structured data and representation, while the second one covers modelling, analytics and final interpretation. To this end, the specific importance of integrating the maritime big data framework and mentioned processes into a common collaborative environment has been analyzed in [109] with the aim to show outstanding big data applications in maritime safety and surveillance agencies. Specifically, big data framework/infrastructure in the form of a complex database known as Data Lake, contains important modules for collecting the data from maritime sources like VTMIS, AIS, radar, NMSW, LRIT, etc.; data aggregation, semantic layers, and harmonization. These layers ingest and process data providing final and relevant information for decision support tools which are embedded in Command and Control (C2) and other management systems. Analyzing the big data repositories, volume, challenges and requirements, [110] shows developed concepts of Big Data Ocean, its comprehensive architecture, data lakes and modules including semantic enrichments, data integration, query processing, visualization and management. Following the wide big data applications in the maritime industry, [111] analyzed the implementation of developed IT systems based on big data techniques in the maritime logistics and transport, ship navigation route optimization, maintenance control, AIS data collection and distribution, energy efficiency improvement and maritime safety and surveillance implications, as well.

Specifically, challenges and opportunities for Big Data in shipping, as discussed in [112] are reflected in more efficient technical and operational solutions that, using the appropriate analytical tools and techniques, can significantly improve vessels' technical and reporting systems performance. This involves the exploitation of applications such as Online ship decision support, Ship performance and fleet optimization and predictive analysis. In maritime transport, the capabilities of big data analytics and tools yielded many innovations supporting the e-navigation concept, calculation of arrival times and vessel speed in seaports, based on AIS static and dynamic data, weather routing and ship security thanks to LRIT [113]. Considering the main features of big data such as volume, velocity, variety and others, the maritime traffic and especially surveillance and monitoring systems enable the composite and sharable picture of all activities at sea, which is known as Recognized Maritime Picture (RMP) with the aim to raise Maritime Situational and Domain Awareness (MSDA). This implicates the existence of multiple sources and sensors with collecting, handling and storing maritime big data, which then provide their transfer and aggregation in the form of a data fusion process for establishing one single representing and comprehensive framework. For running this process, a Data Fusion Model maintained by the Joint Directors of Laboratories (JDL) Data Fusion Group is developed in five levels, comprehending: source preprocessing, object refinement, situation assessment, impact assessment, cognitive refinement. Represented capabilities are integrated with the methodological approach for identification of behavior patterns including maritime anomalies substantialized as Open Data Anomaly Detection System (ODADS) [114]. Furthermore, the management of big data in the maritime industry has several important challenges, which according to [115] involve many privacy issues, near-monopoly providers of data, data governance, ability to handle and analyze data together with the availability of powerful software tools for big data processing. However, big data are a vital part of many aspects of maritime and vessels operations, especially considering the technical maintenance, vessel energy efficiency, and commercial operations. Particularly, with the growing introduction of automated technologies, big data are involved in safety control and performance, autonomous shipping and operations, as well as management and monitoring of accidents and environmental risks.

Big data as fundament, operational and decision-making systems have grown in specific highly developed computational tools equipped with machine learning and other mathematical algorithms that are able to recognize, distinct, extract knowledge and provide reliable information for implementation of real actions. These technologies are known as artificial intelligence and their exploitation in contemporary maritime industry and business is of vital significance for the effectiveness of various maritime and vessel operations. Specifically, [116] discusses the artificial intelligence (AI) technology and techniques currently available and how they can be used to benefit the maritime industry aiming to show the advantages of machine learning (ML) modules based on big maritime data. Among many important features of AI techniques, [117] states that the autonomous systems will have the ability to distinguish between multiple vessels simultaneously and maintain an improved database of commercial vessels. Also, AI-based systems offer the opportunity to go beyond what is humanly possible, and significantly improve maritime safety and security missions. Furthermore, [118] discusses the developing process of AI data fusion and integration tools concerning a soft information fusion and management toolbox, with the provision of core generic functions and semantic knowledge for high-level information fusion in a maritime safety environment. Apart from ML, the authors of [119] investigate the usage of Deep Learning (DL) Modules for creating the object detection models in the maritime domain, identifying the transport vehicles such as ships, vessels, airplanes and cars. In the quoted study, the AI technologies for maritime surveillance applications and object detection were run based on data retrieved from Copernicus Sentinel-1, WorldView-2 European Cities, PlanetScope and Pleiades data as well as Google Earth images over several EU countries, with result in enhanced Convolutional Neural Networks (CNN) and super-resolution of maritime objects. Another important AI method application is the innovative Multi-Source Dynamic Bayesian Network (MSDBN) usage for Behavior Analysis Service, developed in MARISA H2020 Project, with an aim to advance data and information fusion services. The MSDBN is a vessel behavioral analysis tool based on a probabilistic model with the layered hierarchical structure, whose aim was to improve knowledge acquisition and clearly identify maritime anomalies [120].

Using the wide AIS databases and Kinematic Features in Maritime Traffic Control, Fusca et al. in [121] presented an important approach for identification of Vessel Class with deep Long Short-Term Memory model (LSTM). The aim of this method is to detect anomalies in maritime traffic and, in particular, to discover vessel activities by running the LSTM model over a specific box area and an adequate sample of ship movements, received from AIS or radar sources. In addition, from streaming AIS databases of Netherlands authorities, in [122], it is shown that using ML for unsupervised maritime waypoint discovery with DBSCAN algorithm enables operators to assess the risks of vessels operations and maneuvering in ports. Further to the significant purpose of AIS data exploitation in artificial intelligence technologies, Hashimoto et al. in [123] present a Development of AI-based Automatic Collision Avoidance System and evaluation by Actual Ship Experiment. Also, the risk of ship collision could be estimated by using the Fuzzy Inference System (FIS) which starts with evaluation parameters from AIS data, proceeds with internal components (fuzzification, inference, rule base, and defuzzification) resulting in collision risk (CR) prognosis. Therefore, the CR evaluation algorithms, deployed in the CY-CISE project, were integrated into the forensic toolbox of OCULUS Sea Platform and showed an accurate and efficient performance of FIS in collision prevention [124].

2.4 Autonomous unmanned vehicles

In the context of data collecting assets, the Unmanned Aerial Vehicles (UAV) and Autonomous Underwater Vehicle (AUV), play a significant role in surveillance missions and actions at sea. Specifically concerning the AUV, which is deployed in the recent COMPASS2020 project, the efficiency of operations of search and rescue, narcotics trafficking prevention, illegal migrations, illicit goods transfer suppression and other criminal actions identification at sea, could be additionally raised due to its technical features, underwater performance and autonomous management approach [45]. Therefore, the key features of AUVs are high maneuverability, powered by battery or fuel cell, with capability to explore various geographical areas based on dedicated navigational algorithms and collect data from different positions [44], [125]. In addition to persistent surveillance in the maritime domain from aerial perspective, various UAV systems are used to satisfy the maritime safety requirements, with seamless communication on several levels and ranges coordinated by maritime command and control centers or platforms from patrol vessels. To this end, [46] reviews and gives the comparative advantages of the UAVs deployed under mentioned COMPASS2020 project, considering Zephyr pseudo-satellite, as well as the AR3 Net Ray and the AR5 Life Ray Evolution crafts capable to cover large areas and transfer the processed data to maritime mission systems/C2 centers via STANAG 4586 Protocol. Extending the SWOT analysis of these UAV systems and assets, [44] found that core strengths are lightness, the possibility of manual launching, low energy consumption, lower price in comparison to satellites, high seeing, sensing and communication features, the capacity of both line of sight (LoS) and beyond line of sight (BLoS) operations, large coverage, and durability of flight. As opposite, the UAVs weak sides are complexity of the systems and the requirement of highly skilled personnel for these aircraft design, production, operation and maintenance, along with opportunities like lower costs, lower ecological and logistics footprints. One of the core UAV purposes is to provide real time picture of surveilled area, i.e. to enable shared situational awareness picture by maritime incident identification, monitoring resource management, analysis and internal communication and determination of proper person to receive information about relevant event. To fulfill these tasks, there have been designed a multipurpose based situational awareness system, namely the INtelligentUxV Surveillance (INUS) platform consisting of UAV, terrestrial system, drone pilots workstation and intelligence officers workstation [126]. Among many advantages and besides image data collection, UAV platforms are able to process the collected data thanks to embedded AI/ML modules that detect and recognize autonomous objects in maritime environment [127]. Being equipped with many hardware and software with sensing components (thermal camera, RGB camera, abstraction layer for communication with the flight controller, etc.), the UAVs have the capability to detect various objects based on ML algorithms such as DeepSORT combined with Yolov4 [128].

Concerning the increased need for timely provided information about the current state in the maritime domain, the EU initiative for Common Information Sharing Environment (CISE) has been established in 2010 with aim to foster collaboration between maritime authorities by using network model for vessel data and services exchange. All abovementioned maritime big data collecting and processing assets supported by AI, provide an excellent information base that corresponds to the CISE Data and Service Model. Therefore, it integrates several components mostly based on vessel data received by national monitoring and reporting legacy systems (e.g. AIS, LRIT, radar, etc.), UAV/AUV persistent surveillance assets and Decision Support Tools embedded into Command and Control Systems [43], [129]. Moreover, having in mind the fully secured channels of vessel data processing and services sharing, [130] discusses the CISE as a reliable tool for transferring the sensitive information among maritime agencies. In order to fully test and validate these CISE-based systems there have been run several maritime safety and security projects and case studies among which, one of the recent, deals with trialing the scenarios of shared data retrieval across EU CISE [131]. Further to enabling the continual communication among participants, the specific platforms in the form of modular and collaborative software for information exchange based on CISE principles are designed with aim to raise the maritime situational awareness level. One of these platforms with augmented command and control functions is OCULUS Sea C2I including various forensics tools for a CISE network establishment [132]. Regarding technical structure, the CISE data model, established in the project EUCISE 2020, identifies seven core data entities (Agent, Object, Location, Document, Event, Risk and Period) and eleven auxiliary ones (Vessel, Cargo, Operational Asset, Person, Organization, Movement, Incident, Anomaly, Action, Unique Identifier and Metadata). In order to present these entities, the Unified Modelling Language (UML) and Ontology Web Language (OWL) are used for conceptual modelling of CISE structured network. For enhancing the EUCISE 2020 data model, an EUCISE-OWL ontology is designed, containing the abilities to specify common information sharing environment, transmit the relevant information among decision support systems, events triggering, and action inference with significant enumeration of large number of classes, data and object properties [133].

2.5 Modular containers

An important innovation of contemporary container market and shipping is the introduction of modular containers for overcoming the global problems of trade imbalance. Therefore, the dynamic modular shipping container identification is raised as significant method for resolving the frequent issues in world container seaborne trade by involvement of novel technique with scenario of joining and separating two 20’ modular container units to and from a single modular 40’ container unit [133], [134]. Being deployed as a concern of Horizon 2020 ePIcenter (Enhanced Physical Internet-Compatible Earth-frieNdly freight Transportation answER) project, the use of magnetic e-ink screens is envisaged for this process, which receive instructions from a mini-CPU (Arduino) installed in factory and tamper-proof, automatically instructing the containers to recognize if they are in a single (20’) or coupled (40’) mode and show the unique and unrepeatable container serial number for the detected working mode, regardless of whether the container(s) are a decoupled 20’ or a coupled 40’ unit. Existing data structures and standards largely assume a static one-to-one relationship between a physical object and its identifier. Containers (ISO 6346) and ships (IMO Number) have a unique ID which is used to track their movement. Such emerging technologies are likely to offer significant benefits and become more widespread.

CHAPTER III: Research Methodology

3. Research Methodology

The key element of research design is research strategy. A strategy is a plan for achieving a certain goal. A research strategy assist us to meet research objectives and to answer research questions of the study. The choice for a particular research strategy therefore depends on the research objectives and the type of research questions of the study, but also on researcher's viewpoint on what makes good research and on practical aspects such as access to data sources and time constrains. The research strategy applied in this study is multi-layered one and it includes: (1) causal study examined through multiple linear regression analysis; (2) exploratory and descriptive sequential mixed method design; and (3) comparative study realised through SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis.

Causal studies test whether or not one variable causes another variable to change. In such a study, the researcher is interested in delineating one or more factors that are causing a problem. The intention of the researcher conducting a causal study is to be able to state that variable X affects in a certain extent variable Y. Multiple linear regression model includes n independent variables X, which have different impacts on dependent variable Y. This allows the researcher to identify the extent in which X affects Y. Since multiple linear regression model is complex, it is advisable to use computer for numerical calculations. Of course, the discussion or interpretation of the obtained numerical values is the researcher's task. Multiple linear regression approach is used here in assessing intelligent exploitation of sophisticated ICT&S in developing maritime settings from the perspective of constructs like: knowledge, IT management, system efficiency, and organizational culture.

The objective of descriptive study is to obtain data that describes the topic of interest. Descriptive studies are often designed to collect data that describe characteristics of objects (here particular ICT&S), events, or situations. Descriptive research is either quantitative or qualitative in nature. It may involve the collection of quantitative data, but it may entail the collection of qualitative information as well. Descriptive studies may help the researcher to: understand the phenomenon, to think systematically about aspects in given situation, to offer ideas for further probing and research, to make some (simple) decisions, etc. Within this study such approach has been used for introducing the readers with key performances, advantages and challenges of blockchain technology as a driver of blockchain based maritime supply chain systems.

Exploratory research is applied when: (a) not much is known about a particular phenomenon; (b) existing research results are unclear or suffer serious limitations; (c) the topic is highly complex; or (d) there is not enough theory available to guide the development of a theoretical framework in a certain setting. Exploratory research often relies on qualitative approaches to data gathering such as informal discussions, interviews, focus groups, and case studies. As a rule, exploratory research is flexible in nature. The results of these studies are typically not generalizable to the population. Exploratory sequential mixed method design, usually begins with the qualitative research and ended up with quantitative one. The qualitative part is used commonly for refining the questionnaires as a part of qualitative research. This approach has been used in this study to assess the level of stakeholders' readiness to implement and adopt disruptive blockchain technology in shipping and port management.

The SWOT analysis is a strategic planning and strategic management technique used to help the researcher to identify Strengths, Weaknesses, Opportunities, and Threats related to business competition or project planning. It is sometimes called situational assessment or situational analysis. In this research, it is used for identifying strengths, weaknesses, opportunities, and threats of autonomous (unmanned) underwater and aerial vehicles deployment in maritime surveillance and safety missions, with the aim to prevent illegal migrations and narcotics smuggling across the sea borders.

The applied methodological framework for the purpose of this research project is presented graphically in Figure 6.

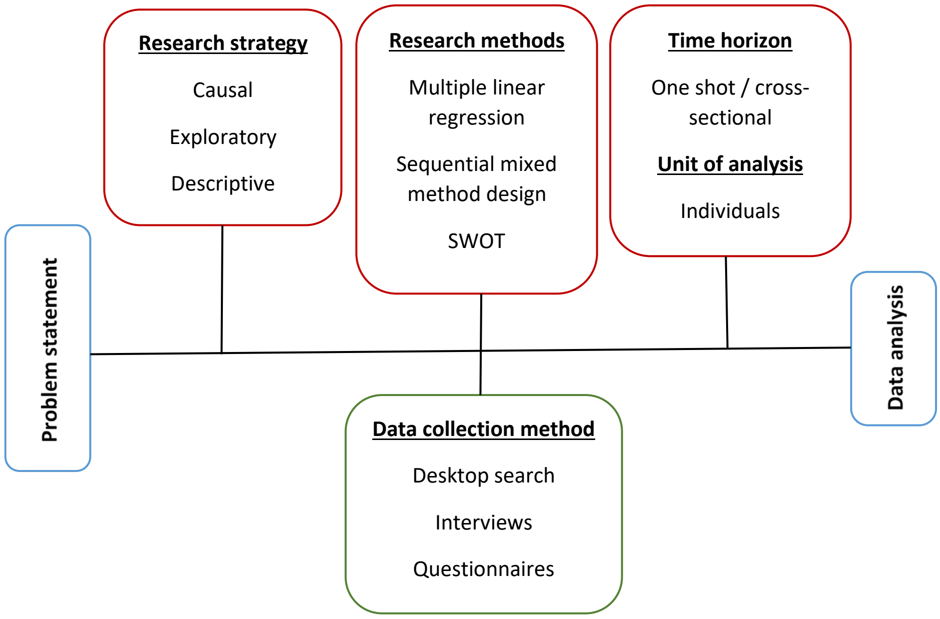


Figure 6. Research design and applied methods (Source: Own).

This research design will be used in the following sections for: (a) assessment of the level of rationality in deploying contemporary ICT&S in maritime developing environments; (b) evaluation of the readiness of selected stakeholders in maritime from South Africa and Montenegro to adopt blockchain technology; and (c) introducing readers with advanced autonomous (unmanned) sea vehicles, which can be used in combination with conventional vessels for sea borders' protection.

3.1 Smart ICT&S adoption in maritime

We live in a time of massive progress in the field of info-communication technology and systems (ICT&S). The question is do we really need all these innovations and do they always make our lives easier and better. In order to get the best out of ICT&S, we need to know which of these technologies we actually need and how to use them purposely. When it comes to a business environment, it is very important that higher management structures are aware of these needs and discuss them with employees. This is especially important in maritime business, bearing in mind that, stakeholders in maritime are usually conservative and not early new technology adopters. There are several studies that consider ICT&S rational, intelligent or smart implementation and adoption of advanced ICT&S in maritime [32], [33], [36], [135], [136], [137]. Through the Holtham's & Courtney's model, it has been examined how stakeholders in maritime assess key constructs in the model, regarding some developed and developing countries in Europe. The considered countries were treated as the European Union (EU) and non-European Union (non-EU) ones. Before presenting applied methodology, an overview of the applied Holtham's & Courtney's model is given.

3.1.1 Holtham's & Courtney's model

The Holtham's & Courtney's model is composed of four constructs: knowledge, ICT&S strategy, system effectiveness and ICT&S management. These constructs are supported by organizational culture and top manager's mind set (Figure 7).

Knowledge can be described as understanding of a subject that one gets by experience or study, known either by one person or by people generally; or, as the state of knowing about or being familiar with something [137]. Furthermore, Cambridge dictionary depictures knowledge as awareness, understanding, or information that has been obtained by experience or study, and that either is in a person's mind or possessed by people generally; or, as skill in, understanding of, or information about something, which a person gets by experience or study [138]. Symbolically, knowledge is one of the steps in so-called ladder of knowledge. This ladder of knowledge encompasses data, information, knowledge itself, and wisdom stairs. The data and information have easier explanations than the concepts of knowledge and wisdom. In this context, the focus will be on knowledge stair, as a key for understanding contemporary ICT&S and their rational implementation in maritime business. Knowledge here means consciousness about advanced ICT&S availability at the market, including the ICT&S purposiveness regarding particular business strategies, processes and activities.

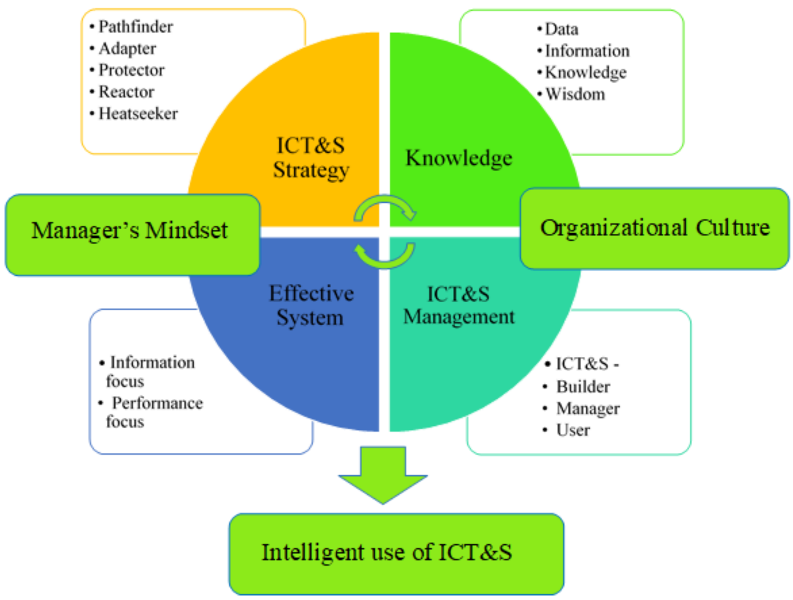


Figure 7. Adapted Holtham's & Courtney's model (Source: [139]).

The ICT&S strategy brings together business and technology. Due to the Holtham's & Courtney's model there are five different strategic orientations.

Pathfinder: Systematically seeks and selectively exploits relevant ICT&S trends to gain competitive advantage and enable entry into new markets. Pathfinder is willing to experiment with new, advanced ICT&S. Pathfinder constantly seeks for a competitive advantage by detecting or sensing emerging ICT&S trends and opportunities.

Adapter: Functions at two types of market: one relatively stable and focused on efficiency, and the other where ICT&S plays an increasingly important role. Adapter applies different rates of technological uptake in each. This split feature is typical for businesses where different rates of technological adoption are present, and adaptability rather than uniform solutions are applicable.

Protector: Meticulously assesses ICT&S investment for its efficiency orientation and applies technology primarily to reduce costs of investments and increase communication processes rather than new market opportunities creation. Protector is control orientated and slow to innovate. These organizations work in domains where core ICT&S-based technologies are commonly available and easily replicable.

Reactor: This is a characteristic of an organization where technology is not perceived as a strategic tool. It responds slowly to change, and tends to view ICT&S applications as standalone tools. In this strategic orientation, the ICT&S platforms usually appear to be weak or obsolescent. The risk is that the organization could quickly become non-competitive through lack of capacity to meet customers' needs.

Heat seeker: Seeks upon ICT&S fashioned instead of strategically analysing the best ICT&S fit for its business processes. Heat seeker is typical for an organization whose structure is in constant change, experimenting with innovations before obtaining steady business performance. This organization is receptive to ICT&S spends and subsequent partial reversals when intended benefits are not realized quickly.

The system effectiveness can be achieved by setting and communicating critical success factors (CSF) [64] and developing them steadily. The first step is to use technology to create an effective operational platform, primarily with internal information. Then, the CSFs can be widened to foster improved skills to use technology. This will start with employees and then extend to suppliers and customers. Once when these two steps work well, the CSFs can be broadened to encompass external information about markets, customers and competitors. After these, three steps comes business intelligence, which allows organizations to identify and manage risk while developing new products, services and markets to ensure successful future.

The ICT&S management is based on ICT&S builders, ICT&S managers and ICT&S users. A person or management team that communicates the needs of ICT&S users in to ICT&S builders or designers has to be engaged in the organization as a knowledge navigator, or information resource manager. There are business organizations, which recognized this triangle and which work on filling and improving the personnel skills towards achieving this goal [140], [141].

These four constructs, which form the backbone of the Holtham's & Courtney's model are underpinned by organizational culture and top manager's mind set.

Concerning the organizational culture, there is universal agreement that it exists and plays an important role in shaping behaviour in organizations. However, there is a little consensus on what organizational culture actually is. Here are quoted several expressions that can be used in absence of universally accepted one [142]: organizational culture is how organizations do things; organizational culture is the sum of values and rituals, which serve as glue to integrate the members of the organization; organizational culture is civilization in the workplace, etc.

Top manager or top management team role is to weave a fabric of horizontal (information, technology, people, and organization) and vertical (direction, knowledge, process, and climate) threads mutually intertwined. In organizations where knowledge is a core dimension, managers have frequently identified people’s skills as the major influence, along with organizational climate. Moving from the information-based to the knowledge-based enterprise is a major challenge for today’s companies [143]. Therefore, managers have to combine properly notions from several different domains: organizational behaviour, human resource management, big data, analytics, artificial intelligence, etc. Technology is a key enabler, but not usually as significant as skills and climate. Top managers’ team mind set covers all considered constructs and it affects intelligent or rational use of ICT&S.

These constructs are used in the following analysis as independent variables. As a control variable is used non-compliance between technology-led potential and its everyday usage, while dependent variable is intelligent use of ICT&S, which reflexes efficient and smooth communication between tasks, technologies and employees [40].

3.1.2 Tentative statements

Based on the Holtham’s & Courtney’s model, a survey was conducted among stakeholders in maritime in terms how rationally they use the ICT&C in their business. Selected stakeholders from four EU (Croatia, Greece, Italy, and Slovenia) and from four non-EU countries (Albania, Bosnia & Herzegovina (B&H), Montenegro, and Serbia) were included into the survey. Forty experts (five per each considered country) from maritime administrative bodies, agencies, private marine companies, ports and universities (i.e., maritime departments) were asked to evaluate the set of fifteen tentative statements or hypothesis by means of Likert (1-5) scale (Table 5). The last two statements refer to the control and dependent variables in the model, respectively, while the rest of the statements correspond to the independent variables.

Table 5. Survey content (Source: Own).

Construct	Tentative statements
C1: Knowledge	S1.1: Knowledge is important for business success. S1.2: Knowledge and skills of employees are important for efficient and effective use of ICT&S.
C2.1: ICT&S Strategy *Pathfinder*	S2.1: New ICT&S solutions adoption is risky for the organization.
C2.2: ICT&S Strategy *Adapter*	S2.2: Analyzing carefully the existing ICT&S solutions prior to their introduction into the organization is important.
C2.3: ICT&S Strategy *Protector*	S2.3: The ICT&S reduce operational costs of the organization.

C2.4: ICT&S Strategy *Reactor*	S2.4: The available ICT&S solutions can be adapted to the current business needs of your organization.
C2.5: ICT&S Strategy *Heat seeker*	S2.5: The latest ICT&S solutions are the best ones.
C3: System effectiveness	S3.1: Your customers intensively use ICT&S resources of your organization (web site and various online users' apps). S3.2: The ICT&S allow you to become familiar with the current market trends in the area of your business.
C4: ICT&S management	S4.1: The ICT&S functions are important for successful functioning of the organization and its business success. S4.2: The usage of ICT&S for operational takes within your organization (accounting operations, database of employees, database of business partners, market analysis, etc.) is extensive.
C5: Culture	S5: Positive organizational culture and clime are important for effective use of ICT&S.
C6: Manager's mindset	S6: Manager's mindset is important for effective use of ICT&S.
C7: ICT&S capacities versus exploitation	S7: There is a divergence between ICT&S capacities and their real application at daily basis in your organization.
C8: ICT&S intelligent exploitation	S8: The ICT&S serve as a connective tissue among tasks, technologies and employees in your organization.

The level of respondents' agreement with the proposed statements is labelled due to the following scheme: (a) if the average score per a group of experts from a certain country is between (1.0-2.5) than the level of experts' agreement is "low"; (b) if it is between (2.6-3.5) than the level of agreement is "moderate", and (c) if it is between (3.6-5.0) than it is "high".

3.1.3 Multiple linear regression approach

Multiple linear regression model has been used to double test in the previous section identified hypothesis upon intelligent exploitation of advanced ICT&S in maritime in emerging business and industry companies.

In general, multiple linear regression model is used to establish analytical relation between dependent variable: intelligent use of ICT&S, in this case, and independent variables grouped as: knowledge (X_1), IT management (X_2), system effectiveness (X_3), and organizational culture (X_4). Our task was, in line with the requirements of multiple linear regression [40], [144] to determine the coefficients (b_1, b_2, b_3, and b_4) and to calculate mean expected value of the dependent variable in the model by equation (1), in accordance to the respondents feedback:

$$\overline{Y} = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 \qquad (1)$$

Where is,

$\overline{Y}$ - mean expected value of the dependent variable;

b_0 - Y-axis intercept, determined on the basis of an appropriate sample; and,

(b_1, b_2, b_3, b_4) - vector of linear coefficients for the variables X, respectively, or slopes of the corresponding lines.

This practically means that for any new value of each independent variable from a predefined interval, we can estimate the value of the dependent variable. The mean expected value of the dependent variable is average estimated value, because it is the mean value of the probability distribution of possible values of Y for a given value of X. To determine this value, the least-squares method is used. In fact, our goal here is to determine the coefficients (b1, b2, b3, and b4), so as to minimize the sum of squared errors (SSE), which is represented by formula (2):

$$SSE = \sum_{k=1}^{n}\left(Y_k - \overline{Y}_k\right)^2 = \sum_{k=1}^{n}\left(Y_k - \left(b_0 + b_1X_{1k} + b_2X_{2k} + b_3X_{3k} + b_4X_{4k}\right)\right)^2 \qquad (2)$$

Where is,

$\overline{Y}$ - real value of the dependent variable, given by the k respondent, k=1,n;

X_{nk} - the estimated value of the dependent variable on the basis of the model, in the case of k respondent, k=1,n; and,

n - number of respondents.

Using the least-squares method, here is actually determined a straight line, which minimizes the sum of vertical differences for each pair of points. In other words, identified is a straight line that best fits the given set of points, by determining the optimal value of Y-axis intercept (b_0), as well as coefficient (b_1, b_2, b_3, b_4) vector, in order to obtain a more accurate value of the estimated value of the dependent variable for the given values of X and Y. The realization of multiple linear regression is very complex, and therefore it is better to leave it to the computer. For this purpose can be used, e.g. SPSS and special Excel VBA tools as Excel Module solver, which we used in this particular study. In addition to the forecasted average value of the dependent variable and vector of coefficients b, based on the model applied, determined can be the following statistical values: mean absolute deviation, mean square error, mean absolute percent error, standard error of regression estimate, correlation coefficient and coefficient of determination. The formulas used to calculate these values are given below, along with their brief explanations.

- *Mean absolute deviation* (MAD), indicates the numbers on how much the value of the dependent variable, obtained through multiple regression analysis, corresponds to the estimated value by the respondents, or in other words, to what extent the model reflects the perception of the respondents (3).
- *Mean square error* (MSE) is the mean value of squares of the individual errors of assessment. In other words, if we have n number of respondents, MSE value is calculated using the formula (4). MSE points expressed deviations.
- *Mean absolute percent error* (MAPE), indicates the error between the estimated value and value of dependent variable as a percentage, obtained by using the model. MAPE is the simplest statistical value for interpretation (5).

The formulas for determination of the values of the previously described errors in the model are given below:

$$MAD = \sum_{k=1}^{n}\left|A_k - F_k\right| / n \qquad (3)$$

$$MSE = \sum_{k=1}^{n} (A_k - F_k)^2 / n \tag{4}$$

$$MAPE = 100 \sum_{k=1}^{n} [|A_k - F_k| / A_k] / n \tag{5}$$

Where is,

A_k - real value of variable (value estimated by respondent), k=1,n;

F_k - estimated value of variable, k=1,n; and,

n - number of respondents.

- *Standard error of the regression estimate* (SE), is also called the standard deviation of regression. This statistical value is suitable for the formation of the so-called confidence intervals around the regression line. It indicates how much the value of the dependent variable, obtained by the model, can vary (numerically) (6).

- *Correlation coefficient* (r), is used to estimate the strength of linear relationships. Generally, if correlation coefficient is higher than 0.6, it is considered to be a strong linear relation and vice versa (7).

- *Coefficient of determinati*on (r^2), is a value between 0.0 and 1.0, which indicates to what extent (percentage) dependent variable depends on the independent variables included in the model. E.g., if r^2 is 60%, it means that the value of the dependent variable 60% depends on the independent variables in the model, and 40% on other factors (variables) that are not included in the model (8).

General formulas for calculating the standard deviation, correlation coefficient, and coefficient of determination are given below:

$$SE = \sqrt{\sum (A_k - F_k)^2 / (n-2)} \tag{6}$$

$$r = \frac{n \sum A_k F_k - \sum A_k \sum F_k}{\sqrt{\left[n \sum A_k^2 - \left(\sum A_k\right)^2\right]\left[n \sum F_k^2 - \left(\sum F_k\right)^2\right]}} \tag{7}$$

$$r^2 = \left\{ \frac{n \sum A_k F_k - \sum A_k \sum F_k}{\sqrt{\left[n \sum A_k^2 - \left(\sum A_k\right)^2\right]\left[n \sum F_k^2 - \left(\sum F_k\right)^2\right]}} \right\}^2 \tag{8}$$

Where is,

A_k - real value of variable, k=1,n;

F_k - estimated value of variable, k=1,n;

n - number of respondents.

The respondents were asked to estimate the dependent (Y) and four independent variables (X_1, X_2, X_3, and X_4) in the corresponding models, each with a number on a scale from 1 to 5. Also, the values of statistical parameters, described afore, have been determined in order to analyse the reliability of the resulting predictive model.

By using Excel Module solver, the results of multiple regression analysis are obtained. More precisely, determined are coefficients in function of the dependent variable, that is, the slice on the Y-axis (b_0) as well as the coefficients (b_1, b_2, b_3, b_4), which correspond to the independent variables X included into the model.

To summarize this section of research methodology, we would like to highlight that the Holtham's & Courtney's model has been used for establishing causal framework between dependent (intelligent exploitation of ICT&S in maritime sector) and independent (knowledge, IT management, system efficiency, organizational culture) variables in the model. Hypothesis set upon this theoretical framework were tested numerically by basic statistics and also through multiple linear regression model in SPSS and MS Excel Module. The obtained results will be presented in Chapter 4.

3.2 Blockchain adoption

Blockchain is designed to record and track transactions. It is very important to understand this technology to become capable to deploy it rationally across maritime clusters for documentation exchange, instant payments based on complex crypto-currency mechanisms, containers tracking and tracing, near-instant logistics adjustments, automated risk management, insurance purposes, and much more. Blockchain technology starts to build a block or individual blocks that become a chain, and that is a ledger. One can put information in a ledger, while all involved in the transaction can see that information. If a mistake is made, one has to build a new block that relies on the block before it. If one has multiple transactions, that person can build multiple blocks with multiple people and everybody can see the progression of whatever these multiple transactions are. This is a great advantage from a logistics, accounting, and risk-management perspective to be able to see all these [41].

One of the pieces behind blockchain technology is so-called Hyperledger. Blockchain programs are built on this platform or framework. The IBM has moved blockchain from in house to Linux Foundation, and consequently all the code is open source, as a catalyst to move blockchain forward into different industries, including maritime. Danish Maersk uses IBM-established collaboration through the TradeLens platform in 2017 to track container locations, cargo details, trade documents, and sensor readings. The TradeLens offers the oversight control and automated risk management to every stakeholder in the supply chain: beneficial cargo owners, ocean carriers, ports, terminal operators, inland carriers including rail and tracking, shippers, freight forwarders, customs authorities, financial service providers, etc. The TradeLens uses Hyperledger Fabric permissioned blockchain to guarantee the immutability and transparency of trade documents. It has a powerful Application Programming Interface (API) model, but it is easy to use web interface to deliver insights into equipment number, bill of lading number, cargo manifest number, booking number, and all important information related to the container shipment. Key milestones that include hundreds of events can be followed up and down the supply chain, including near-instant logistics adjustments, so disruptions are kept to a minimum.

Currently, the platform handles 10 million events and more than 100 000 documents every week. It is worth mentioning that there are 120 shipping events types [75] developed within TradeLens platform. Within this context, it is important to note that more than US$16 trillion in goods are shipped across international borders each year. Approximately 80% of consumer goods used daily are carried out by the ocean shipping industry. By reducing barriers within the international supply chain, global trade could increase by nearly 15%, boosting economies, and creating new jobs [84].

Legacy data systems and manual document handling cause friction that costs both time and money for business and people throughout the supply chain. The TradeLens enables unprecedented transparency, collaboration, and efficiency in global supply chain. It provides control and management of shipping data and supplies innovative Apps to every stakeholder. Access to shipping data and information is managed by TradeLens sophisticated permission model at each stage of shipment and provides a blockchain-encrypted audit trail of all critical actions. The TradeLens document store allows documents to be securely stored, viewed, and actioned by various parties. Documents can be uploaded and shared, as either structured or unstructured (scans or PDFs). The last allows information sharing between supply chain partners with disparate IT capacities. The TradeLens platform permits access to documents according to the permission matrix, so the right people can securely manage their supply chain in real time. It breaks down longstanding data and processing silos that exist among some trading partners and simplifies the flow of documentation, which accompanies every shipment.

3.2.1 Descriptive approach

Bockchain in maritime is a far broader system than cryptocurrency-based electronic financial transactions mechanism. In literature, it is named as Blockchain-based Maritime Supply Chain System (BMSCS) [77]. It includes smart contracts and payments, tracking and tracing cargo, empty containers placement, early risk assessment, and services that can create new added values in maritime (Figure 8).

Maritime is an indispensable link in global supply chains. Hereof, blockchain technology is likely to become unavoidable in shipping and port management, in striving to optimize global supply chains and make these more efficient and effective. The BMSCS should reduce the volume of administrative work, errors that occur due to manual work, delays in the delivery of goods and consequently overall costs of transportation and delivery of goods. Due to some studies, the costs of global supply chains should be reduced for approximately 15% by implementing blockchain technology [84].

In addition to these advantages, blockchain also has certain disadvantages. Maritime sector is generally risk averse, tending not to be early adapter of new potentially risky technology [145]. Some stakeholders in maritime want to keep their data secret, since “competition is fierce” and “a lot of industry actors are basically competing with the same service” [146]. In other words, some partners among the supply chain consider information as a competitive resource and are unwilling to share them. Positional data might be used to track vessels by identifying port locations, fuelling locations and routes [147]. This is particularly the case with tracking dangerous and hazardous goods, pharmaceuticals, or food. The use of blockchain does not guarantee that the information recorded in the ledgers is correct and does not prevent tampering data prior to entering it into blockchain ledger, e.g. the contents of a container, fuel consumption, testing or combustion, and the like [98]. Due to huge amount of data and traffic generation, including data storage, blockchain requires a wideband like G5 or G6 [148], while the internet speed can be low when the working stage is offshore. Further, blockchain causes high-energy consumption [94]. Blockchain in the maritime sector indicates the potential to reduce transaction costs in a number of areas, including reducing the need for intermediaries such as brokers and courier services, and to reduce related financial expenses and energy costs. However, one should not forget that this does not include the costs of the overall investment and expenses associated with blockchain implementation and adoption, especially in developing or emerging economies [41], [42].

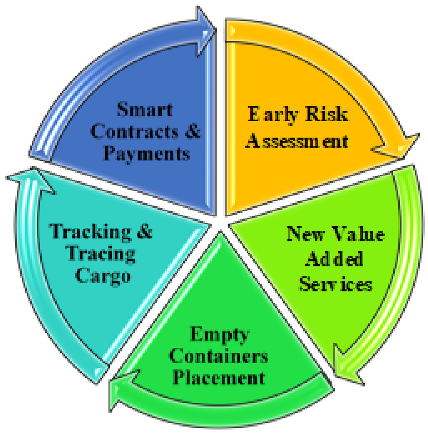


Figure 8. BMSCS intertwined dimensions (Source: Own).

Present level of awareness, knowledge, and expertise about blockchain is scarce among the stakeholders. Therefore, educational, training or capacity building programs are necessary at regulatory, administrative and operational levels. Higher level of standardization across the global supply chain is necessary as well. The Digital Container Shipping Association (DCSA) conducts efforts in this regard, but further, more extensive, actions are necessary. In general, there is a hesitation by stakeholders in maritime sector to invest in blockchain systems in terms of technological integration, regulatory, organizational, and educational costs, since maritime sector traditionally relies on its legacy systems. There appears to be a gap between what practitioners in the blockchain area suggest and what has been a range of state-of-the-art approaches in the software engineering and information security research and practice [81]. Furthermore, the major liner shipping companies are the most likely parties to benefit from blockchain regarding the complexity of their blockchains and huge requirements on financial resources [149]. This can put other potential actors in the global supply chain at a disadvantage. The last but not the least, the basic attitude should be that technology, in this case blockchain on the top of global supply chain should improve the human condition, and not replace humans [30]. Therefore, human and ethical dimensions of blockchain technological development and more extensive deployment, should not be neglected.

3.2.2 Exploratory sequential mixed approach

Through this research study, we aim to collect the information relevant for blockchain adoption in maritime, in two developing countries, i.e. South Africa and Montenegro. As a research strategy, we used sequential mixed method, i.e. a combination of closed and open-ended questions. Set of close-ended questions was conceived in a manner to assist us in more precise designing of open-ended questions in the second iteration. In both cases we used survey as a system for collecting information from people to describe, compare, or explain their knowledge and attitudes towards using blockchain in maritime business. This strategy allows us to collect both quantitative and qualitative data and information. The survey was used for exploratory and descriptive purposes as a one-time or one-shot survey. As the survey instrument, we used self-administrated questionnaires that respondents completed on their own via the computer. After data were obtained through questionnaires, these were coded, keyed in, and edited. The questions were conceived after a detailed study of Upadhyay [150] on 'demystifying blockchain'. In addition, we used Rogers [66], Lee & Kim [151], Kapoor et al. [152], Kim & Laskowski [153], Kapidani et al. [40], and Zhou et al. [154]. We applied triangulation of these various approaches and came up with the key dimensions for our questionnaire (Figure 9).

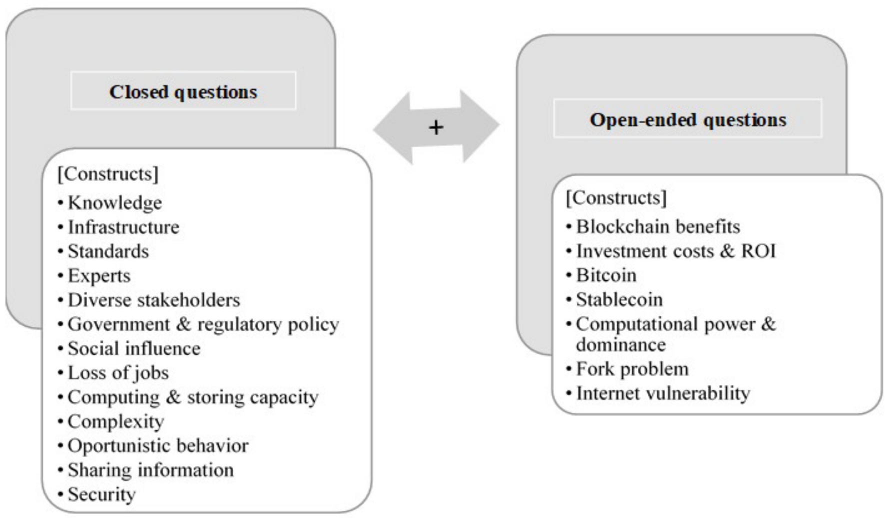


Figure 9. Survey structure and key constructs (Source: Own).

We used both closed and open-ended questions, while we were avoiding double-barrelled, ambiguous, leading, and loaded questions [39]. Closed questions were conceived in a way that participants identify advantages or disadvantages of certain blockchain dimensions, and then chose one of the numerical values of Likert scale: 1, 2, 3, 4, or 5. Due to this scale, 1 represents the lowest level of agreement or disagreement, and 5 represents the highest level of agreement or disagreement with the tentative statement. The rest of the offered numerical values are respectively in-between these two extremes. The open-ended questions allow respondents to express their opinion in free writing style. The respondents were selected among IT and maritime experts from South Africa and Montenegro. They are from maritime companies, agencies, research organizations, governmental bodies, insurance companies, and universities. They are from executive management level at industry and governmental bodies, and active researchers, professors and lecturers at the universities. Responses were received back from 20 experts, of which 10 were from South Africa and 10 from South Montenegro. The majority of the respondents from Montenegro are partners or external experts at several ongoing European Commission Horizon 2020 projects in blockchain, while the respondents from South Africa are from the universities and the biggest national multimodal transportation company in the country (TRANSNET). After reception, the responses were tested, edited, coded, and analysed, while the obtained results are presented in Chapter 4.

All questionnaires sent back by the selected experts were meticulously filled in and there were no missing or 'wrong' data/answers. It was clear that the experts took their roles seriously and understood the importance of the conducted research.

Quantitative analysis

The quantitative dimension of the survey analysis comprises average values assigned to "agree" or "disagree" attributes to each considered category within closed-ended questions. The level of their agreement or disagreement with the proposed tentative statement, the respondents expressed due to the Likert's (1-5) scale. Set of the analysed statements is given in Table 6.

Table 6. Set of tentative statements for quantitative analysis (Source: Own).

Tentative statement	Agree	Disagree
1. The level of awareness and knowledge of blockchain (BC) affects its adoption.	1…2…3…4…5	1…2…3…4…5
2. The BC adoption is affected by the availability of the infrastructure and functionality to integrate and interoperate within and across the business ecosystem.	1…2…3…4…5	1…2…3…4…5
3. Standardization and ensuring smooth interoperability is necessary, otherwise, BC can make things difficult instead of making them easier.	1…2…3…4…5	1…2…3…4…5
4. The BC adoption is affected by the availability of skilled and expert resources.	1…2…3…4…5	1…2…3…4…5
5. The BC adoption is affected by a large number of stakeholders, with different mind-sets, organizational culture, and working habits.	1…2…3…4…5	1…2…3…4…5
6. The BC adoption is increased by favorable government and regulatory policies.	1…2…3…4…5	1…2…3…4…5

7. Social influence positively affects the behavioral intention of using BC.	1…2…3…4…5	1…2…3…4…5
8. A perception that BC implementation might lead to loss of jobs can be an obstacle in its adoption.	1…2…3…4…5	1…2…3…4…5
9. Development in storage, computing, and cloud infrastructure will affect the BC adoption.	1…2…3…4…5	1…2…3…4…5
10. The BC adoption reduces opportunistic behavior (opportunistic behavior means maximization of economic self-interest and occasioned loss of the other partners).	1…2…3…4…5	1…2…3…4…5
11. The BC adoption is reduced if the information is not shared by the partners, while some stakeholders are hesitant to share information considering it is a competitive advantage.	1…2…3…4…5	1…2…3…4…5
12. Privacy and security of models and data need to be ensured, as BC technology is still immature and vulnerable.	1…2…3…4…5	1…2…3…4…5
13. Blockchain offers a high level of complexity and observability at the same time.	1…2…3…4…5	1…2…3…4…5

Qualitative Analysis

Regarding the qualitative part of the study, which was conceived and conducted through seven open-ended questions around the categories shown in Figure 9, the following issues were considered (Table 7).

Table 7. Set of open-ended questions for qualitative analysis (Source: Own).

Question	Answer
1. Which benefits South Africa/Montenegro might have, for instance, of introducing blockchain solutions in maritime (shipping) industry?	[…]
2. It will have lot of cost in terms of time and money to change the existing system, especially when it is an infrastructure. We have to make sure this innovative technology not only creates economic benefits and meets the requirements of supervision, but also bridges with traditional organization, and it always encounter	[…]

difficulties from internal organization, which is happening now. What do you think accordingly?	
3. Use bitcoin for example, the characteristics of the decentralized system will weaken the central bank's ability to control the economic policy and the amount of money, which makes government be cautious of blockchain technologies. Authorities have to research this issue, accelerate formulating new policy, otherwise, it will have a risk on the market. To which extent do you agree with this statement?	[…]
4. Are you familiar with 'stablecoin'?—Can it assist regarding the previously mentioned challenge and in which way?	[…]
5. Even though it is an advanced technology, blockchain still struggles with some security issues. For instance, if someone has more than 51% computing power, then he/she can find nonce (number blockchain miners are solving for) quicker than others can, which means that he/she has authority to decide which block is permissible. What is your opinion concerning this issue?	[…]
6. Another issue is the 'fork' problem. It is related to decentralized node version agreement when the software is upgraded. Then, nodes are divided into old and new ones, and different problems of their mutual communication can appear.	[…]
7. Blockchain uses internet. Does it mean that it is prone at this instance to common internet attacks like 'botnets', for instance?	[…]

Besides the descriptions of blockchain in general and in maritime, here are presented the closed- and open-ended questionnaires used to assess the level of selected maritime professionals in South Africa and Montenegro readiness to implement and adopt blockchain in their businesses. The obtained results will be presented in Chapter 4, while the accompanied discussion will be given in Chapter 5. Next section explores another disruptive technology in maritime, i.e. autonomous (unmanned) underwater and aerial vehicles for sea surveillance and safety actions in preventing illegal sea border migrations and narcotics smuggling.

3.3 Unmanned underwater assets for maritime missions

In maritime missions are usually involved unmanned underwater vehicles in addition to surface and aerial once [48]. Two main types of unmanned underwater vehicles are: (a) remotely operated underwater vehicles (ROV) and (b) autonomous underwater vehicles (AUV). The ROVs are controlled from the surface by a wired connection. These can do many different tasks, but the wired connection restricts their maneuverability and capacities to reach remote areas. The AUVs navigate autonomously due to the dedicated navigation algorithms and collect surrounding information. Once launched, they collect data and come back to the surface after completion of their specific task. Since AUVs are not connected via wire to the ship or ground they have high maneuverability, powered by battery or fuel cell, they can reach remote locations, follow narrow composite pathways, avoiding at the same time human fatigue and reducing operation expenditures.

The AUVs are very versatile autonomous systems and can be used for numerous purposes as [155]:

- *military* (surveillance, anti-submarine warfare, mine countermeasures, site inspection, inspection of wreckage, payload delivery to ocean floor, search and rescue, aircraft crash investigation, i.e. black-box search and retrieval during the investigation, ocean exploration and bathymetric study, mapping of ocean floor, locating and retrieval of dumped illegal loads, etc.);
- *scientific* (marine biology studies, close-up observations of aquatic life without disturbance, geological survey, archeological survey, underwater environmental monitoring in rivers and lakes, track oil-spill and gas leakage, etc.);
- *industry* (repair and maintenance, track and repair underwater cables and pipelines, underwater structure inspection, etc.); and,
- *other* (underwater video footage collection, fishing, entertainment, sports, tourism, and the like).

The idea of designing and developing AUVs is not a new one. The first AUV, or the self-propelled underwater research vehicle was developed by Murphy and Francois in 1957 in the Applied Physics Laboratory at the University of Washington (USA). This craft operated at 2-2.5 m/s up to a depth of 3600 m. In the 1970s few AUVs were developed in MIT and also in the Soviet Union [155]. These early underwater robots were heavy, expensive and inefficient. Today's AUVs can have six degrees of freedom, travel faster than 20 m/s, accurately detect obstacles and map ocean floor at depths of up to 6000 m. They are more sophisticate, less expensive and consequently accessible for wider exploitation like fishing, sports, tourism, entertainment, etc. However, AUVs have yet to go a long way in terms of becoming fully autonomous, capable to explore deep and hazardous underwater habitats. In Table 8 are given some basic data on actual AUVs producers, AUVs' applications and key technical features.

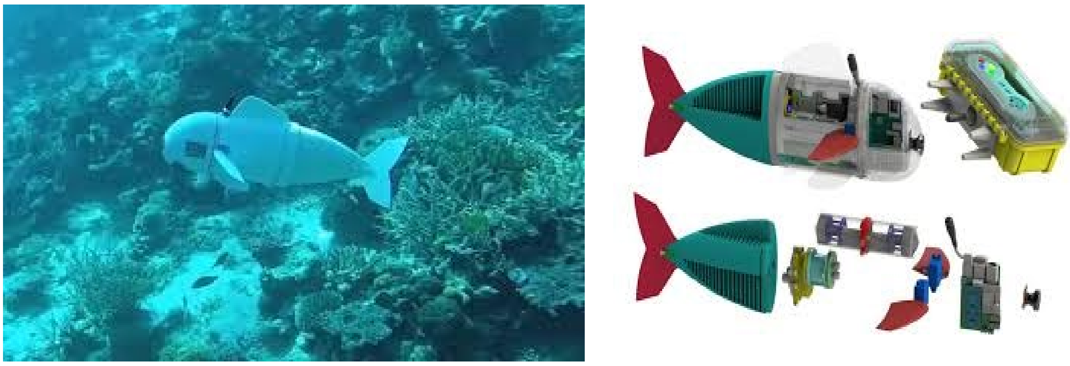
Table 8. Actual AUVs types, producers, applications and basic features (Source: [155]).

Heading level	Applications	Dimensions	Depth
AE1000, Japan	Inspection of underwater telecommunication cables	2.3 m x 2.8 m x 0.7 m	1000 m
Maya AUV, NIO, Goa, India	Oceanography study	1.742 m, dia. 0.234 m	200 m
Theseus AUV, Canada	Under-ice bathymetric surveys	10.7 m, dia. 0.127 m	2000 m
Autosub 6000, AUVAC, USA	Scientific survey and mapping	5.50 m x 0.90 m x 0.90 m	6000 m
HUGIN, Kongsberg	Seabed mapping, pipeline inspection, mine reconnaissance	5.2-6.4 m, dia. 0.75 m	3000-4500 m

REMUS-6000, Kongsberg Maritime	Oceanography study, monitoring, surveillance, reconnaissance, etc.	3.96 m, dia. 0.71 m	6000 m
AUV-150, CMERI, India	Oceanography study, mapping, surveillance, reconnaissance, etc.	4.85 m, dia. 0.5 m	150 m
D. Allan B, MBARI, USA	Seafloor mapping	5.18 m, dia. 0.54 m	6000 m
SOTAB, Osaka University, Japan	Track of leakage from oil mines	3.0 m, dia. 0.27 m	200 m
AE 2000A, Japan	Under-ice survey	3.0 m x 0.7 m x 0.7 m	2000 m
Tri-TON 2, University of Tokyo, Japan	Estimate ore resources in underwater hydrothermal deposits	1.4 m x 0.7 m x 1.4 m	2000 m
SeaCat, Germany	Autonomous inspection of underwater structures	2.5 m x 0.58 m x 0.67 m	600 m
Bluefin21, 2016, General Dynamics, USA	Search and explore, oceanography, mine countermeasures	5 m, dia. 0.53 m	4500 m
A27, ECA Group, France	enduring vehicle capable of carrying a large payload in atmospheric housing	4.7 m x 0.730 m	300 m
A9, ECA Group, France	High resolution data acquisition, 3D data acquisition, shallow waters, harbor and coastal survey	2m, dia. 0.23 m	300 m

Inspired mainly from submarines, AUVs are generally torpedo shape. These are highly maneuverable and can exactly travel in complex pathways and access remote areas, without engendering human life. Some AUVs are of hydrofoil shape, while some other mimicked aquatic animals as snakes, turtles, beetles and crabs. So called, fish robots are mostly popular among the bio-mimetic AUVs. As an example SoFi (Soft Robotic Fish) can be given (Figures 10.(a) and 10.(b)). It is designed and developed by the team from MIT's Computer Science and Artificial Intelligence Laboratory. SoFi is made of silicone rubber and enables closer study of aquatic life. In fact, it gets closer to marine life than humans can get on their own [156], [157].

The AUVs are often equipped with different acoustic sensors like side scan sensors, forward looking sensor, or multi-beam echo sounder, etc. They are usually of modular structure, containing propulsion, sensing, controlling, navigation, communication and other modules. These modules can be easily and quickly replaced in the case of malfunction and/or for the purpose of different missions. The AUVs usually produce low level of noise (or no noise at all in some cases) and consequently don't disturb aquatic ecosystem.



(a) SoFi in searching elusive marine environment (b) SoFi's key modules

Figure 10. SoFi UAV (Source: Web).

3.3.1 Navigation principles

The AUVs navigate underwater autonomously based on predefine plan. Localization is of key importance in navigation, since it enables AUV to follow the predefined path precisely and reach the final destination. As Global Positioning System (GPS) does not function underwater and high frequency radio signals propagation in the underwater environment is suppressed, localization and navigation are very challenging for AUVs. When using GPS, AUV has to resurface in intervals. In general, methods of AUVs navigation can be broadly divided into inertial, acoustic and geophysical.

Inertial navigation. An embedded inertial navigation system (INS) is a navigation device, based on submarine of world war, that uses a computer, motion sensors (accelerometers) and rotation sensors (gyroscopes) to continuously estimate by dead reckoning the position, the orientation, and the velocity (direction and speed of movement) of a moving object (here AUV) without the need for external references [158]. INS is usually used for small, inexpensive UAV, since over the time it can accumulate errors generated by accelerometer and gyroscope. A regular recognition is needed to compensate the drifting.

Acoustic navigation. When it comes to acoustic navigation, the range is estimated from the time of travel of the acoustic signal from AUV to the external transducers (devices, which generate and receive sound waves) and backward. The AUV position is known in real time thanks to calculating on the principle of triangulation. Three different types of acoustic navigation are briefly described below:

a. In the case of Ultra-Short Baseline (USBL) the AUV is positioned relative to a surface vehicle fitted with an array of acoustic transducers (Figure 11.(a)). Relative distance is calculated from the time of travel of the acoustic signal and direction from the phase difference of the signal received by different transducers. Here the transducers are placed close to one-another and major disadvantage is precise range detection.

b. In the case of Short Baseline (SBL) the transducers are placed in front and back of the surface vessel (Figure 11.(b)). Therefore the baseline is limited to the length of the vessel, which limits the positional accuracy of the AUV.

c. In the case of Long Baseline (LBL) the transducers are widely placed over the mission area on the seabed (Figure 11.(c)). Localization is done by triangulating the range estimated by acoustic transducers. The major limitation is the huge cost and time involved in placing the transducers on the seabed [155].

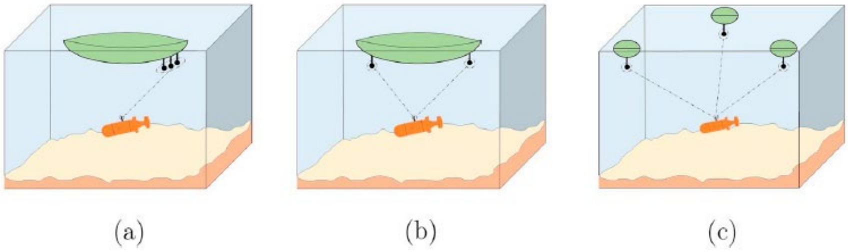


Figure 11. Principles of acoustic navigation (Source: [155]).

Geophysical navigation. When it comes to geophysical navigation, external environmental features are used as landmarks for positioning. Optical and sonar are two main modes of geophysical navigation. Simultaneous localization and mapping is predominantly used for it [155]. In the case of optical navigation, monocular or stereo cameras can be used to take images of the underwater environment and features extracted from the images can be used for simultaneous localization and mapping (SLAM). In such setting different visual odometry[2] techniques are used. On another side, high-power SOund NAvigation and Ranging (SONAR) is a device for detecting and locating objects especially underwater by means of sound waves sent out to be reflected by the objects[3]. Sonar is a commonly used technique for communication, detection of objects, and navigation by using sound propagation. A comprehensible description of Sonar can be found in [159] and it states: "When AUV[4] is used to map the topography of the ocean's floor, it sends out sound pulses, often referred to as pings, towards the bottom of the ocean within its vicinity. As these sound pulses travel downwards they will encounter physical features such as hills, valleys, rock, etc. These sound pulses are subsequently reflected back up towards the AUV, having been modified by the objects along their path. These reflected pulses are often called echoes. Receivers on the AUV that detect these echoes can than reconstruct the topology of the region from which the echoes bounced off". Sonar is very like the echo sounder. The difference is that the sound beam can be steered in the desired directions and present images of the bottom topography on suitable display. Synthetic Aperture Sonar (SAS) is a relatively new principle in hydro acoustics. Together with advanced image processing the method can produce very detailed images of sea bed and objects. It operates in such way that one moves sonar along a line and therefore illustrates stationary objects from several directions. The transmitting antenna's synthetic aperture in relation to the object will then be the length the sonar has moved (Figure 12). These systems that are now in use can give resolution of 2x1 cm, which is typically 10 times better than what ordinary sonars can give. Kongsber produces an SAS (HISAS-1030), which is used at AUV

[2] Odometry is the use of data from motion sensors to estimate change in position of an object (here AUV) over time. It is used in robotics by some robots (for AUV, too) to estimate their position relative to a starting location. The word odometry is composed from the Greek words *odos* (meaning "route") and *metron* (meaning "measure").

[3] Marriam Webster Dictionary. Available at: https://www.merriam-webster.com/dictionary/sonar (accessed on 13 April 2022).

[4] Originally "submarine".

Hugin (Figure 13). It works at 70-100 kHz and can be delivered with Focus software [160], [161].

Some AUVs should have ability to carry out long-distance missions fully autonomously and without supervision from surface ship. Combined with inertial navigation, the use of one or several transponders on the seabed is an accurate and cost-effective approach towards achieving this [160], [161]. An extensive description of actual advanced AUVs' propulsion solutions, control systems and their key components, state estimation methods, path planning models and techniques along with object detection and obstacle avoidance can be found in [162], [163].

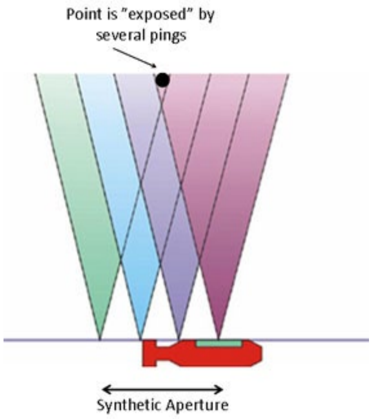


Figure 12. Principle of synthetic aperture sonar (Source: [160]).

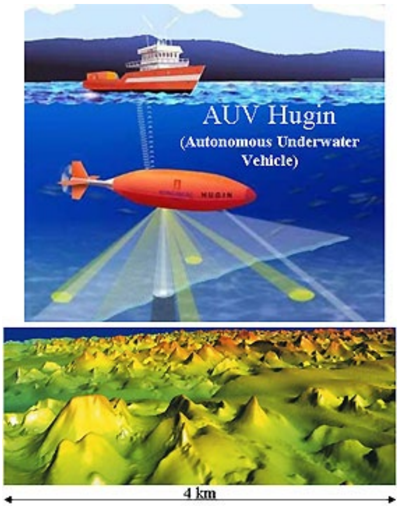


Figure 13. AUV Hugin: image from 1000 m depth, the tops that are shown on the map are 30-40 m high (Source: [160]).

3.3.2 Communication channels

Underwater wireless communications are implemented using communication systems based on acoustic, radio frequency, and optical (light and laser) waves. Underwater acoustic wireless communications have been one of the most used technologies since they can provide connection over rather long distances (Figure 14). However, acoustic waves have many drawbacks as scattering, high delay due to the low propagation speeds, high attenuation and low bandwidth. Additionally, acoustic signals generated by communication systems and sonar devices have harmful impact on the underwater mammals and fishes. Therefore, research has been carried out in the past to use low frequency radio waves (30-300 Hz). These waves have numerous disadvantages like high attenuation, low data rate, adverse effect of shallow areas, long antennas, etc. For worldwide communications with submarines, e.g., for depths up to a few 10 m very low frequency (VLF) transmitters from 10-30 kHz are used. In oppose to acoustic and radio waves, optical waves can provide high-speed underwater optical communications at low latencies, thanks to high propagation speed and high data rate in return for a limited communication range (tens of meters). In Table 9 are given key features of underwater acoustic, radio and optical wireless communications.

Table 9. Underwater acoustic, radio and optical communications features (Source: [164]).

Feature	Acoustic	Radio	Optical
Range	< 20 km	< 100 m	100-200 m
Attenuation factors	Conductivity	Conductivity and frequency	Distance vs. inherent optical properties
Speed	1500 m/s	2.25x108 m/s	2.25x108 m/s
Power	10 W	100 W	1 W
Cost	High	High	Low
Data rate	< 10 Kbps	< 0.1 Gbps	< 10 Gbps
Antenna size	0.1 m	0.5 m	0.1 m
Latency	High	Moderate	Low

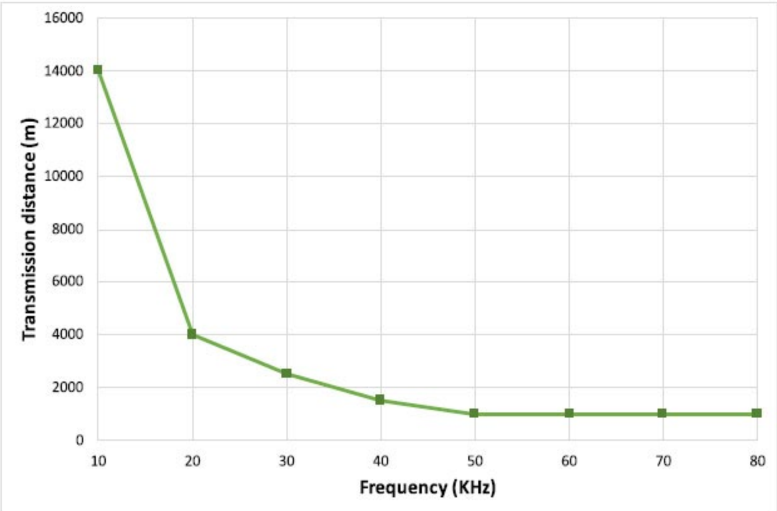


Figure 14. Average achievable transmission distance by various commercial acoustic modems (Source: [164]).

All three considered underwater wireless communication modes have certain advantages and disadvantages dependent of various underwater conditions. The subject remains open and further research is necessary for conceiving and implementing more practicable and accurate communication, networking and localization schemes.

The AUVs have a variety of military, scientific, industrial and other applications. They can be very complex and expensive, but there are some that are available for educational and recreational purposes. It is a common opinion, present in the literature that these systems have been developed to a very high standard, but that there is plenty of room for further research and improvement. The last refers to better adaptive control techniques using neuro-fuzzy techniques, more accurate localizing using improved INS non-linear Kalman filters, cooperative localization (swarm intelligence), artificial intelligence vision and object detection, odometry, underwater wireless communications, high-density battery power supply, energy harvesting methods, etc. By improving all these dimensions, AUVs will become fully autonomous long-range underwater robots, capable to explore the deepest, inapproachable and harsh corners of the seabed. In the case of European Commission Horizon 2020

COMPASS2020 project [44], [45], [46], [47], [48], [165], e.g., underwater autonomous vehicles have to be integrated into the complex system composed of autonomous aerial vehicles (Zephyr, AR5 and AR3), sea surface oceanic patrol vessel (OPV), including Naval Group mission system (MS) onboard OPV and shore based marine operations center (MOC). At the moment, the experts' team within afore mentioned project is designing algorithms for seamless data acquisition, analysis, storage and presentation. This research work is based on the experts' knowledge, skills and experiences acquired through several realistic case studies and recent test-beds in European sea waters. Following research work should target harmonizing actions of all involved manned and unmanned vehicles and optimizing relevant data/information flow schemes. In parallel, improving bidirectional, communication links between all involved parties in the case of emergency at sea is be further explored.

3.3.3 Unmanned underwater A18-M and A9-E vehicles

In this section, crucial features of AUVs like A18-M and A9-E are briefly presented. The inspiration for selecting these particular AUVs is found within Horizon 2020 COMPASS2020 project [44], [45], [46], [47], [48], [165].

The A18-M is the military configuration of ECA Group A18 AUVs family (Figure 15). Its applications for the defense and security sector encompass: (a) Rapid Environment Assessment (REA); (b) Intelligence, Surveillance and Reconnaissance (ISR); (c) organic underwater mine warfare: mine countermeasures mission module for large multipurpose vessel and mission module for oceanic mine warfare, and (d) conventional underwater mine warfare: detection and classification. The system can be delivered with a Launch And Recovery System (LARS) allowing automatic underwater recovery. Data post processing can be made with Triton imaging applications. It performs autonomous missions up to 300 m depth, and is easily transportable by plane for overseas missions. Due to its large endurance, very high area coverage rate (2 km^2/hour) and payload capacity, it is able to host high performance payloads according to the mission's requirements as Synthetic Aperture Sonar (SAS), Conductivity, Temperature and Depth (CTD) sonde, video, forward looking sonar (FLS), multi-beam echo sounder, and others [166]. For navigation, it uses Inertial Navigation System (INS), Doppler Velocity Log (DVL), military global navigation satellite system (GNSS) and Global Positioning System (GPS) periodically, after resurfacing. It can communicate via WiFi, Ethernet, Iridium and/or acoustic wireless communication channel. Its average speed is 3-5 knots (while the maximum is 6 knots). It withstands harsh environmental conditions and offers a greater stability when encountering heavy turbulence from waves. The high degree of stability enables this AUV to capture high-resolution images. The information obtained by the platform is processed to the command center [167].

Figure 15. A18-M (Source: [167])

The A9-E AUV is the configuration of ECA Group for environmental monitoring (Figure 16). In addition to the seabed image acquisition, the A9-E AUV can record bathymetric data as well as environmental information such as water turbidity, conductivity, temperature, fluorescence, dissolved oxygen and/or pH. Mission planning and monitoring are done through user friendly software which allows operator to follow the vehicle at any time during its mission. This underwater drone has been designed to meet STANAG 1364 requirement; as such, its acoustic and magnetic signatures are minimized in order not to trigger any underwater mines when doing the mine warfare survey. As part of early trials for the SWARM project, ECA Group's A9-E fitted with the interferometer side looking sonar demonstrated ability to conduct surveys in a shallow water of 13-20 m depth. It uses a phase differencing bathymetric sonar that increases area coverage by close to 200% over conventional multi-beam echo sounders in shallow water [168]. For navigation, it uses INS, DVL, GPS and for communication purposes radio (UHF), WiFi, Ethernet and the acoustic wireless communications. Its payload consists of, but it is not limited to: Interferometer Side Scan (ISS) sonar, video, CTD, and environmental sensors (turbidity, pH, fluorescent Dissolved Organic Matter (fDOM) / waste water discharge).

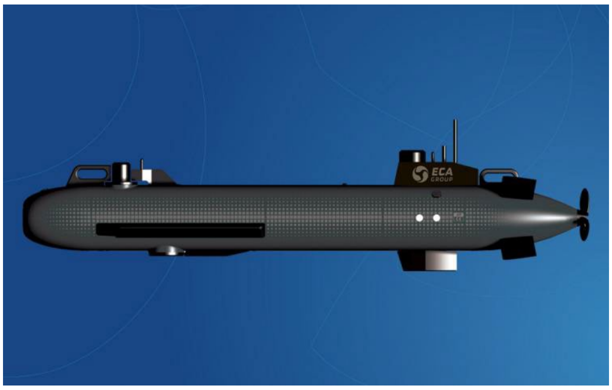


Figure 16. A9-E (Source: [168]).

Within the COMPASS2020 project plans, the AUVs are to be deployed from the offshore patrol vessel into a strategic location that is coincident to the traffickers' typical routes. The AUVs are programmed to follow circular trajectories in the area of interest, navigating underwater at low depth in order to remain undetected from the smugglers and at the same time staying closely enough to the surface in order to optimize the possibility of detecting the target. The AUVs carry sets of hydrophones that enable detecting speed boats and localize dumped cargo (cases or bags with narcotics). After detection of the target, the AUVs can communicate to the Zephyr, which is used as a communication relay in the system [169].

3.3.4 Unmanned aerial Zephyr, AR5 and AR3 assets

In this section general features of UAVs like Zephyr, AR5 and AR3 have been given. The inspiration for selecting these particular UAVs is found in recently set up EC Horizon 2020 COMPASS2020 project.

The Zephyr is the first unmanned aircraft capable to fly in the stratosphere, harnessing the sun's rays and running on a combination of solar cells and high-power lithium sulphur batteries (solar-electric power) above the weather and conventional air traffic. It is a High Altitude Pseudo-Satellite (HAPS) [170], [171] capable to fly for a month at a time combining the persistence of a satellite with the flexibility of an UAV (Figure 17). As HAPS, the Zephyr uses high-definition electro-optical and infra-red cameras to produce real-time visuals in any lighting. It costs around 5 million US$, while an orbital satellite costs between 50 and 400 million US$ [165], so it is considerably cheaper than a satellite. At the moment, Airbus possesses two types of the Zephyr, designed to accommodate a variety of payloads. The production model Zephyr S has a wingspan of 25 m and weighs less than 75 kg. It is able to carry see, sense and connect payloads. Presently, the larger Zephyr T, which is under development, has a wingspan of 33 m and a Maximum Take-Off Weight (MTOW) of 140 kg [172].

Figure 17. Zephyr launching (Source: Airbus).

The Airbus' Zephyr S has been firstly launched on 11 July 2018 in Yuma, Arizona, USA. Previously, it was transported from Farnborough, UK. It had a small ground infrastructure. It was a historical take-off, when after eight hours Zephyr reached the stratosphere. Its lower altitude was 18 km, and the highest 23 km. This was, at the time, the longest flight without refueling, lasting 25 days, 23 hours and 57 minutes. Unfortunately, on 15 March 2019, the Zephyr aircraft crashed near its launch site in Wyndham, Western Australia [170], [173]. This was caused by severe adverse weather. Luckily, it happened in an extremely remote location and caused no injuries or property damage. Work on the Zephyr improvements is continued, especially in its mechanical launcher.

The Zephyr was conceptually integrated in the proposed COMPASS2020 architecture, as a valuable asset for future concepts of operation. Due to its potential of acting as a high altitude platform capable of performing early detections and providing the respective warnings to the system, it is considered to bring added value to the solution, by providing persistent surveillance and the first detection of potential events of interest. The goal of the project is to develop the solution in such a way that it will be possible and simple to integrate the Zephyr (both physically and in terms of data processing) within the overall system, once this platform has reached a development maturity that allows it to be operationally deployed.

The AR5 Life Ray Evolution is a medium-endurance and medium-altitude fixed wing UAV (Figure 18). It is designed for wide area land and maritime surveillance, pollution monitoring, fisheries inspection and communication relay [174]. The AR5 has advanced on board capacities in terms of data processing. It can simultaneously process Electro-Optical/Infra-Red (EO/IR), radar and AIS data [175].

Figure 18. AR5 EVO (Source: Tekever).

The AR5 Life Ray Evolution is sub-tactical UAV dealing with 180 kg MTOW. It allows high speed beyond line of sight (BLoS) satellite communications (SATCOM). It also provides high precision video, imagery and sensor data in real time. Its features include a flexible architecture, supporting multiple types of payloads and datalinks. Moreover, this platform complies with the highest production standards as the first European-wide UAV-based maritime surveillance system, which is International Traffic in Arms Regulations (ITAR) free [176]. As an UAV that requires a runway for take-off and landing, its automatic take-off and landing capabilities, as well as the fact that it can use short and unpaved airstrips, are great advantages. The AR5 EVO has a cruise speed of 100 km/h and a standard endurance of approximately 16 hours. The available payload capacity is up to 50 kg, wingspan 7.3 m and length 4.0 m. It is equipped with a three axis multi-sensor gyro-stabilized gimbal, capable of supporting the integration of multiple types of payloads. This includes AIS transceiver, multiple EO/IR sensors, Emergency Position Indicating Radio Beacon (EPIRB), radar, etc. [177], [178]. Figure 19 presents AR5 mission at sea, i.e. capturing detail on sea surface vehicle (ship) from the air.

Figure 19. AR5 mission at sea (Source: Web).

Within COMPASS2020, the AR5 EVO UAV plays an important role as a middle layer platform, which is able to provide wide maritime area surveillance, complementing the operational gap between the wider coverage but lower resolution capabilities of the Zephyr, and the lower altitude and more localized situation monitoring provided by the AR3 Net Ray.

The AR3 Net Ray is a ship-borne UAV designed to carry out several types of maritime and land-based missions (Figure 20). These missions include: intelligence, surveillance, target acquisition and reconnaissance (ISTAR) actions, pollution monitoring, infrastructure surveillance and communication support operations. This UAV is capable of delivering an endurance up to 10 hours, which makes it an ideal solution to carry out both maritime and land based missions. The payload capacity is 4 kg and it includes: multiple options for EO/IR sensors, near-infrared to long-wave infrared (LWIR) sensors, laser illuminators, communication relay systems, AIS transceivers and EPIRB. It provides real time collection, processing and transmission of high definition video. Its communication range is up to 80 km within radio Line of Sight (LoS), cruise speed is 85 km/h, MTOW is 23 kg, launch is conveyed via catapult, recovery via parachute and airbags (for land based operations) or using a net system (for maritime based ship-borne operations). The AR3 dimensions are 3.5 m of wingspan and a length of 1.7 m [179].

Figure 20. The AR3 Net Ray taking-off (Source: Tekever).

The AR3 Net Ray UAV will be included in the COMPASS2020 surveillance ecosystem as an organic asset of the oceanic patrol vessels operated by the maritime authorities. This UAV will be operated (launched, piloted and recovered) from the vessel to provide the tactical teams with enhanced real time information to help decision making. The AR3 will cover a surveillance level below the AR5, providing a more localized monitoring of events and situations of interest.

The comparison between key features of UAVs like Zephyr, AR5 and AR3 is given in Table 10. As can be noticed from Table 10, the considered platforms operate at different altitudes and have different payload capabilities.

Table 10. Comparison of Zephyr, AR5 and AR3 key features (Source: Own).

Feature	COMPASS UASs		
	Zephyr	*AR5*	*AR3*
Wingspan	25 – >32 m	7.3 m	3.5 m
Flight height	21 km	915 m	305 m
Cruise speed	42 km/h	100 km/h	85 – 140 km/h
Communication range	1000 km	100 km (RLOS)	80 km (RLOS)

Feature	COMPASS UASs		
	Zephyr	***AR5***	***AR3***
		Unlimited (SATCOM)	
MTOW	55 - 140 kg	180 kg	23 kg
Payload capacity	5 kg	50 kg	4 kg
Endurance	900 h	20 h	10-16 h
Recovery	Belly-landing	Automatic landing, unprepared airstrip	Parachute or Net System
Launch	Manual	Automatic take-off, unprepared airstrip	Catapult

One of the main innovative aspects proposed in the project of the sea board protection is the complementary approach to cover different surveillance levels, using different types of unmanned platforms to enhance capacities of maritime authorities. These assets, as mentioned previously, have different features that support this complementary approach. When designing the solution, the project's team took advantage of this complementarily (from high altitude unmanned aerial platforms to unmanned underwater platforms), capable of providing data to the operators at different stages of the missions and with distinct level of detail. Following this approach, it allows the authorities to accommodate the performing of missions in a coordinated and effective way with the already existing platforms, enhancing the situational awareness and thus the time of response to the incidents.

The communication and collaboration between different AUVs and UAVs is conceptually (schematically) presented in Figure 21. Different altitudes at which these vehicles operate during the sea border safety missions are also presented on the left side of the graph (1000 feet under water, up to 70 000 feet in the air). The span of altitudes is high and allows systematic access to the spot in matter by ensuring high level of situational awareness in the risky situation.

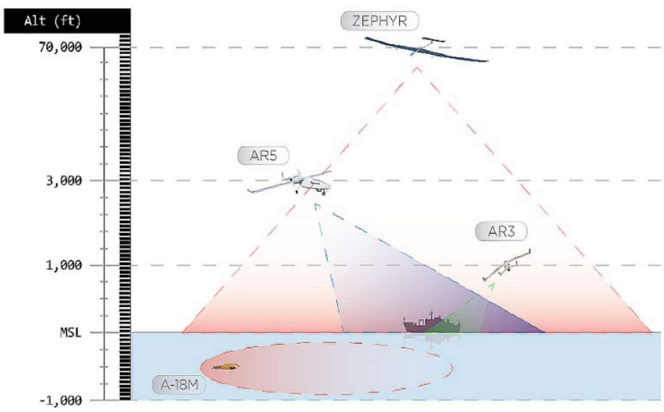


Figure 21. Multiple layer approach in sea border missions with UxVs (Source: [169]).

3.3.5 Sea borders protection

In 2015 European Union (EU) has been faced with 1.8 million illegal border crossings. This is more than six times the number of detected illegal migrations in 2014. It takes three years to change the situation and to reduce by nearly 90% the illegal border crossings and reassure the security of EU borders. However, there is still pressure on EU external borders, especially when it comes to the Western Mediterranean route. Therefore, COMPASS2020 project has been conceived to reduce the number of illegal border crossings through improving coordinated actions supported by manned and unmanned (underwater, sea surface and air) vehicles (UxV). Besides struggling with illegal migrants, EU has a problem related to narcotics trafficking. It is estimated that every year approximately 125 tons of cocaine worth USD 33 billion are consumed, the majority coming from Latin America to Europe on transatlantic routes. There are some new narcotics routes from Northern and Eastern Africa targeting Spain and Portugal, while the most traditional routes target Belgium and the Netherlands, i.e., major European shipping ports. Consequently, the project was also conceived to combat this issue. To address these challenges, the development of a unified system based on open standards that will enable the combined operation of multiple unmanned assets (from distinct providers), manned platforms currently used under marine surveillance context, and the future accommodation of other platforms and services with minor integration efforts. The project contributes to improve the situational awareness beyond coastal waters through integration of multiple manned and UxVs operating in different environmental conditions, ranges and altitudes. On the other hand, pollution monitoring is also an increasingly important part of maritime safety, as global commerce increases from/to the EU, leading to a growth of vessels and cargos crossing European waters. Higher maritime traffic results in a higher probability of occurrence of pollution incidents, such as oil spills, as well as an increase in ships sulfur emissions. Such incidents, especially the ones that occur due to severe weather conditions (strong winds and high sea state) can lead to high negative impacts to the environment. In this context, the solutions under development in the project represent safe alternatives to monitor such disasters, in particular in remote areas where access through manned assets may represent life-threatening risks to the operators. Therefore, the project platform can be an answer to such situations, providing a cost-effective solution based on UxVs that can be highly effective and, at the same time, reduce the risk to the humans involved in the operation, with the ultimate goal of minimizing the impact of this kind of incidents [45], [169].

The following sections are organized in a manner that its first following part describes the integration of the AUVs and UAVs; the second one deals with terminology and different levels of autonomous marine vehicles self-managing capacities; the third one gives literature review on several recent projects and achievements in the field; while the last one in this section provides inferences and highlights further research endeavors in achieving concurrent command, control and tracking of multiple manned and unmanned air, sea surface and underwater vehicles in the marine environments which are exposed to the risk of illegal border crossings and threats of trafficking of narcotics, including consequent search and rescue activities.

3.3.6 Integration of AUVs and UAVs

The COMPASS2020 project is expected to achieve a comprehensive solution for maritime surveillance, based on the coordination of manned and unmanned assets with enhanced capabilities, which will allow addressing many of the challenges currently faced by authorities and governmental organizations with responsibilities in this domain. The ultimate goal of this solution is to help governments contain, control and effectively respond to a growing number of diverse threats and incidents: from piracy and smuggling of goods and narcotics, to irregular migration and maritime pollution, including Search and Rescue operations. Due to the afore stated, the project proposes to demonstrate the benefits of the developed solution by tackling two specific scenarios during the project's lifetime: (i) Search and Rescue mission derived from irregular migration and (ii) interception of narcotics smugglers. For these purposes the following assets will be used: (1) the Oceanic Patrol Vessel (OPV) operated by the Portuguese Maritime Authority designed as a multi-mission platform; (2) AR-3 Net Ray - a fully autonomous small UAV with an endurance of up to 10 hours and a range of up to 150 km, launched by catapult and recovered by a net or parachute. It can serve maritime and coastal surveillance missions, working as operational extender for vessels as well as a communications relay to other vehicles and communications range extender; (3) AR-5 Life Ray - a medium-altitude and medium-endurance fixed-wing UAV specifically designed for search and rescue, long range surveillance and maritime patrol (up to 16 hours of endurance and a range of 1600 km); (4) Zephyr HAPS (UAV) - a high altitude pseudo-satellite (HAPS) that fills the gap between satellites and UAVs (70 000 ft). This platform is being conceptually considered as part of the project solution as it enables real-time mapping, internet and a number of surveillance opportunities to meet a broader range of requirements; (5) the A18-M - an autonomous underwater vehicle (AUV) that can be launched from OPV - it is capable of performing autonomous missions up to 300 m depth and it is easily transportable by plane for overseas missions. Its area of coverage is 2 km2 per hour and it is widely used for defense and security actions. The layout of the main project assets is shown in Figure 22.

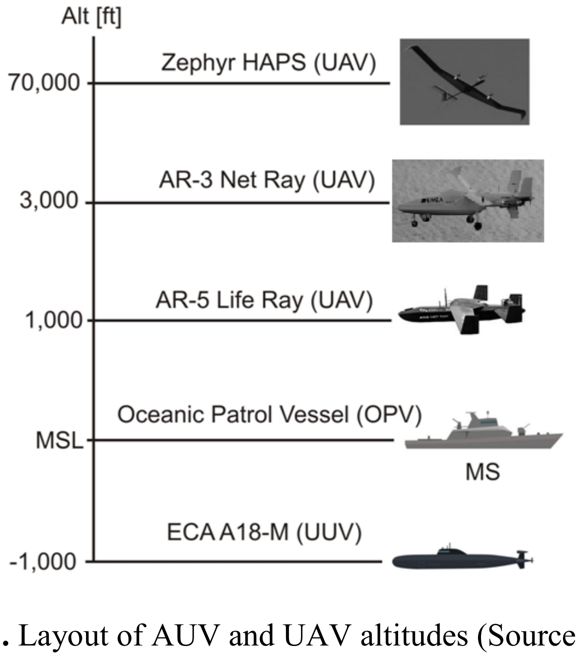


Figure 22. Layout of AUV and UAV altitudes (Source: Own).

In the case of search and rescue (SAR) mission derived from an irregular migration situation – a vessel carrying irregular migrants is in a distress situation beyond coastal waters, sending out EPIRB (Emergency Position Indicating Radio Beacon) signal in order to alert the European authorities. At the first phase of the mission, three types of assets are in the area performing persistence surveillance: the OPV, the Zephyr, and the A18-M. At the moment it receives the EPIRB alert, Zephyr immediately communicates this information to the operational commander that is working from the Marine Operations Center (MOC) through the COMPASS2020 Mission System (MS) replica onboard the OPV. In the following phase, the OPV will launch an AR-3 capable to collect data regarding the vessel in distress, thus enhancing the situational awareness of marine authorities concerning the risk level of the situation and allowing them to act timely and properly. This action/data flow is schematically shown in Figure 23.

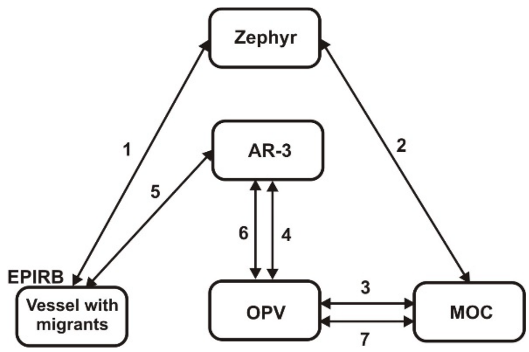


Figure 23. Action/information flow in the case of SAR mission derived from irregular migration (Source: Own).

When it comes to interception of narcotics smugglers – the OPV, the Zephyr and the A-18 M are in action in the border area. The Mission System (MS) is running onboard the OPV and it is always connected with its replica at MOC. Zephyr is launched from MOC and it has to collect an overall picture of the area that is being surveyed. In addition, an AUV was previously deployed from the OPV into a strategic location that is coincident to the traffickers' typical routes. The AUV is programmed to follow circular trajectories in the area of interest, navigating underwater at low depth in order to remain undetected from the smugglers and staying closely enough to the surface in order to optimize the possibility of detecting the target. It carries a set of hydrophones that enable detecting speed boats. After detection of the target, the AUV can communicate to the Zephyr, which is used as a communication relay in the system. The Zephyr sends automatically an alert to MS onboard OPV and its replica in the MOC. Once the MOC receives the alert, the officers proceed with the deployment of an AR-5 platform. The AR-5 has to come close to the vessel and acquire more detailed information about it. In accordance to this information, the officer onboard OPV can decide how to intercept the threat and act efficiently. If the smugglers try to get rid of the cargo, the AUV has the capacity of searching for it by making use of side scan sonar. Data flow in this type of action is given in Figure 24.

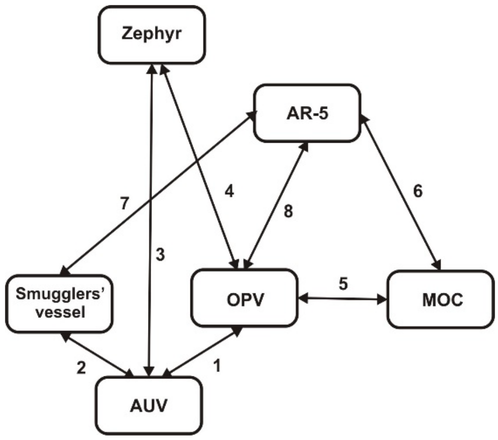


Figure 24. Action/information flow in the case of interception of narcotics smugglers

(Source: Own)

3.3.7 Autonomous vehicles taxonomy

The most advanced components of the surveillance and supplementing SAR actions proposed by the project in order to address the challenges mentioned above are unmanned (air, sea, and underwater) vehicles, or shortly UxVs. The operational coordination of these kinds of assets is an under-explored field and therefore below will be given some basic information concerning operation of marine fully autonomous and unmanned vehicles.

The first implementation of unmanned vehicles took place in space transport. Then, commercial use of rail unmanned transport devices was implemented to carry freight and people. Further applications take place in air transport for both military and civil transport purposes. Commercial use of autonomous cars and trucks on generally accessed roads are still at the phase of research. Similar situation is within sea transport [45].

The implementation of autonomous and unmanned vehicles at sea has to be preceded by solving numerous problems concerning legal, organizational and technological ones. When it comes to legal issues, International Maritime Organization (IMO) is working on it. Recently, Maritime Safety Committee has been established as a working group dealing with safety issues at and in the vicinity of places where tests over autonomous and unmanned vessels are done. Besides this, Lloyd's Register (LR) produced a document entitled "Cyber-enabled ships: Ship Right procedure – autonomous ships" (2016). In 2017 it produced another document titled "LR Code for Unmanned Marine Systems", which identifies goals and objectives for different unmanned vehicles. Also, it is important to mention that LR defines seven autonomous levels of marine vehicles:

- AL0: no autonomous functions; all operations are manual;
- AL1: on-vessel decision support; data will be available to crew;
- AL2: off-vessel decision support; shore monitoring;
- AL3: human-on-the-loop; semi-autonomous vessel; crew can intervene;
- AL4: human-on-the-loop; ship operates autonomously with human supervision;

- AL5: fully autonomous vessel; there is a means of human control; and,
- AL6: fully autonomous vessel that has no need for any human intervention.

On the latter ends of this scale one can see further class of vessels/ships called unmanned and this refers to vessels that are operated remotely so there is no one on board. Today almost all vessels have a certain level of autonomy, since numerous functions operate by themselves. So, the transition from "classical" to autonomous vehicles used at sea will be evolutionary rather than revolutionary. In other words, the transition will be gradual, and it will last most probably several decades.

Different operational issues are still unsolved and under consideration. However, technological solutions are already available to a large extent. Intensive research is done, including simulation tests, experiments on physical models and construction of prototypes. Below are listed some of the relevant projects in this domain [45]:

- MUNN – Maritime Unmanned Navigation through Intelligence in Networks;
- AAWA – Advanced Autonomous Waterborne Applications Initiative;
- STM Validation – Sea Traffic Management Validation Project; and,
- AVAL – Autonomous Vessel with an Air Look, etc.

The basic information on these projects are available online. The COMPASS2020 is relying in terms of technology, safety and security on findings of these and several other projects in the field. They are listed and shortly described in the project proposal [169]. It is realistic to expect that research and development (R&D) activities will be continued in order to ensure successful implementation and sustainability of the project, including follow-up projects in the future.

3.3.8 Recent research and development achievements

In attempt to support further activities on smart adoption of UxVs, we have made a search of similar research endeavors when it comes to autonomous and unmanned maritime vehicles. Thanks to our professional contacts we are introduced with the Faculty of Logistics and Maritime Technology of Satakunta University of Applied Sciences (SAMK) from Rauma (Finland) work on building and testing of the autonomous ship technology on miniature training ship Kaisa (Figure 25). This work has been done in collaboration with Rolls-Royce Ltd and WinNova Ltd, the institute for vocational training education in Satakunta. Namely, the platform called ELSA utilized the miniature training ship Kaisa built in 1994, which is a model of passenger cruise ship Society Adventurer built in 1991. The detail description of this autonomous sea vehicle can be found in reference.

Figure 25. Kaisa prototype of an unmanned vessel (Source: [180])

The model is remotely controlled from the control center. The center is located in the main building of the Faculty of Logistics and Maritime Technology of SAMK. It is equipped with large LCD screens for displaying the image provided by the onboard cameras, sensor data display and human machine interaction panel for remote manual steering of Kaisa. The lidar and machine vision data are collected onboard. The track control and DP computers for fully automated operation of the model are located in the remote-control center. The data transmission link between the vessel and the control center is a crucial part of the whole system and 4G network is used for this purpose. Kaisa is an objectified experiment used for students training and as an experimental polygon for postgraduate students at SAMK work on their master and doctoral thesis. It has certain advantages in comparison to simulation (more realistic) and full-size testing (more cost-effective). Continuation of experiments over Kaisa should bring new findings in the field, which support (in)directly some challenges within UxVs' platforms, particularly when it comes to data fusion and UxVs self-managing functions.

In addition to this experiment on a prototype in laboratory setting, numerous theoretical studies have been recently conducted. Some of them will be mentioned here as kind of guidelines for further research work in this domain. For instance, one research concerns Autonomic Computing (AC) as a potential solution to implement efficient self-management (i.e., self-managing capacities as: self-healing, self-protecting, self-organizing, self-optimizing and self-configuring) in autonomous maritime vehicles (AMVs). The aim of this research work is to indicate that the advanced versions of AC with fully integrated approach to autonomous capacities for next generation of AMVs should be more similar to human physiology and behavior.

There is also a comprehensive research work on AMVs in the domain of optimal path planning and control methods with different sensor technology like sonar, laser, acoustic modems and stereo vision systems for localization, navigation and mapping. Also, it is important to mention that underwater wireless communications have recently achieved development. Communication links and data fusion along with central control system and human-machine interface are among the key concerns in the UxVs' domain, including UxV successful implementation, so that the above listed research studies and similar ones might be used as referential ones.

It is worth to mention in this context two extensive studies on autonomous/unmanned vehicles perception [181], [182]. The first study provides up-to-date information about the advantages, disadvantages; limits and ideal applications of specific sensors. The second one deals with putting men back in the headlines despite the rise of autoimmunization in marine and shipping industry. Namely, according to this study "85% of those surveyed agreed that seafarer skills will remain an essential component in the long-term future of the shipping sector" [182, p.4]. In other words, the findings of the study suggest that the human will remain an essential component in the long-term future of shipping, even if that future is autonomous.

If we go back to the COMPASS 2022 project, its purpose is twofold: (a) dealing with irregular migrations and (b) preventing narcotics smuggling. When it comes to search and rescue operation with focus on an irregular migration situation, a craft carrying irregular migrants is in a distress state and emits EPIRB signal to alert the European marine authorities. When it receives the EPIRB signal, the Zephyr immediately sends this information to the operational commander working from the Maritime Operations Center (MOC) through the Mission System

(MS) replica onboard the OPV. Then, the OPV launches and the AR3 ready to gather all data on the vessel in distress, enhancing in such way the situational awareness of European marine authorities. The AR3 can provide better awareness about the event through OE, NIR and LWIR sensors. Afore described data flow is schematically presented in Figure 26.

In the second case of interception of narcotics smugglers, the OPV, the Zephyr and the A18 M are in operation along the border area. The Mission System (MS) is operating onboard the OPV and it is constantly connected to its replica at Maritime Operations Center (MOC). The Zephyr is launched from MOC, which is land based, and its task is to collect a picture of the area being surveyed. Besides, an AUV has been previously released from the OPV into a strategic location connected to the traffickers' typical routes. Once when it detects the target, the AUV can communicate to the Zephyr used as a communication relay.

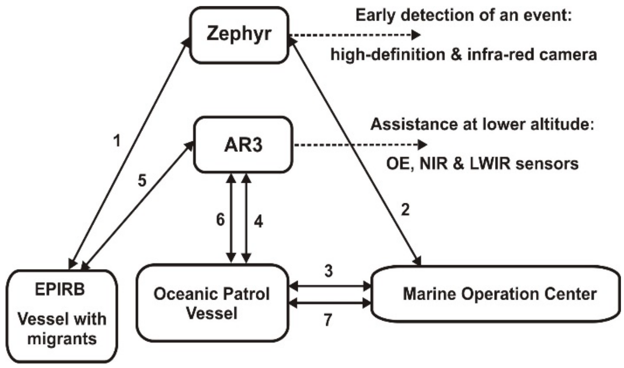


Figure 26. Irregular migration mission data flow (Source: Own).

After that, the Zephyr transmits automatically an alert to MS onboard OPV and its replica in the MOC. Once the MOC receives the alert, the officers proceed with the deployment of an AR5 platform. The AR5 task is to approach the vessel closer and collect more information through (S-)AIS transponder, EO/IR sensors, EPIRB and Radar. Thanks to this information, the officer onboard OPV can decide how to intercept the threat and work effectively. In the case that smugglers try to get rid of the cargo, the AUV has capacity of finding it out by means of side scan sonar. The scheme of key information flow in the second case of action is drawn in Figure 27.

Presently, the experts' team within the project is designing algorithms for seamless data acquisition, analysis, storage and presentation. This is based on the experts' knowledge and also experiences acquired thanks to several realistic case studies and recent test-beds in Mediterranean Sea. Following research work should target harmonizing actions of all involved man and unmanned crafts and optimizing relevant data/information flow algorithms. The schemes for improving bidirectional communication links between all relevant stakeholders in the case of alert are to be explored in some more detail, as well.

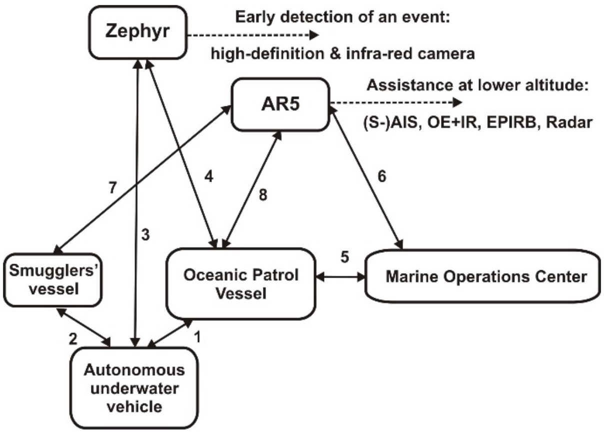


Figure 27. Interception of narcotics smugglers (Source: Own).

3.3.9 Common Information Sharing Environment

The project ANDROMEDA was forerunner of the COMPASS2020. Its aim was to enhance assessing Montenegro to the European maritime Common Information Sharing Environment (CISE). Key reference for the following text, which describes this project and it outcomes with reference to Montenegro is [43]. The findings of this part of the research can be used as a model for developing maritime economies integration into larger ICT&S platforms and data searching pools.

Efficient border security within the realm of independent states as well as in the wider context of the European Union (EU) remains an enormous and cumbersome task. Each EU member state holds responsibility for its own border security but adheres to organized and coherent approaches conducted under multi-lateral agreements such as Schengen. There is a substantial complexity in organizing border security efforts as there are 17 EU countries with almost all of them having an external border segment, either maritime or land, towards non-EU countries. The migration crisis of 2015 was a clear indication of the magnitude and risks associated with unsecured European borders. Illegal border crossings soared to unprecedented numbers: 1.8 million across the borders of Europe [169]. Remedy actions that followed included EU measures for effective management of similar situations, strengthening internal security and cross-border cooperation between the member states.

This section of the study is constituted on the efforts towards augmentation of the maritime surveillance capabilities with future work potentially including the land border situations. European maritime borders are vast with a long length, many islands and insufficient resources to cover and patrol all areas. There is a continuous emergency of the novel types of vessels and a large volume of leisure traffic that is relatively unrestrained all adding to the surveillance challenges. Of particularly interest is the Mediterranean region, from the Iberian Peninsula to the Middle Eastern border stretching across the areas between southern Europe and North Africa. Apart from the incursion risks by illegal migration there are many additional threats requiring expedited coordinated surveillance efforts: piracy, narcotics trafficking, smuggling of illicit good and arms, illegal fishing, environmental crimes and maritime accidents and disasters. Alleviating these maritime surveillance threats is specifically critical as Europe continuously depends on safe commerce by sea and via maritime affairs.

There is evidently a great necessity for further coordination between European and national (government) authorities and maritime stakeholders by cross-border and cross-sectoral cooperation. Experience has shown that threats to maritime cybersecurity are diverse and most of the data acquired in the process tends to be robustly protected within the maritime authorities [183]. Past efforts in sporadic and unstandardized sharing of data between the trusting and collaborating maritime authorities in different states, have often led to data collection replications, asynchrony, and inconsistent availability in the maritime areas of interest. In 2010, the European Commission and EU/EEA member states laid out a roadmap towards the maritime Common Information Sharing Environment (CISE), aiming to make it fully operational by 2020, as a ubiquitous facilitator of technical and semantic interoperability [184]. This initiative has been jointly developed by various EU member states and institutions through numerous EU funded projects and support of relevant agencies (e.g., FRONTEX, EMSA, EFCA etc.). The CISE builds upon the previous initiative of the European Border Surveillance System - EUROSUR [185] of a lesser scope, which had the main objective of augmented situational awareness and reaction capability at external EU borders, focusing on southern maritime and eastern land borders. This is taken further in the CISE, which aims to make different maritime systems interoperable by facilitating exchanges of relevant maritime surveillance data and services by reusing the existing standards and their vocabularies. Importantly, a design principle formulated in the constituent CISE initiative states that no changes would be needed in present legacy systems. Hence, the existing surveillance systems and networks are effectively to become integrated through sharing of information needed in their operations across EU borders. Such an environment being instantiated through the CISE network is political, organizational and legal and spans across the seven relevant sectors and user communities: transport, environmental protection, control of fisheries and borders, general law enforcement, customs and defense.

This part of the study originates from the H2020 ANDROMEDA project [186] that commenced in 2019, which in essence aims to unlock the capabilities of the CISE by both enhancing the maritime CISE models and extending the scope to land surveillance. The study is heavily inclined towards demonstrating the CISE features in several trial use-cases being conducted across the borders of Europe. The trials are showing CISE compatibility, exchanges and interconnections with existing Command & Control (C2), Data Fusion (DF) and Decision Support (DS) systems in the involved European maritime and land agencies. The ANDROMEDA adopted CISE architecture is shown in Figure 28, where the specific surveillance systems deployed in each partner's country (Socrates in Spain, Engage in Greece, GeoC2 in Portugal, Smart in Italy) all connect to the EU CISE network using the CISE Adaptors and facilitate the interconnections through CISE Nodes (or CISE Gateway if the functionalities are more basic and relate to solely facilitating the network connections). AMSPM is involved in the ANDROMEDA project (as an End User) in a specific arrangement of the collaborative CISE development through a "restricted" research and implementation membership. One of the demonstration trials in the project is in the Ionian-Adriatic seas region that occurred in March 2021. The trial's aim was rendering of the common operational picture instances between the Greek, Italian and Montenegrin (i.e., AMSPM) partners involved for detection of human trafficking, common interventions during maritime accidents, improved detection of threats and shortening of the existing C2 and DS timelines. The technical framework for the AMSPM's participation in the CISE trial is shown in [129]. Furthermore, experience in proxying the AMSPM connection to the CISE during the Ionian-Adriatic trial over a high-level operational C2 system: Socrates (provided by GMV, Spain www.gmv.com/en/Products/socrates/).

There will be a prior decision to allow unrestrained modality of operation within the EU CISE network in the meantime. This is currently being sought after by AMSPM acting as the national stakeholder, which is associated with and conforms to the mutual agreements with the national ministerial bodies and specific executive maritime security and safety institutions: Border Police sector and Navy (with Army). The current situation with the EU position on the CISE expansion is stated by the CISE governance structure specifying that during the current transitional stage of CISE, only EU member states can participate either as active participants or as observers. It is colloquially conveyed that the transitional phase of CISE is temporary and that the EU, together with its CISE Stakeholder Group, is working rigorously to extend the CISE initiative further. This research reflects and supports the foundational processes required in assessing and pursuing the CISE implementations. These are motivated by the Montenegro initiate but deemed as relevant to any similar considerations. Participations in the CISE are voluntary and collaborative. It is most fittingly decided upon and planned by any stakeholder if there is a comprehension of all implications of the immediate use of the CISE, as well as implicit and long-term projections of its benefits as a technology investment.

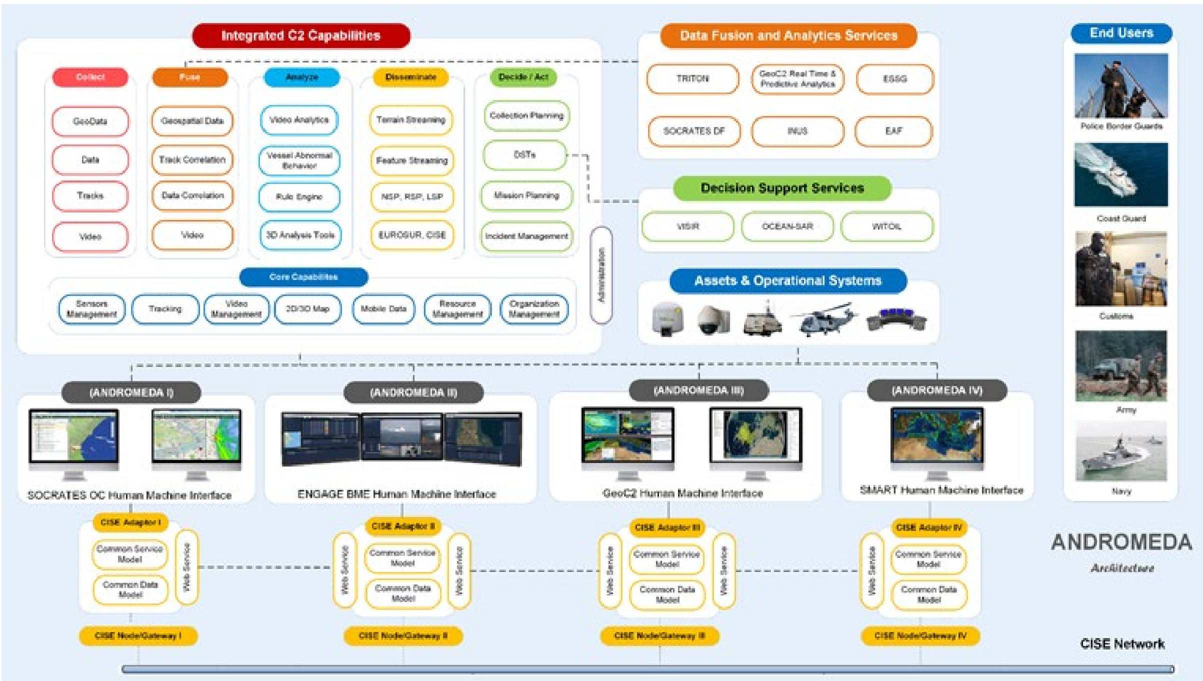


Figure 28. The enhanced CISE architecture (Source: [186]).

To summarize this section, it is to be noted that SWOT analysis of the autonomous (unmanned) underwater and aerial vehicles for maritime surveillance and safety actions, will be presented in Chapter 4, while the discussion will be given in Chapter 5. We assumed that CISE should be the common platform for integrating considered autonomous vehicles in safety at security missions across sea borders in Europe, including both EU and non-EU, i.e., developing countries. Similar conceptual framework should be developed and implemented in other emerging countries in Africa, e.g., and worldwide.

CHAPER IV: Data Analysis

4. Data analysis

After data have been collected either through desktop search or questionnaires sent to a representative sample of the population, the next step is to analyze the data to answer the research questions. However, before we start analyzing the data, some preliminary steps need to be completed. This help to ensure that the data are accurate, complete, and suitable for further analysis. After data are obtained, they need to be checked, coded, keyed, and edited [39]. A categorization scheme has to be set up before the data can be typed in SPSS, Excel Module or some other software package for statistical data analysis. Data coding involves assigning a number to the participant's response so they can be entered into the database. Then, it is recommendable to copy or transcribe the data from the questionnaire and key them into the database. After the data are keyed in, they need to be edited. For instance, the blank responses, if any, have to be handled in some way, and inconsistent data have to be checked and followed up. Data editing deals with detecting and correcting illogical, inconsistent, or illegal data and omissions in the information returned by the participants of the study. An example of an illogical response is an outlier response. An outlier is an observation that is substantially different from the other observations. An outliner is not always an error, even though data errors (entry errors) are a likely source of outliers. Because outliers have a large impact on the research results they should be investigated carefully to make sure that they are correct. Inconsistent responses are responses that are not in harmony with other information. In such a case, the researcher can edit such responses. Illegal codes are values that are not specified in the coding instructions. The best way to check for illegal codes is to have the computer procedure to check it for illegal codes. Omissions may occur because respondents did not understand the question, did not know the answer, or were not willing to answer the question. 'Problematic' data are typically changed by the researcher to avoid problems in the next stages of data analysis process.

The results of data analysis collected in the cases of: (a) intelligent use of the available ICT&S in selected maritime companies; (b) stakeholders' readiness to adopt blockchain in maritime supply chain systems; and (c) comparative (dis)advantages of advanced autonomous vehicles in maritime surveillance and safety missions over sea borders are presented in the following sections. These data are gathered through desktop search and questionnaires. After checking, coded and keyed in, the data were entered and processed in both SPSS and Excel Module, or presented in the form of SWOT scheme.

4.1. Intelligent exploitation of advanced ICT&S

Regarding the intelligent exploitation of ICT&S in selected maritime companies in EU and non-EU countries (section 3.1), for the primary data collection we used a questionnaire. This is widely used method of collecting data to obtain information on an issue of interest. We have structured questions upon the methodological framework and tentative statements (see Table

5). Since we used computer-assisted approach, we sent the questions to the respondents via mail and reminded them twice to send us feedback in due course. At the end, we had forty conscientiously populated questionnaires by the experts employed in maritime administrative and business companies located in four EU countries (18 interviewees): Croatia (5), Greece (6), Italy (4), and Slovenia (3); and four non-EU countries (22 interviewees): Albania (6), Bosnia and Herzegovina (5), Montenegro (10) and Serbia (1). They preferred to remain anonymous. We used a quantitative approach in terms of the Liker's interval scale with denominators 1–5 associated with linguistic labels "not important-extremely important", etc., that assist respondents to populate the questionnaire. The survey also included a table that listed commonly used and advanced info-communication systems in maritime. Respondents were required to mark those systems they used. In this segment, a binary approach was applied, i.e., if a system was marked as available, we anchored it by numerical value "1" and in the opposite case by a blank.

Toward encouraging interviewees to identify their current positions and strategic trajectories for the business and the appropriate ICT strategy, constructs: Pathfinder (C5), Adapter (C6), Protector (C7), Reactor (C8), and Heat seeker (C9) were examined. All interviewees expressed their opinion regarding this issue towards the Adapter strategy. It is interesting that interviewees from both EU and non-EU countries share the same or similar attitudes towards ICT strategy orientation and business trajectories of the organizations in which they work. Only the interviewee from Serbia answers indicated equal inclinations towards Reactor and Adapter strategies. The strategic orientation of an Adapter works in two business domains. One relatively traditional and relational, being concerned with internal controls. The other where ICT plays an increasingly important role in linking the organization to its customers or the users' marketplace. The Adapters are looking for a middle path regarding business and ICT strategic orientation. When it comes to a Reactor, this organization significantly lags others in ICT introduction. In the case of Reactor, technology and ICT applications are often introduced towards the end of the technology life cycle and usually only when forced to do so by competitor pressure. The mean values of the constructs: knowledge (C1), IT management (C2), effective system (C3), organizational culture (C4), managerial mindset (C10), and ICT capacities vs. exploitation (C11) are given in Table 11. It is obvious that all participants from both EU and non-EU maritime organizations highly appreciated knowledge, proper deployment of skills and roles mediated by top management, system effectiveness achieved via proper communications within the organization, with customers, and for the purpose of market exploring, as well as organizational culture highly. The control variable in all cases corresponded well to the level of intelligent use of ICT and in all cases it has a relatively low level.

Table 11. The assessment of the independent, mediating, and control variables (Source: Own).

Country/Criteria	C1	C2	C3	C4	C10	C11
EU respondents						
Albania	4.10	4.25	3.75	3.83	3.50	2.50
Bosnia & Herzegovina	4.50	4.00	3.00	3.00	3.00	3.00
Montenegro	4.40	4.90	4.80	4.90	4.80	2.50
Serbia	5.00	5.00	4.00	5.00	3.00	2.00
Non-EU respondents						
Croatia	4.80	4.75	3.45	4.40	4.40	2.10
Greece	4.40	4.30	3.70	3.40	3.10	2.90
Italy	4.38	4.50	3.50	3.50	3.75	2.75
Slovenia	4.67	4.50	3.83	3.33	4.00	3.33

The interviewees from both EU and non-EU countries estimated the level of the rationality of using ICT&S within maritime organizations in which they work as relatively high. However, when it comes to the number of ordinary and advanced ICT&S solutions applied in the examined organizations, it became evident that maritime organizations in EU countries have considerably more ICT&S than those in the non-EU countries. The evidence is given in Table 12.

Table 12. The availability of the ICT&S (Source: Own).

Info-Communication System	Non-EU Countries				EU Countries			
	AL	B&H	MN	SR	CR	GR	IT	SL
Electronic Data Interchange (EDI)		1	1		1	1	1	1
Enterprise Resource Planning (ERP)		1	1		1	1	1	1
Customer Relationship Management (CRM) System	1	1	1		1	1	1	1
Electronic Logistics Marketplace (ELM)		1				1	1	1
THETIS (PSC—Port State Control)			1		1	1	1	1
Blockchain based Maritime Supply Chain System (BMSCS)								
Automatic Identification System (AIS)	1	1	1	1	1		1	1
Long-range identification and tracking (LRIT)	1		1		1	1		1
Vessel Traffic Monitoring Information System (VTMIS)	1		1		1	1		
Sea Traffic Management (STM)	1				1		1	1
e-Navigation					1			1
e-Maritime					1			1
Common Maritime Communication Platform (CMSP)					1			1
Maritime Surveillance Services (MSS)	1				1			1
SafeSeaNet (SSN)			1		1	1		1
Maritime Single Window (MSW)					1	1	1	1
Automatic Guided Vehicles (AGV)								
Digital twins							1	
Remotely controlled vessels								
Unmanned area, sea or underwater vessels (UxVs)						1	1	
Earth Observation Services—SAR sensors					1	1	1	1
Earth Observation Services—Optical sensors					1	1	1	1
Satellite-based oil spill detection system at sea			1		1			1
Oil spill prediction modeling system			1		1		1	1
River Information Services (RIS)				1				
Score:	**6**	**5**	**10**	**2**	**18**	**12**	**13**	**19**

Due to the binary approach applied, where "1" means availability of the system, it is clear that maritime organizations in EU countries have a considerably larger number of available ICT&Ss: 19 (Slovenia, SL), 18 (Croatia, CR), 13 (Italy, IT), and 12 (Greece, GR). On the other side, the non-EU countries have a significantly lower score in this regard: 10 (Montenegro, MN), 6 (Albania, AL), 5 (Bosnia and Herzegovina, B&H), and 2 (Serbia, SR). This means that the non-EU countries have to reconsider their business development strategies and ensure funds for new ICT systems and the renewal of the existing ones. The non-EU maritime administrate and business organizations should follow actual trajectories and scenarios in efficient and effective digitalization through the available sources of relevant information. The appropriate ICT systems and tools are an unavoidable part of ensuring sustainability in shipping, ports, and maritime logistics, which has to take into account maritime governance, development, and interventional plans at national, regional, and global levels. The proper use of contemporary ICT&S solutions can contribute to increasing the visibility and industry stakeholders' understanding of the current situation in sustainability (tracking sub-standard ships, accidents, pollution, waste management, contingency plans, and measures, etc.). It can also assist them in designing appropriate managerial insights and help develop appropriate sustainable policies, along with implementation strategies and methods across maritime clusters.

4.1.1 Results of multiple linear regression analysis

In an attempt to refine our quantitative analysis, we modeled a multiple linear regression functional relationship between the independent and dependent variables in the model. We used all responses from both EU and non-EU countries and obtained the results presented in Table 13. The analysis was realized in the Excel Module software embedded into Microsoft Excel on an Intel(R) Core(TM) i5 CPU@1.6 GHz and 8GB RAM PC. The simulation time was negligible, i.e., we almost instantly received the results.

Table 13. Multiple linear regression analysis results (Source: Own).

Intelligent Use of ICT	Knowledge	IT Management	Effective System	Organizational Culture
bi (i = 1,4)	0.124	0.855	0.107	0.407
b_0			−2.700	
r			0.799	
r^2			0.639	

Coefficients b_1 to b_4 (Table 13) correspond to independent variables in the model: knowledge, IT management, effective system, and organizational culture, while b_0 represents the regression line intercept. When independent variables are jointly regressed against the dependent variable (intelligent use of ICT&S) in an effort to explain the variance in it, the size of individual regression coefficients indicates how much an increase of one unit in the independent variable would affect the dependent variable, assuming that all the other variables remain unchanged. In this case, IT management has the highest impact on the dependent variable, i.e., intelligent use of ICT, then organizational culture, knowledge, and system efficiency, respectively.

The individual correlations between the independent variables and the dependent variable collapse in a regression coefficient multiple r or the square of multiple r (r-square or r^2), which is the amount of variance explained in the dependent variable by the predictors. The obtained regression coefficient (r^2=0.639) indicated a strong relationship between the independent variables and dependent variable in the model. In other words, if r^2 is 63.9%, it means that the value of the dependent variable 63.9% depends on the independent variables in the model and 36.1% on other factors (variables) that are not included in the model. This is a high correlation between the considered dependent and independent variables in the applied research approach.

4.1.2 Positive experiences in ICT&S adoption

Montenegro, as a non-EU country, has successfully implemented several maritime ICT&S imposed by international organizations, such as the International Maritime Organization (IMO), International Mobile Satellite Organization (IMSO), and European Commission (EC) and European Maritime Safety Agency (EMSA).

In early 2003, the Global Maritime Distress and Safety System (GMDSS) was deployed. The GMDSS was later renewed and upgraded in 2015.

In 2009, Montenegro successfully implemented Long Range Identification and Tracking (LRIT) by establishing the National LRIT Data Centre. This system enables Montenegro to use satellite-based tracking of vessels sailing under the flag of Montenegro worldwide. The positions of all ships are updated every six hours, or more often, if necessary. The system also provides information on foreign ships, which sail towards Montenegro's ports for the purpose of search and rescue at sea.

In 2013, Montenegro successfully implemented the CleanSeaNet (CSN) system previously approved by the EC and EMSA. The CSN is the European satellite-based oil spill monitoring and vessel detection service, developed and operated by the EMSA. The service analyses images, mainly from synthetic-aperture radars and optical missions. Montenegro was the first "developing country" that has joined the CSN system.

In 2015, the Vessel Traffic Monitoring Information System (VTMIS) center was officially opened in Montenegro. The sophisticated equipment for maritime surveillance, along with providing safety and security of sea traffic, was installed in three sites along its coast. The VTMIS center has required IT/IS equipment for sharing VTMIS data with respective stakeholders from Montenegro, as well as the EU partners. The personnel was trained to work as VTMIS managers and operators, as well as technicians, to maintain the system.

The aim of Montenegro is to improve the VTMIS system in the future by adding new types of sensors and new sites to cover blank spots. In addition, concepts and systems, such as augmented reality, Sea Traffic Management (STM), Common Information Sharing Environment (CISE), National Maritime Single Window (NMSW), are considered highly for the implementation. Now, the Administration for Maritime Safety and Port Management (AMSPM) is involved in several EU research projects where systems, such as CISE, unmanned aerial and underwater vehicles, NMSW, and STM, are subject of further research and improvements.

4.2 Deploying blockchain in maritime business

When it comes to blockchain and its implementation in maritime in developing environments, then experts from Montenegro and South Africa were asked to participate into the case study, which aim was to reveal the readiness of stakeholders to adapt new, advanced ICT&S administrative, logistics and payment digital mechanisms encompasses by blockchain. The respondents from Montenegro are partners or external experts at several ongoing large European projects, while the respondents from South Africa are from universities and the biggest national multimodal transportation company in the country (TRANSNET). After reception, the responses were checked, coded, keyed, edited, and analyzed.

The results of the quantitative part of the survey received from 20 experts (10 from Montenegro and 10 from South Africa) are presented in Table 14. The five statements with the highest "agree" and "disagree" assessment rates are categorized in different PESTEL dimensions: political, economic, social, technological, environ-mental, and legal, along with their rank (Table 15). The ranks and their connections with PESTEL dimensions will be discussed in Chapter 5.

Table 14. Quantitative assessments of blockchain adoption dimensions (Source: Own).

Statement	Agree	Disagree
1. The level of awareness and knowledge of BC affects its adoption.	4 + 5 + 5 + 5 + 5 + 5 + 5 + 5 + 5 + 5 +4 + 5 + 4 + 4 + 5 + 5 + 4 + 4 + 5 + 4 = 9.30	-
2. The BC adoption is affected by the availability of the infrastructure and functionality to integrate and interoperate within and across the business ecosystem.	1 + 5 + 5 + 3 + 5 + 5 + 5 + 3 + 5 + 5 + +5 + 5 + 5 + 5 + 5 + 5 + 5 + 4 + 5 = 9.10	-
3. Standardization and ensuring smooth interoperability is necessary, otherwise, BC can make things difficult instead of making them easier.	4 + 3 + 4 + 3 + 5 + 5 + 5 + 5 + 4 + 5 + 5 = 4.30	2 + 5 + 1 + 3 + 3 + 2 + 3 + 5 + 5 = 3.44
4. The BC adoption is affected by the availability of skilled and expert resources.	1 + 5 + 4 + 4 + 5 + 5 + 5 + 5 + 5 + 5 + +5 + 5 + 5 + 4 + 4 + 3 + 5 + 4 + 4 + 3 = 8.60	-
5. The BC adoption is affected by a large number of stakeholders, with different mind-sets, organizational culture, and working habits.	3 + 4 + 4 + 5 + 3 + 4 + 4 + 4 + 4 + 4 + +4 + 5 + 5 + 4 + 3 = 3.80	1 + 1 + 1 + 2 + 1 = 1.20
6. The BC adoption is increased by favorable government and regulatory policies.	5 + 3+5 + 4 + 2 + 4+5 + 2 + 5 + 5+ +5 + 5 + 4 + 4 + 5 + 5 + 5 + 5 + 5 + 4 = 8.70	-
7. Social influence positively affects the behavioral intention of using BC.	4 + 4 + 4 + 5 + 3 + 3 + 5 + 2+3 + 2+ +4 + 3 + 4 + 5 + 2+3 + 4 = 3.53	2 + 2 + 3 = 3.50
8. A perception that BC implementation might lead to loss of jobs can be an obstacle in its adoption.	3 + 1 + 5 + 4 + 5 + 5+4 + 3 + 5 + 4+ + 3 + 4 + 4 + 5 + 5 + 5 = 4.06	2 + 5 + 1 + 5 = 3.25
9. Development in storage, computing, and cloud infrastructure will affect the BC adoption.	2 + 5 + 5 + 5 + 5 + 5 + 5 + 4+ +4 + 3 + 5+5 + 4 + 5 + 4 + 4 + 4 = 4.35	2 + 2+1 = 1.67
10. The BC adoption reduces opportunistic behavior (opportunistic behavior means maximization of economic self-interest and occasioned loss of the other partners).	1 + 4 + 4 + 3 + 3 + 3+5 + 5 + 3 + 4 + 2 + 4 + 3 = 3.38	1 + 5+4 + 5+5 + 4 + 5 = 4.14
11. The BC adoption is reduced if the information is not shared by the partners, while some stakeholders are hesitant to share information considering it is a competitive advantage.	3 + 5 + 5 + 4+5 + 4 + 5 + 5 + 5 + 4+ +3 + 4 + 5 + 4 + 3 + 5 = 6.90	1 + 3 + 5 + 1 = 2.50
12. Privacy and security of models and data need to be ensured, as BC technology is still immature and vulnerable.	5 + 5 + 4 + 4 + 3 + 4 + 5 + 5 + 4 + 4 + 5 + 4 + 4 + 3 = 3.9	2 + 3 + 3 + 2 + 1 + 1 = 2.00
13. Blockchain offers a high level of complexity and observability at the same time.	4 + 2 + 5 + 3 + 5 + 5 + 2 + 5 + 3 + 5 + +4 + 5 + 4 + 4 + 5 + 3 + 2 = 4.47	5 + 4 + 4 = 4.33

Table 15. PESTEL analysis of blockchain adoption (Source: Own).

P Political	E Economic	S Social	T Technological	E Environmental	L Legal
Respondents “Agree”					
* Favorable government policies (rank 3)	* Hesitancy of sharing information (rank 5)	Awareness and knowledge about BC (rank 1) Skilled and expert resources (rank 4)	Infrastructure (rank 2)	* Hesitancy of sharing information (rank 5)	* Favorable regulatory policies (rank 3)
Respondents “Disagree”					
	Reduction of opportunistic behavior (rank 2)	Social Influence (rank 3)	Complexity and observability (rank 1) * Standardization (rank 4) ** Ensuring privacy and security (rank 5)	** Ensuring privacy and security (rank 5)	*Standardization (rank 4) ** Ensuring privacy and security (rank 5)

In the next paragraphs will be given some selected responses to the open-ended questions from the side of Montenegrin and South African interviewed experts, regarding blockchain adoption in maritime business.

1. *Which benefits Montenegro/South Africa might have, for instance, of introducing blockchain solutions in maritime (shipping) industry?*

Montenegrin expert: “Allowing tourists to spend their crypto currencies/coins during their stay in Montenegro would bring wealthier tourists. Also, it would bring tourists with crypto savings to spend more money than they planned to spend. The newest technology and tourism always comes together. Bringing wealthy and highly sophisticated digital nomads in and out of high season would bring Montenegro a significant raise in economy. Not to mention other gains like a longer season and employment of local IT experts with a significant raise of GDP. Tracking of tourists’ behavior such as spending and rewarding them with some usable tokens/coins would bring Montenegro tourism, which is dominantly connected with sea, growth, and development.”

South African expert: "Blockchain can help by placing the crucial data in one place and creating a unique platform for solution providers, ports, and agents that operate along the supply chain. Allowing tracking cargo in real time using block-chain technology, shipping companies and ports can plan land procedures ahead of time, speeding up terminal works and cutting down costs. Maritime blockchain increases trading safety and transparency. Adopting blockchain technology would elevate the industry to the next level in terms of efficiency and would also impact positively mistakes being done on a daily basis by the personnel in maritime."

2. *It will have lot of cost in terms of time and money to change the existing system, especially when it is an infrastructure. We have to make sure this innovative technology not only creates economic benefits and meets the requirements of supervision, but also*

bridges with traditional organization, and it always encounter difficulties from internal organization, which is happening now. What do you think accordingly?

Montenegrin expert 1: "Montenegro needs a law that would regulate digital assets, together with crypto exchange and ICO (Information Commissioner's Office) regulation. Tokenizing big tourist investment via crypto would allow the crypto community worldwide to invest in Montenegro future projects."

Montenegrin expert 2: "Definitely, technology is advancing faster than human habits. Are our brains ready for all technological changes, and all that information delivered every day? Adoption is very slow; most of the people do not even use credit cards or e-banking services. It just needs decades, for new digital generations to come."

South African expert 1: "Blockchain technology will transform the maritime industry, as it is still struggling with high costs and a high level of pollution. Blockchain technology can help with both issues, by cutting down administrative costs and providing environment-friendly solutions."

South African expert 2: "Yes, changing from the old system to the new one will have a lot of financial implications for the organizations, but I consider it will be worth it, and ultimately will come with a lot of positives to the traditional organizations."

3. *Use bitcoin for example, the characteristics of the decentralized system will weaken the central bank's ability to control the economic policy and the amount of money, which makes government be cautious of blockchain technologies. Authorities have to research this issue, accelerate formulating new policy, otherwise, it will have a risk on the market. To which extent do you agree with this statement?*

Montenegrin expert: "Bitcoin is unstoppable; its network is not censorable. There is no sanctions, no age, gender or any other restrictions. It is free for whole world to use it with the same rules for all. Banks will embrace bitcoin. It will become ex-changeable in every bank as the dollar is today. Bitcoin is safeguarded against limitless money printing. It would not replace dollar or euro, but it could be complementary to gold, something as 'digital gold'."

South African expert: "Government will have to look at this system from all different angles in an attempt to find any serious loophole that might come with the system, especially in institutions like banks."

4. *Are you familiar with 'stablecoin'?—Can it assist regarding the previous challenge and in which way?*

Montenegrin expert 1: "Local stable coin would bring to Montenegro the newest technology and long-awaited Easy Payment/PayPal-like options, which would for sure boost the Montenegro economy. If most merchants accept stable coin, this will lead to a significant Montenegro economy boost."

Montenegrin expert 2: "Major central banks are running pilot projects with stable-coins. The key question is how money laundering, tax heavens, and corruption will work with stablecoins that are more transparent than current financial systems. I guess we shall have transparency for ordinary people, while big players will continue to hide their wealth.

South African expert 1: “I am familiar to a limited extent.”

South African expert 2: “I am honestly not familiar with stablecoin.”

5. *Even though it is an advanced technology, blockchain still struggles with some security issues. For instance, if someone has more than 51% computing power, then he/she can find nonce (number blockchain miners are solving for) quicker than others can, which means that he/she has authority to decide which block is permissible. What is your opinion concerning this issue?*

Montenegrin expert 1: "There are several technologies developed, which practically make the 51% attack almost impossible to happen if applied correctly. Still, I al-ways suggest using strong BC projects with huge hash power mining community—POW Blockchain networks, like Ravencoin, BitcoinCash, etc., or some reputable Blockchain networks - POS, like Etheraum, Ripple, etc."

Montenegrin expert 2: The 51% is really for smaller coins, but not for bitcoin. This is only a theoretical threat for the bitcoin network, and here is why. Firstly, it will cost billions in equipment to achieve that big hash rate with dubious benefits. The price of bitcoin will go sharply down. Bitcoin mining system is made that way to be more profitable to the honest miner. If an attacker could control the network for a longer period of time, the value of bitcoin would go down to zero, because trust in the bitcoin network would be zero. So, they would manage to get control of a lot of bitcoins that would be worthless. Not to mention worldwide storage of chips, such attack is not even possible right now."

The South African experts consulted from maritime industry were sincere and stated that this issue is beyond their scope of interest and expertise presently.

6. *Another issue is the ‘fork’ problem. It is related to decentralized node version agreement when the software is upgraded. Then, nodes are divided into old and new ones, and different problems of their mutual communication can appear.*

Montenegrin expert 1: "It is democracy, who ever have 51% or more votes, it’s a le-git version of BC. There will be always one bitcoin, no matter how many times they fork it."

Montenegrin expert 2: "Some argue that while no technology is completely secure, no one has yet managed to break the encryption and decentralized architecture of BC. Decentralized networks can be much or less resilient to shocks, which can affect participants directly, unless careful thought is given to their design."

However, the majority of the consulted respondents are not familiar with this particular issue.

7. *Blockchain uses internet. Does it mean that it is prone at this instance to common internet attacks like ‘botnets’, for instance?*

Montenegrin expert: "BC is not prone to classical botnet attacks, but there are similar ones. Especially when fees for transactions are low, multiple spam attacks are aimed to slowdown transactions and increase fees. Nevertheless, those people are just 'burning' their money, with increased fees; they increase the cost of the spam transactions also."

South African expert: "This is something we live with for all internet services. However, with proper implementation, monitoring, and improvement that would be made on the BC system over time, it would not be prone to any internet-related attacks."

The discussion of this qualitative part of the research, which concerns smart deployment of blockchain in maritime in developing economies, at the cases of Montenegro and South Africa will be given in Chapter 5.

4.3 SWOT analysis results

This sub-section of the study presents results of SWOT analysis in the context of autonomous (unmanned) underwater and aerial vehicles in sea surveillance and safety missions in preventing illegal migrations and drugs smuggling across the sea borders. As a base for drawing up this scheme (Table 16), an extensive desktop search of academic and "grey" (online media) resources has been conducted. Also, projects' documentation of two European Commission projects COMPASS2020 (Coordination Of Maritime assets for Persistent And Systematic Surveillance) and ePIcenter (Enhanced Physical Internet-Compatible Earth-frieNdly freight Transportation answER) has been consulted.

Table 16. The SWOT analysis of the UAVs and AUVs (Source: Own).

Strengths	
UAVs	AUVs
− Lightness. − Manual launching or reduced logistics footprint. − Low energy consumption. − Lower acquisition price in comparison to satellites. − Better quality of information in comparison with satellites. − Lower operational costs in comparison with manned aircrafts used for the same mission profiles. − Ability to fly for more hours continuously in comparison to manned aircrafts, as there is no need for aircraft downtime for pilot rendition. − High seeing, sensing and communication capacities. − Capacity of both LoS and BLoS operations. − Large coverage and durability of flight without recharging. − High level of automation. − Possibility to be safely integrated with commercial aviation. − Capacity to support high risk activities.	− Capacity to support high risk activities. − Capacity to reach areas inaccessible for humans. − Capacity to explore unexplored marine habitats. − Capacity to monitor and repair underwater constructions, pipelines and cables. − High level of autonomous navigation, collecting data and coming back to the sea surface vessel. − Silence operation and consequently not disturbing the environment and being imperceptible to potential foes. − Being tight and waterproof. − Having shape that mimics sea creatures (fishes, crabs, turtles, beetles and snakes). − High appropriateness of kinetic and dynamic properties for underwater environment. − Capacity of delivering with a Launch And Recovery System (LARS). − Navigation with combination of Inertial Navigation System (INS), Doppler Velocity Log (DVL), military

– Capacity to reach areas inaccessible for humans.	global navigation satellite system (GNSS) and Global Positioning System (GPS) periodically. – Possessing advanced sensors like: Synthetic Aperture Sonar (SAS), video, forward looking sonar (FLS), multi-beam echo sounder and like. – Communications via acoustic, radio and optical (light and laser) waves.
Weaknesses	
UAVs	AUVs
– Complexity of the UAVs makes them more vulnerable. – Requirements for highly skilled personnel for designing, creating, operating-controlling, maintaining and upgrading the UAVs. – Lack of law regulations at a wider scale. – Lack of management and operational knowledge at different levels of the UAVs operation. – Lack of common communication capacities between the UAVs and other vehicles within integrated traffic and transportation system. – The link between the UAVs and ground control stations. – Maneuvering and obstacles' avoidance algorithms and features are under development. – Computer vision is also still until development.	– Better adaptive control using neuro-fuzzy techniques is needed. – More accurate localizing using improved INS non-linear Kalman filters, cooperative localization (swarm intelligence), artificial intelligence vision and object detection, odometry, are to be developed. – Underwater wireless communications are to be improved, particularly at the longer distances. – High-density battery power supply is necessary. – Energy harvesting methods are to be improved.
Opportunities	
UAVs	AUVs
– Increasing safety and security at sea and in general. – Reduction of traffic congestion in areas with high density traffic. – Approaching up to now inapproachable areas. – Approaching areas of high risk for humans. – Gathering more information on distance areas, entities, constructions. – Lower ecological footprint. – Developing 3D path planning with obstacle avoidance. – Developing potentials of autonomous systems. – Further development of artificial super-complex UAV systems.	– Increasing safety and security at sea and in general. – Approaching up to now inapproachable corners of seabed. – Approaching areas of high risk for humans. – Gathering more information on distance areas, aquatic flora and fauna, constructions. – Lower ecological footprint. – Developing 3D path planning with obstacle avoidance. – Developing potentials of autonomous systems. – Further development of artificial super-complex AUV systems.
Threats	
UAVs	AUVs
– Collapse of the UAVs due to severe weather conditions/harsh environments.	– Losing human control over the crafts. – Unsafe Launch And Recovery System (LARS).

− Negative effects of external factors as natural forces and cosmic impacts. − Losing human control over the crafts. − Unsafe landing and recovering. − Internal disturbances and faults in the systems as super-complex ones. − Over-reliance on technology, i.e., UAVs in the analyzed context; − Unauthorized malicious intrusion into the system (hacking); − Scarcity of the cost-benefit analysis; − High investment risks; − The lack of readiness of entrepreneurs to support further development of UAVs; − Uncertain revenue of investments; − Users' reluctance to accept high risk investments in the UAVs innovations; − Questionable innovation acceptance success, etc.	− Internal disturbances and faults in the systems as super-complex ones. − Over-reliance on technology, AUVs in the analysed context. − Unauthorized malicious intrusion into the system (hacking). − Scarcity of the cost-benefit analysis. − High investment risks. − The lack of readiness of entrepreneurs to support further development of AUVs. − Uncertain revenue of investments. − Users' reluctance to accept high risk investments in the AUVs innovations. − Questionable innovation acceptance success.

In accordance with SWOT principles, strengths, weaknesses, threats and opportunities of the considered UAVs and AUVs are highlighted. Current solutions for analyzed UAVs and AUVs are in development and/or testing phases. Therefore, it was not possible to conduct surveys among potential end users such as European coastal or maritime authorities. Developers and researchers involved in the projects have developed the internal documentation with restricted access. Therefore, here presented SWOT analysis is based mostly on secondary literature resources that include [198], [199], [200], and some scarce information upon the results of the field experiments recently being carried on. However, used references are sound and promise quality of conducted study. Through further investigation the examined features of UAVs and AUVs can be assessed within the specific context, which might be different from the analyzed one – European coastal areas monitoring and combat against narcotic smugglers by the maritime authorities. Apart from this, at the current stage of the research in the field, the following SWOT is at high level of abstraction and only partly anchored to the particular research projects as COMPASS2020 and ePIcenter, bearing in mind specific settings within these projects.

4.3.1 Justifying adoption of CISE in Montenegro

Currently, maritime situational picture or Common Operational Picture (COP) is provided by the stand-alone conventional maritime surveillance systems and cooperation mechanisms running between the countries (e.g., Vessel Traffic Service - VTS). One such system is run by AMSPM and operationally centered close to the port of Bar (Montenegro) with additional three remotes sites, several boats and various equipment distributed along the comparably small coast of Montenegro stretching over 294 km. This system is able to trace, track, enquire and inspect vessels crossing South Adriatic region and uses the Vessel Traffic Monitoring

Information System (VTMIS) as the interface for visibility and exchange of data (e.g. AIS, radar, meteo) over a dedicated set of legacy information exchange protocols, e.g. IVEF - Inter-VTS Exchange Format. Integrated maritime surveillance is one operational segment within the responsibilities in the Montenegrin national maritime joint operations. These are combined with executive powers of the Border Police and the Navy, and, under governance of the national ministerial bodies. In specific cases of the joint operations such as Search and Rescue at sea and/or sea pollutions, AMSPM coordinates activities at the sea, and the rest of the institutions' assets (e.g. boats) are at its disposal, command and coordination. The CISE features would extensively augment the situational awareness by detailing and ubiquitously extending the reach of the national coverage and by improving the regional interconnections.

Analysis presented in this study commences with a comprehensive awareness and assessment of the maritime surveillance requirements in Montenegro especially highlighting the country's small size and its current systems. As inherent in the CISE definition and subject to its potential deployment in Montenegro, the common environment for information exchange would include the following specific features regarding maritime surveillance and operations:

- Increased volume and richness of information retrieval and awareness in the maritime domains.
- Installation of a technological platform for advancement of the capabilities in wide-ranging related fields in maritime surveillance and affairs.
- Extending the CISE features such as to land border surveillance.

Increased surveillance visibility in the maritime regions in the Adriatic (and Ionian) would mean an augmented view of the country's waters and bordering sea regions, via interconnections with neighboring countries, i.e., Italy, Albania, and Croatia. These CISE-enabled capabilities come through implementations of its functional components such as CISE Gateways, Nodes and Adaptors.

In addition to the increase in visibility of objects such as vessels, CISE would increase the volume and context of information shared per each instance, i.e. resolution of information, details, accuracy, etc. Namely, information entities/objects would increase compared to what is monitored currently as CISE Data and Service models, which are continuously being extended to include information context such as: anomalies, incidents, documents and comprehensive improvements to the situational awareness in maritime surveillance. The original CISE Data Model composition of data entities is depicted in Figure 29 (UID stands for Unique Identifier) initially defined in FP7 EU project CoopP (Cooperation Project Maritime Surveillance) [188]. It is constantly being perfected and extended as conducted in the ANDROMEDA project with new data entities that describe further surveillance situations and detail being observed.

The CISE enables extending the interconnections inside a country by allowing ubiquitous information flows for creating a truly common national environment for information sharing, retrieval and interpretations. National support for CISE implementation would ensure interconnections of different organizations and their legacy systems via the adaptation features and through a suitably developed national CISE architecture model interfaced with the European CISE network. Accordingly, information richness and situational awareness throughout the country would increase. Such a transcending country-wide capability between the organisations dealing with segments of maritime surveillance in Montenegro is nonexistent at the moment, i.e. there is a lack of a common maritime digital environment between the security, military, transport, tourism, fisheries, and commercial sectors.

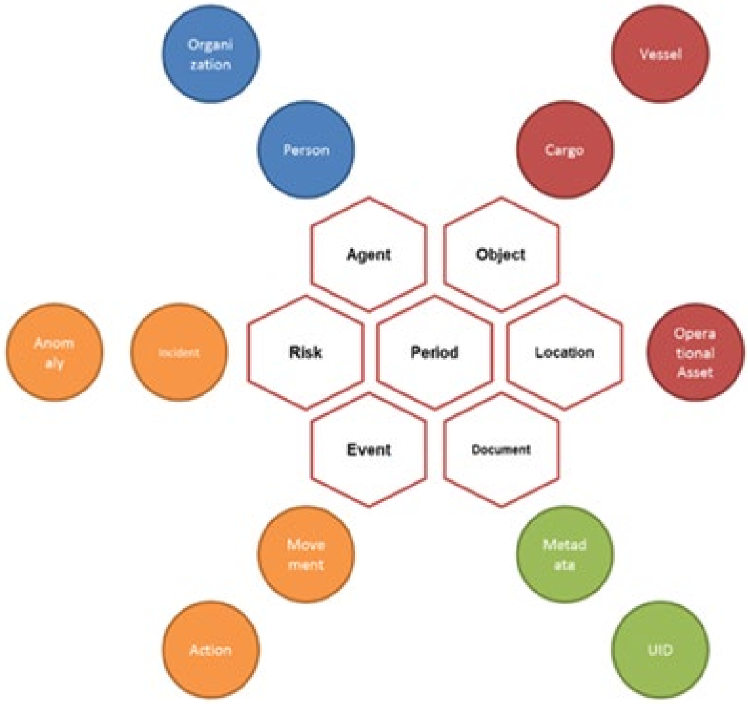


Figure 29. The CISE data model (Source: [188]).

In the first stage of CISE implementations, the primary objectives are the translations and exchanges of data, and, facilitation of the basic services between different organizations and their legacy systems. This means that the full-scale national CISE network, data and service model implementations, as envisaged, might not be the immediate objective for joining organizations such as AMSPM, or police. Their legacy systems are already operational within the current scope. The CISE offers controllable and gradual augmentation of the existing capabilities, via collaborations, interconnections and translational features towards ultimately establishing it as a full-scale solution. Thus, CISE deployment follows a top-down approach that initially needs to be spurred, envisaged and planned as a strategic investment on the national and regional scale. Its wide-reaching economic benefits emanate upon it becoming (fully) collaborative as a universal technological platform (similar to the Internet model) for maritime surveillance.

The translational features between legacy systems and CISE are to enable linking, interpreting and sharing information at the national and cross-border/EU levels in both directions of data exchanges and subject to a variety of deployment scenarios. It is reiterated that being part of the CISE means that the maritime surveillance features from the EU CISE network and bordering countries become partly available in Montenegro contributing to the effectiveness and value of their proxy capabilities inside the country. The same condition applies to the reversed benefit to all members/neighbors in the EU CISE network. In fact, one of the foundational design principles of the EU CISE network established in the pioneering project EUCISE2020 [189] is the “Responsibility to Share”. In simple terms, this means that when connected to the EU CISE network, a member ought to equally provide as well as receive information. Very importantly, being part of CISE for Montenegro would also mean an open working facility for extending the existing features in maritime surveillance, as plugins for existing legacy tools for: translations design, web service, DF, DS and C2. The CISE is a work-in-progress initiative, with continuous extensions of data models, services and opportunities for local and EU-wide development projects and initiatives. In several EU research and innovation projects including MARISA [190] and ANDROMEDA [186] projects, services are being developed along the idea of constructing the advanced service layer of the CISE Node. Furthermore, the running EFFECTOR EU project develops generic data processing tools to augment the CISE network interconnections [191]. Adapting to and keeping up with these upgrades facilitates growth of the local skills and knowledge in areas related to operations and maintenance, engineering, research, administration, data processing and many more.

The CISE is being extended for land border surveillance thought the EU project ANDROMEDA. Such a deployment environment would necessitate repeating the above analytical processes as conducted for the maritime surveillance and replacing some of the organizations at both the national and regional levels. In the analysis conducted in this paper, we remain focused on maritime surveillance being the objective of the existing CISE specifications and the current functioning of the EU CISE network.

4.3.2 CISE implementation in Montenegro

In this section of the study, a framework for feasibility and cost-bene analysis is done. More precisely, analysis of the CISE deployment feasibility/cost-benefits in Montenegro can consider two distinct realization stages:

- Initial, AMSPM-anchored, ANDROMEDA implementation, with CISE translations and link up with the EU CISE network.
- Fully-fledged country-wide CISE network implementation in Montenegro, with internal CISE interconnections and a common national CISE environment, in addition to also being a part of the EU CISE network.

Subject to these thresholds in the extent of the CISE implementations, a practical deployment strategy and associated assessments need to accompany the feasibility and cost-benefit study. These practical considerations can basically assess several technical and economic prerequisites and the CISE features towards shaping of the deployment scenario(s):

- Scale of the CISE network in Montenegro, subject to setting up of the scenarios of deployment in the country.
- Resolving the objectives behind the two realization stages: a) only as the transitional feature connecting to the EU CISE network and as a limited bridging facility between various legacy systems and organizations nationally, and/or, b) as a stand-alone open network backbone service to grow into a country-wide system with comprehensively integrated CISE services and data models. The latter feature would ultimately allow visibility and data exchanges via standalone CISE tools progressively embedded in organizations rather than via adaptations of internal legacy systems used in each organization involved.
- Numbers and interconnections of CISE entities within the country and with the EU network: CISE Node/Gateway (forming the CISE network) and CISE Adaptors (towards legacy systems) (i.e., also called Andromeda Hubs in the ANDROMEDA

project as they facilitate translations of the newly added features to the existing CISE network through the project [186]) would follow the previous point. This constitutes the practical scale of the network, its purpose and sets up a path for its evolution.

Engineering know-how is required for solving the translational features of each CISE Adaptor and the structure, syntax and many accompanying protocol features of the legacy information protocol used within each organization. For instance, IVEF-to-CISE translations are XML (Extensible Markup Language)-like structure and syntax translation processes. These achieve parsing and transferring of AMSPM's VTS system data model and associated meanings to and from the EU CISE network (e.g., AIS and radar data). In the ANDROMEDA project, a trial with AMSPM's IVEF-to-CISE translation is planned off-the-premises at GMV's cloud in Spain where the CISE Adaptor is located with a direct connection to IVEF [192] source in Montenegro. The connection is appropriately "firewalled" at both endpoints in Montenegro and Spain by specific filters that enable total control over the shared information and its destination. No hardware nor significant software upgrades are required at AMSPM. E.g., the adaptation/translation process means a transformation from one standard such as IVEF to the CISE standard and vice versa. This might mean a field-by-field translation process making the correlations. In some cases, for example with data class - Type (enumeration) the translations would need to be 'forced' as the values might not exactly match. An example is IVEF construction that contains:

> *LloydsShipType = "70">< / Construction>*, where value 70 corresponds to AIS description "Cargo, all ships of this type". The CISE Data models specify many ranges of Cargo data entity descriptions under Cargo Core Entity, including numerous Cargo Type class descriptors such as LARGE FREIGHT CONTAINERS, PALLETIZED, etc. with corresponding description for each of them [193].

4.3.3 Options for commencing CISE usage in Montenegro

The main starting objective of the initial CISE deployment in Montenegro is twofold: facilitate interconnections with the existing EU CISE network, while realizing CISE services inside the country at AMSPM, and, gradually integrate other national stakeholders/organizations through it. Foundational work on CISE architectural deployment frameworks inside EU member states have formulated several models. These are constituted around the setup of the CISE interconnectivity provider(s) inside a country and facilitation of the link up with the EU CISE network [193], [194] (see Figure 30). From these options, the most convenient foundational model that practically suits a small country of the size and maritime costal region of Montenegro is the "Single National Provider of CISE Services" [193]. Such a model would be formed around a national authority, or authority-appointed stakeholder that manages the CISE services inside the country and towards the EU CISE network, i.e. AMSPM.

Having a single focal position for the CISE deployment is quite suitable for a small country. It allows easy establishment of the CISE functionalities (i.e., data models and services) that initially need to be translated and bridged towards the outer EU CISE network. Consequently, knowledge and skills required for implementing these system components would be focused and would consequently accommodate for potential expansion of stakeholders and user communities.

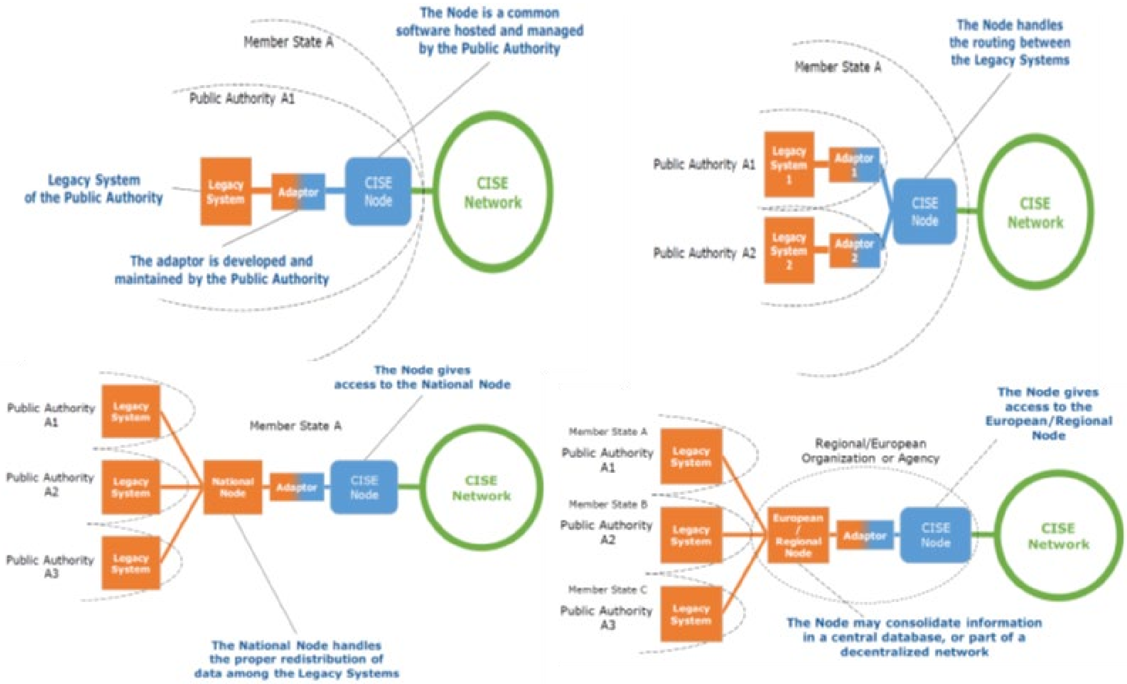


Figure 30. Four examples of connecting to CISE network based on location and ownership of the connecting CISE node (Source: [194]).

As formulated in the foundational CISE architecture visions [193], [194], the initial single provider model, or in fact even the other models specified that are based on multiple providers and user communities, could all eventually transform into a "hybrid architecture" with different setup of stakeholders. In this paper, intention is to analyses the related aspects when CISE deployment starts from scratch in Montenegro for which case the most fitting starting model is based on the "Single National Provider of CISE Services". AMSPM would duly obtain the national support for commencing the CISE deployment, e.g. via Ministry of Transport appointment and support of other involved national authorities. Accordingly, CISE facilitated Montenegro maritime situational picture (also adding the neighboring countries' CISE partners' data besides the current exchanges) would be rendered and maintained by AMSPM either partly by the restricted information available to AMSPM, or, in a comprehensive manner by gathering the information from other national maritime authorities/stakeholders in the country. This is conditional to the agreement(s) between the national authorities on sharing and ownership of the information. This Montenegro maritime situational picture is to be shared with the CISE EU partners according to the "Responsibility to Share" design principle and access rights matrix [195]. At the national level, some of the involved maritime surveillance organizations with their legacy systems, which can ultimately play a part in the CISE interconnections via the single national provider/AMSPM are: police, customs, navy, army, fisheries, tourist organizations, all national and commercial ports, universities (for research, trailing, knowledge and educational purposes), ministries, government, and, (if allowed) associated companies. Recently, a similar nationwide involvement of stakeholders/institutions in Montenegro [125] was pondered upon in the EU COMPASS2020 project's model dealing with a deployment of novel maritime surveillance assets [169].

From the general technical point of view, the architecture is constructed around the placement of typically one CISE Node, which is practically the immediate point of entry into the CISE network. Since AMSPM is to be the starting provider of the CISE services in the country, it is primarily the question of how the starting linkup with the EU CISE network is achieved that subsequently draws upon various implementation issues and analysis. There are already several models of architecture visons and their framework instantiations and organizational structures. These are based on the pivotal CISE Node's location, ownership and connections from the side of the joining state and its stakeholders with their legacy systems. Relevant organizational structures, copied from [194], are shown in Figure 30 organized around the CISE Node placement:

- (top left) a single stakeholder connects directly to the CISE network (e.g. AMSPM connects to EU CISE Network) by adapting its legacy system and owning a CISE Node.
- (top right) several stakeholders connect to the CISE network by using a single CISE Node owned by one of the stakeholders (e.g. AMSPM as the owner proxying connections for other stakeholders).
- (bottom left) the country establishes a shared National (CISE+) Node owned by one of the stakeholders and having access rights and information control for access to and from the EU CISE network and national interconnections (e.g. AMSPM as the owner manages and proxies connections for other national stakeholders).
- (bottom right) using a Regional/European Node and/or proxy owned external CISE Node to connect to the CISE Network (e.g. AMSPM can be a gateway for connection to CISE Network through an external EU partner).

Evidently, at the initial stage of implementation, one of the main operations in launching the CISE services is in adaptation of legacy system(s) towards the CISE network. This requires translations of data models and meanings to and from the CISE network and bridging each of these legacy systems inside the country with an appropriate level of security. At the time of the writing of this paper, EMSA (European Maritime Safety Agency) is drafting a common contract model for information sharing inside the CISE consortium, which would replace the current approach of the bilateral contracts.

4.3.4 Initial feasibility considerations

We can draw parallels with a similar starting feasibility consideration conducted for National Maritime Single Window (NMSW) [196], [197] implementation in Montenegro also facilitated via its anchoring at AMSPM and involving many maritime stakeholders. Although related to a rather non-overlapping segment of maritime affairs, this example further strengthens the candidacy of AMSPM as the national authority stakeholder being technically and administratively suitable for carrying out the implementation of the linkage to the EU CISE network. Operational coupling of the single or hybrid national CISE provider models with NMSW provider was hinted at early in the architecture visions for CISE deployments [193]. Besides, these initial feasibility considerations can provide much support to AMSPM in negotiations with the national authorities and other CISE stakeholders in Montenegro. Similar to the example of the extent of the Montenegro maritime situational picture that would be shared with the outside EU CISE network members as mentioned in the previous section, AMSPM is the anchoring entity in distributing information from CISE network internally to other stakeholders in Montenegro. E.g., a cargo vessel that departs from a Mediterranean port with destination to Montenegrin port of Bar is approaching the port and is visible through the CISE network on its approach. There are other authorities interested in the CISE data about the vessel (customs, police, military etc.) that would extract the relevant CISE data entities' content that are embodied in the CISE Vessel Service for the particular vessel.

Another important distinguishing feasibility consideration is related to the top-down property of each CISE implementation strategy as the facilitating technological platform for maritime surveillance. Business model perspective is void of an immediate revenue generating component such as application of fees used in NMSW [196]. Deployments of CISE features are applied towards evolutions of operational capabilities, not as an immediate capacity to attract customers or charge CISE connections and service deployment (e.g. to vessels or connecting stakeholders). It is therefore important to initially observe the implementation of CISE as a national (and European) master plan mandated to AMSPM in Montenegro. The cost and benefits can therefore be seen as both immediate and long term investment returns especially if the fully-fledged country wide CISE implementation is ultimately achieved (see Section II.ii) in the same context of European CISE network expansion and success.

4.3.5 Identifying essential costs

At the initial stage of implementation, operational aspects that constitute the foundation for feasibility analysis are:

- Investment costs of setting up of the CISE features and adapting and interconnecting the legacy system(s) (quite analogous to conventional CAPEX expenses):
  - Initial hardware and software (HW/SW) installations of the CISE technicalities and components.
  - CISE features for interconnecting with the EU CISE network, adaptation/translations with the legacy system(s) and (optional at the start) national CISE interconnections between the legacy systems.
  - Trainings of personnel for conducing operational tasks.
- Maintenance costs of the operational runtime being dependent on the organizational structure of CISE (similar to OPEX) that can involve several critical tasks mostly related to personnel:
  - Engineering costs of keeping up the operations of hardware (e.g., CISE Node) and essential software components.
  - Continuous design and inspection of adaptation / translation features between CISE and legacy system(s) and facilitation of CISE interconnections at national level.
  - Overlooking the required changes and evolution of the national CISE systems.
  - Continuous education, monitoring, participation and liaising with the European CISE development activities and expansion of the network for maritime surveillance.
- Dedicated expansion costs from a starting organizational structure and towards ultimately a fully-fledged country wide CISE network implementation:
  - Assuming that one standard national implementation of the CISE Adaptor features between the CISE network and a legacy system is reasonably light in terms of costs and effort (e.g., for top left organizational structure in Figure 30), applying the same for each separate legacy system of the joining national stakeholders is a multiplication of this task and not a straightforward extension

of the existing features (e.g. software installation and maintenance costs) as the legacy systems commonly differ in all relevant technicalities to the adaptation process.

- Ultimately, as a long-term ambition, replacement of (many) legacy systems data and service models. This aspect partly includes replacements of obsolete parts of the legacy systems that cannot be further upgraded/updated as the CISE components expand (these could also be associated with the investment costs subject to a scenario).
- Dedicated or related research.

The actual figures behind each cost and weighing of each one of them is proportional to the total cost and is subject to the situation and pricing in each country. Hence, the actual figures can vary as the overall costs are subject to national contracts and the authorities and agencies involved in the design, production and deployment of the needed HW/SW and other components, as well as the way in which the costs of personnel are calculated for each stage and purpose of operations.

4.3.6 Expected benefits

Expectedly, the CISE implementations start small and expand gradually from an anchoring authority that installs the first instance of the CISE configuration. At the current stage of realization of the CISE systems at national levels across Europe, even a large country of the size of Spain has commenced the implementation via the single provider model: The Spanish Navy has bridged and interconnected national stakeholders such as Customs, Border Control, Fisheries, Defence and Maritime Surveillance agencies and all companies associated with maritime surveillance and Search and Rescue. At the time of the writing of this paper, the Spanish Navy operates the top right configuration from Figure 30, as it owns the CISE Node while the other legacy systems belonging to the connected national stakeholders have their CISE Adaptor at their premises. Extent of the information sharing between the stakeholders gets continuously agreed upon. Similarly, the Finnish CISE implementation opted for the same configuration (also termed as CISE Configuration B [189]). In Finland, the Finnish Border Guard is the stakeholder on behalf of the Maritime Authorities Consortium (FIMAC) in CISE. The FIMAC consist of Finnish Border Guard, Navy, Transport and Communication Agency and Transport Agency. The Transport and Communication Agency and Transport Agency are actively sharing information in the CISE network. Due the classification of the CISE network, the Finnish Navy and Border Guard are not physically connected to the CISE network. A breakdown of costs from the recent Finnish CISE implementation and their brief decomposition into a useful approach and experience for the CISE essential costs identified in the previous subsection, are given in Table 17.

In a manner of observing the CISE benefits from a reversed perspective, when it would eventually become implemented in a fully-fledged manner, the achieved benefits are enormous at all levels (being the very intention of the CISE development by EU). Stakeholders, states, regions would benefit by simplified, standardized and converged maritime surveillance capabilities and a manifold reduction in human and equipment expenses required for each legacy system (excluding opportunities via the equally auspicious land border surveillance in this analysis for the time being upon its ultimate formulation via the ANDROMEDA project).

But this is the ultimate goal and needs to be justified by the intermediate investments and costs. As stated earlier there is no direct revenue generating mechanism and majority of the quantifiable benefits are implicit or tangible in retrospective upon the fully-fledged implementation. This is quite similar to the basic view of the Internet model, being the facilitator for a novel way of communications and opportunities. It was originally reiterated that "CISE is not a system" (EUCISE project media presentation link in [189]), rather "it is a set of agreed specifications for an interoperability layer which, once implemented, will ease information exchange". This makes it very analogous to the OSI Presentation Layer features extended to physical and cyber domains of maritime surveillance, i.e. it builds upon XML/JSON compositions of the CISE Data Models. Fitting to this general interpretation of the CISE model would be a European or a country-wide implementation of the CISE features over a cloud structure for the relevant services. This is a possible outcome of the CISE development in its mature stages.

The CISE Adaptor takes care of "translation" of the shared information to and from the legacy systems. The current implementations use the REST/SOAP APIs with web services and conventional PULL, PUSH, SUBSCRIBE communication patterns meaning that the translation to and from CISE Data Models are underlying presentation layer processes within the mechanisms already used. While envisaging that the future versions of some legacy systems might include the CISE data model syntax and structure, constant adaptations/translations are most likely still inevitable requiring dedicated designers' interventions. Thus, CISE Adaptor emerges as extremely important to the Montenegro case where its complexity or customized features (e.g. solely focus on entities of interest to AMSPM, such as vessels) might incur benefits, subject to it being constantly updated with new CISE data models and services. In the case of Montenegro, the starting models applied in Spain and Finland are equally applicable, i.e., top right configuration from Figure 30, where there are many CISE Adaptors connecting over a single CISE Node. Following this discussion, it remains equally recommendable to consider and deploy the bottom left configuration from Figure 30 where all CISE Adaptor features are centralized and facilitated over the CISE National Node, to be run by AMSPM. For the small country of the size of Montenegro this feature might reduce the cost of multiple CISE Adaptors implementation, as the security and access rights can be mandated to AMSPM and where all the adaptor/translation features are centrally placed making their design, maintenance and customization to requirements of each legacy system in Montenegro conveniently manageable. Quantifying CISE benefits for all stages of implementation, for a small country such as Montenegro draws out an immediate conclusion of a significant benefit: focusing the knowhow and investments on a single CISE operational model for all involved national stakeholders/organizations is especially suitable. The capabilities are increased while comparably not losing much in readjustments of systems and personnel in already small scale operational and organization capabilities and structure. It is expected that such benefits are less emphasized for a larger country, getting rid of a significantly larger and bulkier existing operational infrastructure.

Table 17. Indication of costs in the Finish example and general remarks (Source: [43]).

Investment Costs (CAPEX like)	
HW/SW installations	***Finnish case***: Initially consisting of the CISE Adaptor/Gateway designs, productions and installations and the VPN configuration. The CISE Adaptor design was the most expensive and time consuming, amounting to approx. 100 000€. Part of the CISE Adaptor design costs can be related to the next bullet/box. Having the current knowledge and understanding, the CISE Adaptor cost could be reduced to upwards from 40 000 €. Highly dependent on numbers and types of legacy systems to be connected on CISE, the services and data provided / consumed etc. CISE Gateway/Node design and VPN configuration were under the outsourced agencies' service contract, thus only estimated to around 20 000 €. CISE Gateway/Node production and installation were approximately 6 000€.
Connection to EU CISE Adaptation / translation to legacy systems National CISE interconnections	***Finnish case***: The deployment costs were approx. 10 000€ including the VPN maintenance and connections to servers. CISE network VPN configuration in Finland was initially part of an innovation and research project. Two out of four involved authorities provided limited information to the CISE network sharing them via the information Transport Agency's CISE Gateway. Navy and Border Guards had their own CISE Adaptor (as the Transport Agency) but due the public classification of the CISE network, these were not open and no information were shared from them.
Personnel training for operational tasks	***Finish case:*** Personnel implicitly involved and trained as part of the CISE research and innovation project. No dedicated personnel training.
Maintenance Costs (OPEX like)	
Engineering HW/SW operations	***Finnish case:*** The maintenance is part of outsourced service agency contract costs.
Continuous design and inspection of CISE bridging with legal system and national CISE interconnections	***Finnish case:*** Configuring and running the VPN at the beginning was the most time consuming. The VPN configuration includes both CISE network and RTI network (RTI installed/ deployed the CISE Gateway software remotely). This part can also relate to the Investments cost for the relevant components.
Overlooking the national CISE changes and evolution	***Finnish case:*** The Finnish Maritime Authorities Consortium (FIMAC) decided the national evolution, from the operational point of view. CISE is still a research and innovation initiative. In terms of the practicalities of the technical changes and evolution, these are part of Transport Infrastructure Agency's service contract.
Continuous education, monitoring, participation and liaising with the EU CISE development	***Finnish case***: Assumed as the responsibility of each stakeholder. LAUREA - University of Applied Science was part of CISE as a research institution. For any responsible involved stakeholder these costs can be calculated indirectly as part of the research and innovation projects (national or European).
Dedicated Expansion Costs	
Expanding CISE adaptor. features	***General Comment:*** Subject to each countries' extent of the CISE deployment and often independently handled by each stakeholder.
Replacement of legacy systems' data and models	***General Comment***: Relevant to enhancements of the CISE Adaptor and/or Node as legacy systems stay unchanged due to the CISE design principles. Interconnections can be related to CISE networks, internal/external, i.e. via VPN, e.g. in a Restricted or Confidential mode.
Research	***General Comment***: At this stage still indirect via participations in research projects. Likely, to be handled by each stakeholder in the future. Can expand to academic and star-up related research.

Use and advancements of the European initiative for interoperability of the diverse legacy systems in maritime surveillance through a common shared environment – CISE, is gaining momentum via many collaborative efforts and real trails. Endorsements of the CISE technology inside countries as an augmenting operational patch of the exiting surveillance legacy systems is a well-informed executive decision. It usually requires forethoughts beyond just extending the existing operational features. The CISE commenced as a collaborative platform and a tool for extending the surveillance capabilities by facilitating interconnections between EU and national stakeholders. As such, it is an investment choice and it necessitates a combination of understanding of the deployment options, together with opportunities in expanding each of their features. It is generally assumed that if the CISE is realized at each national and EU-wide level in a fully-fledged manner, benefits would be far reaching and enormous at both the technical and economic-impact levels. But to reach that stage, many individual implementations need to assess both the immediate benefits and feasibility of pursuing the prospect of the CISE roadmap.

We analyze many technical prerequisites for introducing the CISE in Montenegro, subject to this being initially executed through AMPSM as the Single Provider of the CISE services. Three major costs are differentiated in this study: investments, maintenance, and dedicated expansion costs, each particularly relevant to an implementation stage of the CISE deployment. Finally, we elaborate on the specific benefits of the deployment options and technicalities (e.g. CISE components) and progression of the CISE features inside the county. To support the analysis, a recently conducted Finish implementation is outlined and the costs incurred are reviewed. It is concluded that the CISE feasibility is to be ensured as a relatively modest commercial investment in technology. However, it is a continuous process of gaining skills and know-how. The attained knowledge and skills can be then deployed in planning smart adoption of common communication platform in Maritime – in South Africa, for instance, or in other developing countries with similar socio-economic and political dynamics.

CHAPTER V: Discussion

5. Discussion

This section attempts to justify the results presented in the previous section. The results presented in Chapter 4, are the outcomes of the original research work realized through thorough desktop research and the surveys conducted among the experts in maritime sector in developing countries in Europe and Africa.

5.1 Enhancing smart ICT&S adoption

Concerning the level of rationality in using ICT&S solutions in selected maritime administration and business organizations in the non-EU and EU countries, we tried to identify weak points and countermeasures. The questionnaires were conceived in a way to explore the employees' strategic orientation towards ICT&S, along with their attitudes towards knowledge, IT management, system's effectiveness, organizational culture, and manager's mindset, while ICT&S were treated *a priori* as a key perpetrator of sustainability in social, environmental, and economic aspects.

As a result of the investigations in this domain, the following has been found:

- All interviewees were Adapters when it comes to ICT&S strategical orientation. This means that emphasis was often on modifying rather than fundamentally re-configuring existing ICT systems and applications;
- Only one respondent hesitated between the Adapter and Reactor. The latest meant that technology was not seen as strategic, with ICT&S platforms appearing weak and obsolescent.
- All respondents highly appreciated knowledge, the role of IT management, system effectiveness, positive organizational culture, and an open manager's mindset. The average assessments on the Likert scale (1–5) were all above 3, while the majority were between 4 and 5.
- The respondents from two non-EU and two EU countries assessed the use of ICT&S in their organizations as highly intelligent, while the rest respondents assessed this key construct in the model as medium intelligent.
- Control variable in the model, which considers disharmony between the ICT&S capacities and exploitation, confirmed in all cases that responses negatively correspond to the level of intelligence in deploying ICT&S. On the Likert scale (1–5), the control variable was between 2 and 3 for the corresponding values.
- Furthermore, there was a strong linear correlation between dependent and independent variables in the model. The value of the dependent variable, more than 60% depended on the independent variables included into the model.

Through the analyses, the tentative statements given at the beginning of the research, have been confirmed. However, when we came to the point of exploring the availability of contemporary maritime ICT&S in selected organizations, we faced the challenge of the lack of some key ICT&S for ensuring business success and sustainable development in the non-EU maritime environments. For instance, none of the non-EU examined maritime entities had strategies and plans for implementing e-Navigation, e-Maritime, maritime Cloud or CMCP, and blockchain technologies. This can be perceived as a discrepancy in implementing and adopting new strategies to increase safety and reduce the environmental impact on the marine ecosystem, which should function as unique since it is connected to the world's oceans. This is the point where the EU, through its positive politics and practices, should provide recommendations and support to the non-EU maritime organizations to a larger extent.

Some positive practices in Montenegro, as a non-EU country, have been highlighted and further investigations should be oriented towards transferring these practices and positive experiences into other non-EU countries involved in sea/water transportation, in addition to the support that should be provided by the EU, at both strategical and operational levels.

5.1.1 Summary

This research has been based on the premise that the wise use of ICT&S in maritime enhances social, environmental, and economic dimensions of sustainability. Towards examining this premise, the employees in maritime administration and business organizations in several EU and non-EU countries were interviewed. They had similar opinions regarding analyzed constructs connected to the intelligent use of contemporary ICT systems. Namely, they recognized knowledge, IT management, system efficiency, organizational culture, and manager's mindset as key enablers of rational and profitable use of ICT&S. It speaks in favor of their solid education and awareness about the importance of ICT systems, including environment in which these functions. When it came to ICT strategical orientation, they were careful, i.e., not so prone toward taking risks in terms of investing in new ICT solutions and experimenting in the market. The applied multiple linear regression model confirmed a strong correlation between dependent and independent variables in the model. Notwithstanding, when it came to the availability of common and advanced ICT&S in the considered maritime organizations, it was shown that there were huge differences between the EU and non-EU countries. For instance, maritime organizations in Slovenia had almost all the ICT&S listed in the questionnaire except blockchain or distributed ledger technology, AGVs, digital twins, UxVs, and RIS. Maritime companies in Italy had, for instance, digital twins and UxVs. Croatia and Greece also had quite extensive list of available ICT&S. On another side, examined non-EU countries were modestly equipped. The question is: what are the reasons for such differences, and how these can be addressed to avoid the lack of (corporate) social responsibility, disruptions in the maritime ecosystem, and negative economic implications in the future for the non-EU countries and their neighbors. This should be the subject of the following investigation in the field. In an attempt to conclude our study "optimistically", we presented some achievements that Montenegro has made regarding improvements in its maritime info-communication supra-structure. These include the renewal of GMDSS equipment ashore, implementation of LRIT, CSN, and VTMIS, working on the introduction of STM, CISE, and NMSW, along with the consideration of opportunities for deploying sea surface and underwater unmanned vehicles for environmental safety and security missions. However, it is evident that the EU supports Montenegro in development of ICT&S for environmental and safety purposes, but business-oriented ICT&S that can support economic growth and development are yet not in focus. Montenegro and other examined non-EU countries should make greater efforts in this regard in cooperation with EU countries.

It is expected that non-EU countries should follow positive practices from Montenegro or other developing countries to improve their maritime ICT&S efficiency and effectiveness. This will support ensuring sustainability in maritime, in the region, and more widely, through smart adoption of contemporary ICT solutions in cohesion with all relevant examined constructs. Further research in the field should be oriented toward policies and recommendations for maritime organizations' digitalization management, including the needs of sustainable multi- and synchro-modal transport and logistics.

5.2 Concerning blockchain adoption

Regarding blockchain smart adoption in emerging maritime environments, quantitative study has been carried out, where the respondents had to express the level of their agreement or disagreement with the tentative statements. In the statements evaluation, the respondents used Liker's scale (1-5). Due to the average obtained numerical values per each of the statements, after data editing, the rank of five statements assessed with the highest scores for both "agreement" and "disagreement" considered categories are associated to the PESTEL model, while the following has been drawn out:

- The respondents consider awareness and knowledge about blockchain as a social dimension of utmost importance for blockchain adoption in maritime and related industries. This is understandable, since knowledge is the biggest asset; the only one that grows with exploitation during the time. The second is infrastructure, which falls under technological dimension. This is reasonable, since without it, blockchain adoption is practically impossible. The third are favorable government and regulatory policies that fall under political and legal dimensions. This is of crucial importance, since in developing countries like Montenegro and South Africa, the economy and its development are controlled by the government (i.e., the reminiscence of socialism that was reality in Montenegro in the past, and which is currently tried to be developed in South Africa). The fourth is experts' knowledge, which belongs to social dimension of PESTEL model, and which is to a certain extent connected with awareness and knowledge, but it can be outsourced in the case of its lack, and under the assumptions that awareness and general knowledge about blockchain are present. The fifth is hesitancy of sharing information among the parties, and it falls under both economic and environmental dimensions of PESEL. This is understandable, since once blockchain becomes well-established, the impact of this issue will be reduced.
- The highest disagreement is observed regarding the simultaneous presence of blockchain complexity and observability. The majority of respondents show suspicion regarding this paradox, which is understandable. Then, respondents do not agree with the statement that blockchain will reduce opportunistic behavior. Montenegro and South Africa are countries that for decades have been in a transition, and suffer from the permanent reproduction of crises and injustices. Consequently, the respondents' rather skeptical attitude towards this statement is completely understandable. Social influence is in the third place. The respondents

do not believe that society can impact the implementation of this advanced technology, and this belief is based on their experiences from transitional settings. The statement, which deals with standardization issue, is negatively assessed, but it might be the case due to the experts' belief that standardization must be achieved and that it cannot as such diminish blockchain key advantages. Ensuring privacy and security is negatively assessed, as well. This means that some respondents disagree with the statement that blockchain technology is still immature and vulnerable. Due to their responses, one can conclude they believe that blockchain technology is at a high level of development, that it is less vulnerable, and that it can appear due its complexity and deployment at a global scale. This construct can correspond with technological, environmental, and legal PESTEL dimensions at the same time.

By analyzing the respondents' open-ended questions set around the constructs: blockchain benefits, investment costs, bitcoin, stablecoin, computational power and nodes' dominance, nodes interoperability, and internet vulnerability, we synthesized the following:

- Montenegrin experts see benefits in adopting blockchain for the cruising industry, mostly in terms of easier payment, attracting tourists, increased revenue, distributed development of cruise tourism, etc. Furthermore, due to the experts' opinions, blockchain could have an application in the management of passengers' flows, market analysis, provision of advanced software for cruise industry needs, etc.
- South African experts express positive attitudes in a way that blockchain can help by placing the crucial data in one place, while creating a unique platform for IT solution providers, ports, agents, freight forwarders, insurance companies, etc., that operate along the supply chain. Blockchain allows tracking cargo in real time, while shipping companies and ports can plan land procedures ahead of time, speeding up terminal work and cutting down costs. They believe that maritime blockchain increases trading safety and transparency. Due to their opinions, adopting blockchain would elevate the industry to the next level in terms of efficiency and affect it positively in terms of reducing the number of human errors.
- Regarding the costs of introducing blockchain infrastructure and impediments on changing organizational habits, the experts offered different opinions, but commonly, they believe it should be a part of a much needed and inevitable digitalization process. Changing from the old system to the new one will have many financial implications for the organizations, but ultimately it will come with many positives.
- Concerning the question of the central national banks as a regulatory body, Montenegrin experts see benefits, but in general agree that Montenegro central bank is the commercial banks' control body, rather than central bank. Montenegro does not have its own currency and no reason to consider decentralized crypto currencies as competition to other monetary flows. Of course, experts agreed Montenegro needs digital assets, crypto exchanges, and ICO (Initial Coin Offering) regulations, which would disable eventual money laundering, frauds, or terrorist financial attacks. On the other side, South African

respondents see government as the only entity that can put things under control. In general, South African eyes are usually directed towards the government as a central authority that can assist in solving key economic and social problems in the country.

- When it comes to stablecoin, computational power of blockchain, nodes interoperability, and cyber security - few Montenegrin experts are familiar with these topics, since they are involved in the EU projects, or work as external experts for foreign maritime institutions, or as adjunct professors at foreign universities. However, the lack of technological knowledge is commonly present in South Africa and Montenegro as countries in transition for more than 25/30 years. Therefore, strengthening technological knowledge transfer (not only ready-made technology) among developed and developing countries can assist considerably.

5.2.1 Summary

The study of blockchain in the developing economies presents the results of literature review in the domain of blockchain adoption in general and in particular in maritime industry and business. The literature sources are scarce and dominantly focused on extensive literature review with few papers that concern concrete applications and related issues. In this study, we screened the opinions of several experts from Montenegro and South Africa as developing countries, concerning the attempt to adopt blockchain rationally. The experts in general agree with the suggested benefits of blockchain examined through the quantitative part of the study. However, some oscillations in their assessments are noticed, but commonly there is an agreement with assumed benefits of blockchain implementation in maritime. The observed oscillations mean uncertainty due to the lack of knowledge and experience in blockchain implementation in emerging maritime economies. Through the qualitative part of the questionnaire sent to the experts and later analysis of their responses, we noticed again differences in opinions, which we considered in the discussion. The presence of lack of knowledge and confidence when it comes to some concerns has been noticed, as well. Due to our opinion, the first world countries have been planning and developing blockchain technology, while the third world countries need to invest more time and money in acquiring knowledge in this technology and respected organizational changes to become credible to determine the right directions for implementing this technology rationally, to protect their national interests, and ensure sustainable development. In this regard, closer communication with developers of this technology would be necessary, as well as exploring needs and preferences of the developing environments, more rigorously, longitudinally, and through larger polls.

Since we collected only twenty responses, further research should include in-depth interviews or a survey upon a larger poll of experts and deeper discussion on the respondents’ assessments, comments, and suggestions. In addition, following investigations in the field should include experts from other developing and transitional countries (besides Montenegro and South Africa), including longitudinal studies, too. The majority of consulted respondents are not familiar with botnets, how they can affect blockchain, and how such attacks can be prevented. Few are familiar with stablecoin, computational power, and nodes compatibility issues. Therefore, further investigations, building new, and transferring existing knowledge, primarily on blockchain technological, and then on political, economic, social, environmental, and legal dimensions are needed in developing countries.

5.3 On unmanned vehicles deployment in maritime missions

Thesis considers underwater and aerial unmanned vehicles, which might be deployed in safety and security actions across sea borders in Europe, including both EU and non-EU emerging countries, with Montenegro as an example. These vehicles are still under development and experiments have been carried out experimentally in contrived and non-contrived settings. After extensive desktop search and participation into several field experiments, we can highlight the following:

- Some recent European project developed for surveillance and SAR actions at sea in situations of illegal migrations (border crossings) and narcotics trafficking (interception of narcotics smugglers) are presented in this study. The architecture at high level of abstraction and core action/information flows of the system are presented in the study. Since the system deploys autonomous and unmanned (air, sea surface, and underwater) vehicles, taxonomy dealing with these advanced and complex vehicles, including the degree of their autonomy is given, as well. In order to support further R&D activities within the project, some recent experimental and theoretical studies in the field are introduced. As next steps in the forthcoming research work we plan to explore in some more detail technological performances of each asset deployed in sea missions including communication channels and protocols, as well as data fusion and presentation on the network application layer. This will be done in parallel with experiments in real setting, i.e., in maritime environment under risk threats.
- A review of the UAVs and AUVs within the context of the EU COMPASS2020 project has been given. The Zephyr, the AR5 and the AR3 UAVs and A18-M and A9-E AUVs have been described through pointing out their key features. Based on the findings from secondary literature resources and experiences from the project up to now, some strengths, weaknesses, opportunities and threats of the considered UAVs and AUVs have been identified and highlighted through SWOT analysis.
- Future research in this area should provide a deeper insight of compatibility of the UAV and AUV systems with the existing and well established both manned and unmanned crafts used for the same or similar purposes. Common communication schemes and algorithms among (un)manned, aerial, sea surface and underwater crafts are currently under further development.
- There is a strong argument in favor of increasing initiatives for testing, validating and integrating unmanned systems within current surveillance infrastructures (both land and maritime based), as these assets can assist current surveillance and monitoring capabilities of authorities in a cost-effective and efficient manner. However, the so-called blind-belief in technology, including the analyzed UAVs and AUVs, should be critically reviewed. The willingness of various involved parties to develop, implement and adopt such advanced systems should be investigated with the aim to provide their innovation implementation success in military, civil, industry and other errands.
- Such advanced systems can be used as subjects of further research work and base for applying for research funds not only in developed, but also in developing countries as

Montenegro and South Africa. The scope of the analyzed crafts can be broadened beyond patrolling and combat missions in European seas. For instance, the South African Operation Pakhisa programme inspired by blue economy can enrich its scope by investigating possibilities of optimal deploying the UAVs and AUVs within the national context, in accordance with the actual needs and preferences in maritime.

5.3.1 Summary

Unmanned underwater and aerial assets are segments of maritime safety and security missions in particular in battling against illegal migrations and narcotics smuggling. These smart vehicles are used in combination with conventional surface patrol vessels, while more research effort should be invested into examining swift communication and coordination of actions among all vehicles involved into the missions over sea borders. Research experiments accompanied by *in situ* experiments have been conducted within the sea areas under European jurisdiction, but the acquired experiences can be transferred to other sea regions, including South Africa as a coastal country with high frequency of (inter)national sea traffic. Key issue is common information sharing environment (CISE) and its proper implementation in order to coordinate and synchronize all communications within the system. This study touched this issue at the example of Montenegro as EU assessing country in terms that we evaluated the feasibility of Montenegrin access CISE and estimated preliminary costs by using some Finish experiences in this regard. Similar studies might be implemented in South Africa in the future, in the case that need for such a system become identified. The advantage of combination of manned and unmanned vehicles is better approachability to commonly unapproachable and/or dangerous areas, especially underwater ones. The flexibility of unmanned vehicles is usually higher and as such these are recommendable of security missions at sea in combating trafficking and narcotics transfers as illegal actions. However, further detailed research is necessary when it comes to unmanned vehicles, along with establishing reliable coordination and channels for smooth communications and synchronization of common actions.

CHAPER VI: Conclusion and recommendations

6. Conclusion and recommendations

This dissertation is an analysis and synthesis of research work in the field of contemporary maritime information systems. The research encompasses a whole palette of advanced info-communication systems, with an emphasis on disruptive technologies such as blockchain in global supply chain management and autonomous vehicles in surveillance missions over sea borders. The studies were carried out through both desktop (Elsevier) and 'in situ' experiments during the test beds of several large European projects like COMPASS2020 (Coordination Of Maritime assets for Persistent And Systematic Surveillance) and ePIcenter (Enhanced Physical Internet-Compatible Earth-frieNdly freight Transportation answER). The findings were extended to the case studies in several developing coastal countries, with focus on South Africa and Montenegro. The following are some general conclusions and suggestions for future work:

- Maritime lags behind, in terms of digitalization, in comparison to other industries like road, rail and air traffic and transportation. Reasons are inherently global dimension of maritime and over present disharmony in terms of level of standardization in both shipping and port management worldwide.
- Developing countries are excluded from strategic planning for further development of ICT&S in general and in maritime. Developed countries (somewhat understandably) put in focus their aims and impose solutions, which fit firstly their needs and preferences. Therefore, analyzing the demands and preferences of emerging countries is something that 'must be' in place in the future, in considerably larger extent, in order to enable rational, intelligent or smart implementation and adoption of ICT&S in transitional environments.
- Disruptive technologies like blockchain and autonomous vehicles are introduced by developed countries that left behind developing ones in this respect. Understanding ICT&S 'game changers' at least at the level of their capacities is once again something that 'must be' in place to provide sustainability of the developing countries, including South Africa and Montenegro, in terms of ensuring their competitiveness at constantly growing and developing global maritime market.
- Developing countries need to invest more time and money in acquiring knowledge in contemporary ICT&S and respected organizational changes to become credible to determine right directions for implementing this technology and to protect their national interests. Consequently, developing countries have to establish cooperation with the developers or architects of new technology, as well as to uplift the level of maritime stakeholders' knowledge (predominantly technical/engineering one) in this domain.
- The level of autonomy in maritime 'machine-to-machine' communications and operations is constantly growing. This requires ensuring G5 (or G6) connectivity in developing countries as a prerogative to go in step with developed word, in terms of huge and rapid digital transformation in all spheres.
- Besides the bandwidth, of course, assets, internet accessibility and uninterrupted power supply are key prerequisites for successful digital innovations in maritime and should

be a part of strategy development plans of emerging maritime oriented countries like South Africa and Montenegro, referring to the presented case studies in the dissertation.

- The academics' knowledge in ICT&S in maritime is unfortunately at lower level in comparison to the experts' knowledge in industry. This means that developing countries should invest more in research and development, in particular in academia, since the knowledge is the only resource, which becomes greater over the time, i.e., through its 'exploitation', while academia traditionally was the largest pool of talents.
- We should be not 'technology blind'. It is as good as it serves us good. In 2018, the experiment with the Zephyr HAPS was unsuccessful in Australia. Incidentally, there was no damages, except huge costs in terms of losing this autonomous vehicle itself. This is just one example of new technology fragility.
- Some ICT&S in maritime like blockckain, blockshipping and autonomous unmanned vehicles used in maritime missions are based partly on artificial intelligence, however human factor is still of key importance in controlling these systems, since researchers are still far away of general artificial intelligence (GAI), which might be capable to 'completely replace' humans and their specific cognitive and operational capacities.
- Closer cooperation between all stakeholders across maritime cluster is necessary for smarter adoption of ICT&S in both developed and developing countries. Digital divide cannot ensure sustainability for all to inhabit this planet. Moreover, there is no partial sustainability. Developed countries should become aware of this and stop ignoring developing ones in terms of fair use of ICT&S in the future, at least on proportional basis.

6.1 Key contribution of the dissertation

This thesis provides an insight into the full range of the latest ICT&S solutions in maritime. Sophisticated technologies, including blockchain in port management and logistics, as well as autonomous underwater and aerial vehicles used in security missions at sea, are covered by this research. It has been shown that developing countries are struggling with a lack of a clear strategy in implementing these advanced technologies. The need to intensify cooperation between developed and developing countries in terms of harmonizing the use and advances of new technologies has been highlighted. Only by reducing the digital divide, sustainable development can be ensured for all. In addition, unlimited growth is unrealistic, even in the production and deployment of advanced ICT&S. Conseqequently, balanced development, which will take into account real human needs and preferences, in a certain environment, including environmental impacts, has been recommended. Developing and implementing common ICT&S standards in maritime should be considered as a future goal towards aleviating differences between developed and developing countries in the global world, without borders. In addition, the dissertation gave contribution to the corpora of the objective knowledge through the articles published in the accredited journals and through the results presentations at international scientific and professional conferences in maritime worldwide.

6.2 Future work

Future research in the field should include more case studies, larger polls and longitudinal research. The questionnaires as a dominant data collecting method should be replaced with larger number of in-depth interviews and expert groups. Both quantitative and qualitative analysis should be of larger extent. Involvement of governmental and legislative bodies in the research concerning developing countries should be higher. The interviews with the designers and developers of novel ICT&S in maritime should be arranged in addition to these conducted with digital technology end users. Considerably more funds and specialist work on research and development should be allocated for ICT&S advances and applications in emerging environments like South Africa and Montenegro. Besides, we should be aware that there is no 'limitless', exponentially grow, which we face today in informatics and digitalization. At a certain point of time, this will be limited, planned or unplanned. So, sustainable development of ICT&S in general and in maritime should be envisioned and ensured. This might be the subject of further explorations in the field. In addition, social and economic changes, including numerous ethical implications caused by disruptive ICT&S should be the subject of further research. Since we live in globalized world, development of key enablers of globalization, encompassing ICT&S, should have global attributes. The whole (sub-)continents (e.g., Africa, South America, South East Europe, East and Central Asia, etc.) should not be excluded from plans for technology development as perpetrator of economic and social progress. Putting light onto this issue is something we consider important for development of further research strategies worldwide. Since we share the same planet, we should keep in equilibrium our responsibility for providing sustainable development, for all. Researchers from developing countries should undertake part of the responsibility for ensuring this. Of course, collaboration with administrative and governmental entities in the respected emerging countries is of crucial importance in attaining the ultimate goal of providing sustainability, including ICT&S development, for all at this planet!

CHAPTER VII: References

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APPENDIX

This Appendix contains two papers published in SCIE journals: *Sustainability* (2020) and *Journal of Marine Science and Engineering* (2021), with IFs 3.251 and 2.458 respectively.

sustainability

MDPI

Article

Digitalization in Developing Maritime Business Environments towards Ensuring Sustainability

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Abstract: The paper focuses on assessing the level of digitalization in several developing maritime business environments in Albania, Bosnia and Herzegovina, Montenegro, and Serbia. The assessment has been done in reference to Holtham's and Courtney's Intelligent Information and Communication Technologies (ICT) Exploiter Model. The dimensions as maritime business system effectiveness, roles, and skills of information technology personnel, ladders of knowledge, ICT strategy, organizational culture, and manager's mindset are analyzed. In addition, benchmarking with findings from developed maritime business environments in Croatia, Greece, Italy, and Slovenia, which belong to the European Union (EU), by using the same model, has been conducted. This is done with the aim to outline directions for improving the quality and speed of digitalization in non-EU countries, which have been functioning for decades in transitional conditions. The maritime ecosystem naturally has a tendency to be unique and to function smoothly as such. Alleviating the differences in the level and effectiveness of digitalization in developed and developing European countries is a path towards achieving this goal. By sharing their own expertise in the rational and intelligent use of ICT, developed EU countries can support developing non-EU countries towards ensuring sustainability in the entire European and worldwide maritime business ecosystem.

Keywords: digitalization; maritime; business; intelligent use of ICT; sustainability

1. Introduction

The term maritime deals with the world's oceans. The world's oceans belong to everyone and are an essential life support ecosystem. They absorb carbon dioxide from the atmosphere, generate up to half of the world's oxygen supply, provide essential protein for nearly three billion people, regulate global climate, provide numerous resources used by humans, etc. They enable performing more than 90% by volume and 70% by value of world trade [1] since sea transportation is still the most-effective way of transporting raw materials and goods around the globe.

On the other side, marine habitats, nearshore ecosystems and coastal communities face huge pressures that threaten their sustainability through climate change, ocean acidification, rising sea level, variable fish stock, natural and human-caused disasters, and the like [2].

A paradox related to maritime is the lack of digitalization in today's digital age compared to other spheres of human lives and business activities. A recent systematic literature review of major journal databases resulted in finding only 99 research papers in maritime on topics such as autonomous vehicles and robotics, artificial intelligence, big data, virtual reality, augmented and mixed reality, the Internet of Things, the cloud and edge computing, digital security, 3D printing, and additive engineering, across ship design and shipbuilding, shipping, and ports areas [3]. The same authors stated: "Although maritime transport is the backbone of world commerce, its digitalization lags significantly behind when we consider some basic facts." According to the same source, these facts are that inter-organizational information systems (IOS) are used 75% in the hinterland and only 25% at maritime; ports lag behind in regard to the utilization of information technologies/information systems (IT/IS) [4]; the EU lacks a clear strategy toward digitalization in the maritime industry [5]; basic security is still more of an aim than a reality, even with the tools of the Internet of Things (IoT), which are as widely-used as radio frequency identification (RFID), where it is difficult to find commercial systems without critical security flaws and vulnerabilities [6]; maritime cloud, which is still in its fledgling stages [7], etc. When it comes to digitalization in maritime logistics, Fruth and Teuteberg [8] found out that it is still in its initial stage. This wide-ranging search revealed only a small number of scientific literatures and showed that digitization in the maritime logistics chain is currently being addressed and considered in practical rather than scientific literature. In addition, Fernardo [9] stated that information technology is surprisingly neglected in maritime literature.

Some tangible examples speak in favor of the above theoretical findings. For instance, there is only one autonomous operational ferry boat, "Falco", built by Rolls-Royce and Finferries, while another one, "YARA Birkeland", is planned to be completely operational by the year 2022 [10]. On the contrary, 1400 self-driving vehicles are tested on roads by more than eighty United States of America companies, plus 1.59 million registered drones are in operation [11]. Furthermore, containers with radioactive materials are tracked by RFID technology at the level of any single item/container on road and rail transportation [12,13], but not in maritime [14]. To the best of the authors' knowledge, tracking of containers at the unit level after they leave the departure port and until they reach the arrival port has not yet been achieved. It seems that the Internet of Things or everything is not as vivid at sea as it is on land. Maritime networks need performances close to high-speed terrestrial wireless broadband services on land, but there is a scarcity of in-depth research efforts in this domain [15]. The research of networks at sea is much more complex in comparison to land due to sea surface movements, wave occlusions, etc. Different communication channels, for instance, Very High-Frequency Data Exchange Service (VDES) and Navigation Data (NAVDAT), have been developing with the aim of overcoming the lack or low stability of internet connection at sea [16].

A non-negligible challenge when it comes to digitalization in maritime is the non-International Convention on Safety of Lives at Sea (non-SOLAS) ships. A few years ago, it was estimated that 60,000 non-SOLAS ships would use electronic navigation charts (ENC) and ENC up-date services [17]. The concept of smart or e-Navigation aims to reduce the number of accidents for SOLAS ships by 65%. However, non-SOLAS ships, due to their large numbers, should not be neglected, especially in confined waters and sea areas with heavy traffic. For instance, some experiments were done in Korea. Accidents of more than 3000 vessels were analyzed, and only 13% were SOLAS ships, while the rest were non-SOLAS ships [18]. Therefore, a large number of non-SOLAS ships will undoubtedly slow down the process of e-Navigation implementation.

Efforts are being made worldwide toward more intensive digitalization, both on-board and ashore. However, there are still many impediments on these paths caused by the differences among countries in terms of their economic development, including more or less complex inherent political, legal, and administrative barriers [19]. The scarcity of IT/IS research in developing countries, in general, and, in particular, in maritime, has also been revealed in the literature [20,21].

1.1. Problem Statement

Undoubtedly, there is room for further exploration when it comes to digitalization in maritime in developed, but, understandably, even more in developing countries. In this regard, the purpose of this study is to explore how and in what manner some developing non-EU maritime administration and business entities exploit available maritime info-communication systems and which components they use. Comparisons are made with reference to some EU countries in the same domain. As a theoretical base, we used Holtham's and Courtney's Intelligent Information and Communication Technologies (ICT) Exploiter Model [22]. We aim to benchmark to what extent these entities use rationally available maritime info-communication systems and draw a path for improvements, in particular, when it comes to the sustainable development of the non-EU maritime sector. Improving the scope and level of ICT deployment in developed and developing countries is of crucial importance for providing sustainability in the maritime cluster and health relations between numerous players in this huge and complex business ecosystem in Europe and worldwide.

1.2. Sustainability Matter

Sustainability refers to the ability to exist constantly. In the 21st century, it generally refers to the capacity for the biosphere and human civilization to coexist [23]. It is about planning progress in the future without causing damage to the environment so as to guarantee a safe habitat to the next generations, who will continue to develop their economies and societies [24].

Sustainability is regarded as achieving economic, social, and environmental performances simultaneously that support an organization for long-term competitiveness [25]. In maritime, economic performance is manifested through a port's tendency to attract more freight and passengers; linear shipping companies striving to achieve a higher level of operational and financial effectiveness; maritime supply chain management endeavoring to synchronize processes and partners involved in achieving maximum profits, etc. Environmental sustainability has become a popular topic among academics and professionals in recent years, along with climate change concerns. It relates the ability of maritime companies to attain eco-efficiency in delivering services by reducing air emissions through vehicle speed and fuel consumption optimization, intensifying experiments with hydrogen-powered ships, monitoring and controlling effluent waste and hazardous materials, preventing environmental accidents, and developing contingency measures [9]. Social sustainability focuses on the needs of people and the requirements to implement corporate social responsibility. Being socially responsible benefits people and contributes to maritime companies' economic performance.

If today's focus is on developing smart (partly or fully autonomous) ships, then we have to think about smart ports and smart regulations in terms of preventing accidents in the ports and at sea by mitigating risks and prospective consequences. We have to also take into account the human dimension of technological growth and development in maritime by comparing the advantages and disadvantages of biological and virtual intelligence or virtual smartness. Furthermore, if we are developing e-Navigation, with the primary intention to reduce the number of accidents and reduce the ecological impact, then we have to think about non-SOLAS ships, as well. Additionally, as we are developing a completely connected global ecosystem, then we can not leave ships and ports as separate entities. It means we have to develop, implement and adopt smart IT/IS solutions in maritime as a whole. Within this context, smart IT/IS are those used rationally and intelligently in certain settings, including feasible plans for innovation success and progress. These systems should enable smarter collaboration, enhance operations, satisfy clients' expectations of transparency and predictability, and respond to societal concerns. They should increase the efficiency, safety, and ecological sustainability of the world's maritime industry [26].

Several comprehensive studies have been done in this direction. For instance, Lambrou et al. [27] addressed shipping incumbents' digitalization activities from both technological and management aspects. Sislian and Jaegler [28] analyzed how the port's use of Enterprise Resources Planning (ERP) systems affect the different perspectives of the sustainable maritime balanced scorecard in an efficient and effective manner. Furthermore, Fedi et al. [29] analyzed the influence of information technology solutions during the implementation of mandatory constraints in port operations regarding container verified gross mass to enhance maritime and port safety operations. The Port Community Systems (PCS) was found to have a positive influence on the adoption of this safety regulation. Lee and Nam [30] defined the concept of green shipping and analyzed key problems and countermeasures in its implementation. Felski and Zwolak [10] analyzed the ocean-going autonomous ship challenges and threats at the example of the first fully autonomous small vessel "USV Maxlimer"—SEA-KIT type, which crossed from the UK to Belgium in 2019, etc.

Our research study is focused on managers' and employees' reflections on the optimal deployment of available IT/IS across different maritime organizations in several non-EU and EU countries, including the plans for further digitalization actions.

2. Methodological Framework

Within several previous studies in this field, we were focused on the design, implementation, adoption, and innovation success of contemporary ICT solutions in transitional environments [31–33]. We were driven by users' needs and preferences in some developing economies, faced with ongoing crises and constant lack of funds to provide up-to-date, comprehensive, sophisticated, and efficient ICT systems. For the purpose of this study, we used the Intelligent ICT Exploiter Model [22,34–36]. The Intelligent ICT Exploiter Model was developed upon several basic constructs connected with business entities and ways in which they conduct their businesses activities, i.e., knowledge, IT management, system efficiency through internal and external communications, organizational culture, ICT strategy, and top manager's mindset, which has to bind all other constructs intelligently. The model is shown in Figure 1. We also referred to respected IT experts, who claimed that success in the digital economy would be achieved by companies that are smart about how they use ICT [37]. Besides, we considered [38] a model of adopting new technologies in developing environments by considering innovation, economic, technological, usability, contextual, and organizational factors. Similar to this model is Keszey's [39], which considers environmental variables, organizational variables, easiness of IS use, perceived usefulness of IS, company type and tenure, with company ownership as a ruling variable. A comprehensive model has been developed by Sislian and Jaegler [40] to achieve green management objectives in the port, taking into consideration financial, internal, social, environmental, innovation, and workers' learning constructs. Our methodological framework was based on the triangulation of the previously mentioned approaches, focusing on Holtham's and Courtney's model. We consider the rationality of using available IT/IS systems of key importance in achieving business and prospective innovation implementation success in the considered developing non-EU countries. In fact, we assumed knowledge and skills as key perpetuators of success. Although we do not deny the importance of the previously mentioned factors, they require another type of research approach, and these factors (innovation, economic, technological, usability, contextual, and organizational) might be taken into consideration in further research work in the field. The proposed model was conceived at a high level of abstraction, and it applies to any administrative and business organization, including maritime ones.

2.1. Variables and Hypothesis

A theoretical framework involves the identification of a network of relationships among variables considered important to the problem. It is a foundation for the hypothetico–deductive approach, which we applied. After an extensive review of relevant literature sources in the field and developing a theoretical framework, primarily based on the Intelligent ICT Exploiter Model, we have drawn several hypotheses as tentative yet testable statements. These statements are, as usual, logically conjectured relationships between two or more variables expressed in the form of testable statements [41].

2.1.1. Independent Variables

Independent variables influence the dependent variable in either a positive or negative way. In our model, knowledge, IT management, effective maritime administrative or business system, and organizational culture are considered as the independent variables.

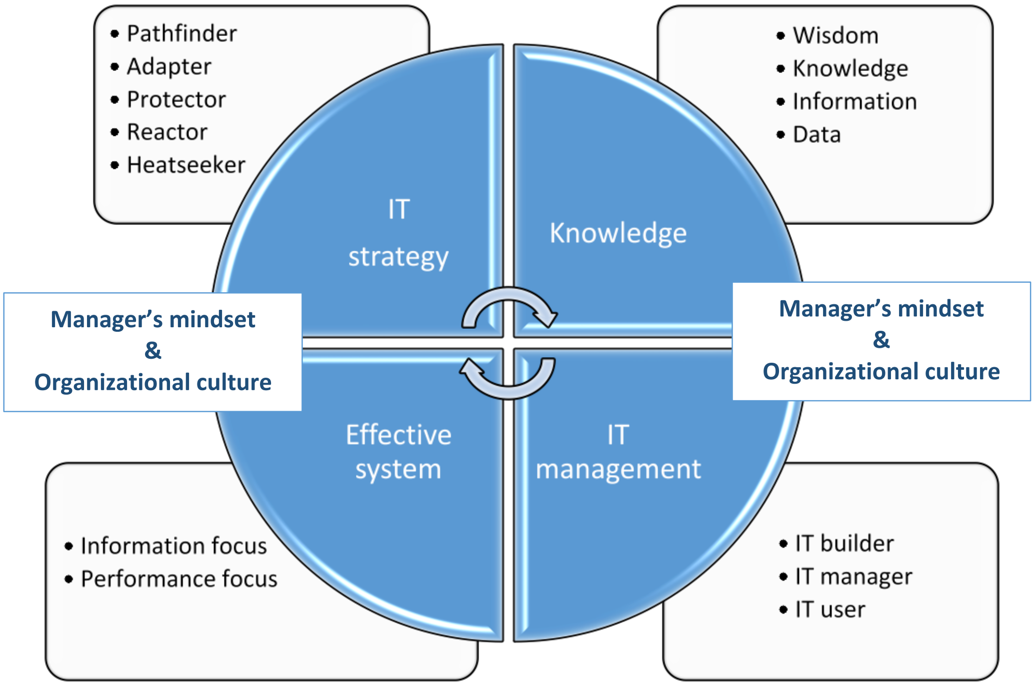

Figure 1. Intelligent Information and Communication Technologies (ICT) Exploiter Model (Adapted from: [22]).

Knowledge. It is metaphorically a stair of the knowledge ladder, including data, information, knowledge, and wisdom. There is a gap between the information technology revolution and the information revolution. The primary idea of the free and unlimited sharing of information failed since it did not take into account the commercial dimension of the process. Information is shared asymmetrically, and those who control the fastest and the biggest computers impose the rules [42]. Consequently, the path: data, information, knowledge, and wisdom is not an easy one, and it requires considerable effort towards achieving professional and business success. Most precisely, two vital tasks in modern enterprises are to speed up the creation of new knowledge by both individuals and communities and to accelerate the sharing of knowledge within and across communities. Due to this, we set the following hypothesis:

Hypothesis 1 (H1). *Knowledge is of key importance for the intelligent use of ICT.*

IT Management. It is based on IT builders or architects, IT managers, and IT users. A person or management team that communicates the needs of ICT users to IT builders or architects is present in the organization as a knowledge navigator or information resource manager. There are business organizations that recognized this triangle, and they are working on filling and improving all necessary skills in this direction [43,44]. Due to the triangle of roles and skills of IT builders, managers, and users, we set the hypothesis:

Hypothesis 2 (H2). *IT managers enable the intelligent use of ICT.*

Effective system. Such a system can be achieved by setting and communicating critical success factors (CSF) [45] and developing them steadily. The first step is to use technology to create an effective operational platform, primarily with internal information. Then, the CSFs can be widened to foster the improvement in skills in the use of technology. This will start with employees and then extend to suppliers and customers. When these two steps work well, the CSFs can be broadened to encompass external information about markets, customers, and competitors. After these three steps, business intelligence allows organizations to identify and manage risk while developing new products, services, and markets to ensure a successful future. Upon this, we draw the following hypothesis:

Hypothesis 3 (H3). *Effective business systems manage and exploit both internal and external information.*

Organizational culture. While there is a universal agreement that it exists and plays an important role in shaping behavior in organizations, there is little consensus on what organizational culture actually is. We quoted several expressions that can be used in the absence of a universally accepted definition [46]: Organizational culture is how organizations do things; Organizational culture is the sum of values and rituals, which serve as the glue to integrate the members of the organization; Organizational culture is civilization in the workplace, etc. In this context, organizational culture is of particular importance since it permeates all considered constructs in a subtle way, and we analyzed it as the fourth construct in our model, connected with the hypothesis:

Hypothesis 4 (H4). *Positive organizational culture enhances the intelligent use of ICT.*

2.1.2. Moderating Variables

The moderating variables have a strong contingent effect on the independent variables–dependent variable relationship. In our study, the ICT strategy moderates this relationship.

ICT Strategy. It is a strategy that has to link business and technology. It has to ensure "C" for communication is fully integrated into strategic business thinking in both a technological and human sense. It is an assessment tool to assist organizations in identifying behavior regarding ICT adoption [47,48]. There are five strategic orientations, which are listed and explained below.

Pathfinder—Systematically seeks and selectively exploits relevant ICT trends to gain a competitive advantage and enable entry into new markets. The Pathfinder is willing to experiment with novel ICT. It constantly seeks a competitive advantage by detecting or sensing emerging ICT trends and possibilities.

Adapter—Operates in two types of market: one relatively stable and focused on efficiency, and the other where ICT plays an increasingly important role. The Adapter applies different rates of technological uptake in each. This split feature is typical for businesses where different technological uptake rates are applicable, and adaptability rather than uniform solutions are applicable.

Protector—Carefully evaluates ICT investment for its efficiency orientation and applies ICT primarily to reduce costs of investments and increase communication processes rather than market creation. The Protector is control orientated and slow to innovate. These organizations work in domains where core ICT-based technologies are universally available and easily replicable.

Reactor—Reactor is a characteristic of an organization where technology is not seen as a strategic tool. It responds slowly to change and tends to view ICT applications as standalone tools. In this strategic orientation, technology is not seen as being strategic, with ICT platforms often appearing to be very weak or obsolescent. The risk is that the organization could quickly become non-competitive through a lack of capacity to meet customers' needs.

Heat seeker—Sized upon ICT fashioned instead of strategically analyzing the best ICT fit for its business problems. Heat seeker is typical for an organization whose structure is in constant flux, moving to frequent new initiatives before obtaining sustained business performance. This organization is prone to frequent initiatives regarding ICT spends and subsequent partial reversals when intended benefits are not realized quickly.

We treated the ICT strategies as five moderating variables in our research model since they are influenced by previously considered constructs, and they have an impact on ICT intelligent exploitation. Upon the above stated, the following hypothesis can be drawn:

Hypothesis 5 (H5). *ICT strategies Pathfinder, Adapter, and Protector are "in fit", while Reactor and Heat Seeker are "out of fit" when it comes to intelligent ICT exploitation in an organization (Figure 2).*

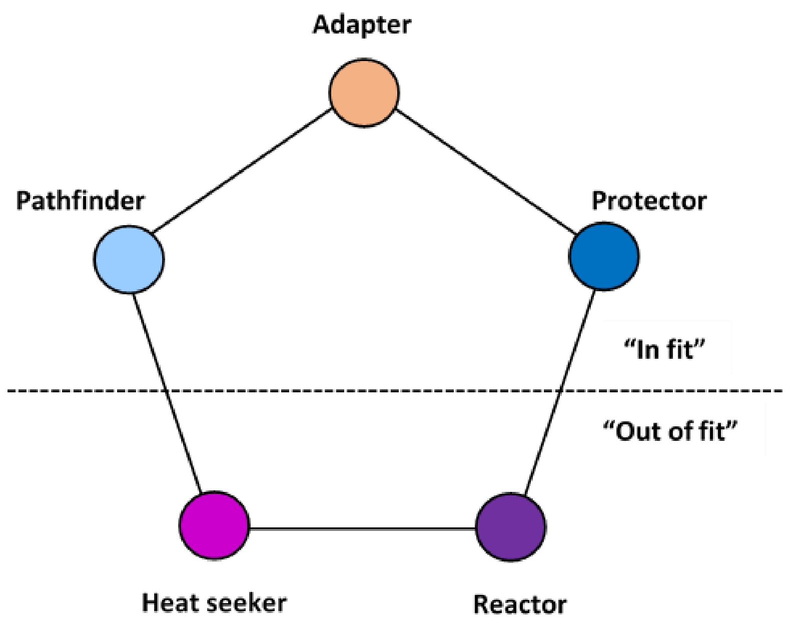

Figure 2. Five types of ICT strategic orientation (Source: Adapted from: [46]).

2.1.3. Mediating Variable

Bringing a mediating variable into play helps to model a process. The mediating variable surfaces as a function of the independent variables operating in any situation. It conceptualizes and explains the influence of independent variables on the dependent variable. In our model, the top manager's mindset is treated as a mediating variable.

Mindset. For the top manager or top management team, a metaphor can be used: Their role is to weave a fabric of horizontal (information, technology, people, and organization) and vertical (direction, knowledge, process, and climate) threads mutually intertwined. In organizations where knowledge is a core dimension, managers have frequently identified skills (people) as the major influence, commonly along with the organizational climate. Switching from an information-based to a knowledge-based enterprise is a major challenge for today's companies [49]. Therefore, managers have to combine notions from several different domains: organizational behavior, human resource management, artificial intelligence, IT/IS, etc. Technology is invariably cited as a key enabler, but not usually as significant overall as skills and climate. The top managers' team mindset covers all considered constructs, and it affects the dependent variable intelligent use of ICT. Therefore, the sixth hypotheses should be formulated as follows:

Hypothesis 6 (H6). *Manager's mindset is of crucial importance for the intelligent use of ICT.*

2.1.4. Control Variable

The control variables are an important part of an eye-tracking experiment. As a control variable in our research, we used non-compliance between technology-led potential and its everyday usage. Based on this idea, we set the seventh-control hypothesis:

Hypothesis 7 (H7). *Gap between ICT capacities and the degree of their exploitation inhibits the intelligent use of ICT.*

2.1.5. Dependent Variable

The dependent variable is of primary interest to this research study. Namely, our goal is to understand and describe it and explain its variability. In the considered model, it explains to what extent the examined maritime organizations are savvy ICT exploiters. We assessed it through a questionnaire, and the eighth hypothesis in the model covers it:

Hypothesis 8 (H8). *Efficient and smooth communication between tasks, technologies, and employees strengthens the intelligent use of ICT.*

The research framework is shown in Figure 3. Through this methodological framework and applied methodology presented in the next section, we tested the previously set hypothesis and opened a space for further discussion among scholars and professionals in maritime administrative and business domains to increase digitalization in compliance with related sustainability goals.

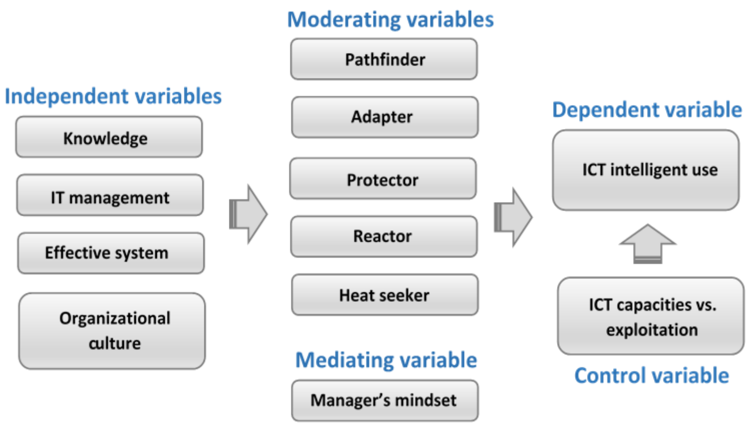

Figure 3. Methodological framework (Source: Own).

Concerned constructs and conjecture relationships among them directly relate to the social dimension of sustainability, but they are intertwined with environmental and economic aspects. Through social awareness and responsibility, maritime organizations are required to attain higher economic and environmental standards. However, to be profitable and reduce adverse effects on the environment at the same time has been a challenge to most maritime organizations. Tangible actions in improving environmental performance while addressing customers and society's economic and social interests will lead to truly sustainable outcomes [50]. Rational exploitation of available ICT resources in maritime and wise planning in adopting new ones are of key importance. This should include internal and external needs and expectations, corporate social responsibility, marine environmental protection (preventing sea pollution, accidents, trafficking, drug smuggling, etc.), along with economic wealth and growth (e.g., safe and green ports, "well covered" by ICT, will attract more freight and passengers, provide better operational performances, etc.). Intelligently used ICT in maritime undoubtedly supports green supply chain management and sustainable business performances.

3. Applied Methodology and Obtained Results

For the primary data collection, we used a structured interview. Structured interviews are widely used methods of collecting data to obtain information on an issue of interest. We have structured the interviews upon the methodological framework in the form of a questionnaire. The questionnaire contained the purpose of the interview, a set of questions in a logical order and accordance with the theoretical model, and suggested probing questions. Since we used computer-assisted interviewing, we sent the questionnaires to the interviewees via mail and reminded them twice to send us feedback in due course. In the end, we had forty conscientiously populated questionnaires by the experts employed in maritime administrative and business companies located in four EU countries (18 interviewees): Croatia (5), Greece (6), Italy (4), and Slovenia (3); and four non-EU countries (22 interviewees): Albania (6), Bosnia and Herzegovina (5), Montenegro (10) and Serbia (1). They preferred to remain anonymous. We used a quantitative approach in terms of the Liker's interval scale with denominators 1–5 associated by linguistic labels "not important-extremely important", etc., that interviewees used to respond. The questionnaire also included a table that listed commonly used and advanced info-communication systems in maritime. Interviewees were required to mark those systems they used. In this segment, a binary approach was applied, i.e., if a system was marked as available, we anchored it by numerical value "1" and in the opposite case by a blank. Key research questions were developed based on the theoretical framework and given in Table 1.

Table 1. The structured interview content (Source: Own).

Construct	Research Question
C1: Knowledge	1. To what extent is knowledge important for business success? 2. To what extent are the knowledge and skills of employees important for efficient and effective use of ICT?
C2: IT management	3. To what extent are ICT systems and functions important for the successful functioning of the organization and its business success? 4. To what extent do you use ICT for operational tasks within your organization (e.g., accounting operations, a database of employees, a database of business partners, etc.)?
C3: Communications	5. To what extent can your customers use the ICT resources of your organization (e.g., your web site, various online users' applications, etc.)? 6. To which extent does ICT allow you to become familiar with the current market trends in the area of your business?
C4: Organizational culture	7. How much is positive organizational culture and clime important for the effective use of ICT?
C5: Pathfinder	8. To what extent is the introduction of new ICT solutions risky for the organization?
C6: Adapter	9. To what extent is it important to carefully analyze existing ICT solutions prior to their introduction into the organization?
C7: Protector	10. To what extent do ICT solutions reduce operational costs of the organization?
C8: Reactor	11. To what extent can the existing ICT solutions be adapted to the current business needs of your organization?
C9: Heat seeker	12. Are the latest ICT solutions also the best ones?
C10: Manager's mindset	13. How is the manager's mindset important for the effective use of ICT?
C11: ICT capacities vs. exploitation	14. To what extent is there a divergence between ICT capacities and their real application on a daily basis in your organization?
C12: ICT intelligent exploitation	15. To what extent do ICT serve as connective tissue among tasks, technologies, and employees in your organization?

Toward encouraging interviewees to identify their current positions and strategic trajectories for the business and the appropriate ICT strategy, constructs: Pathfinder (C5), Adapter (C6), Protector (C7), Reactor (C8), and Heat seeker (C9) were examined. All interviewees expressed their opinion regarding this issue towards the Adapter strategy. It is interesting that interviewees from both EU and non-EU countries share the same or similar attitudes towards ICT strategy orientation and business trajectories of the organizations in which they work. Only the interviewee from Serbia answers indicated equal inclinations towards Reactor and Adapter strategies (Table 2). The strategic orientation of an Adapter works in two business domains. One relatively traditional and relational, being concerned with internal controls. The other where ICT plays an increasingly important role in linking the organization to its customers or the users' marketplace. The Adapters are looking for a middle path regarding business and ICT strategic orientation. When it comes to a Reactor, this organization significantly lags others in ICT introduction. According to Stace et al. [47], in the case of Reactor, technology and ICT applications are often introduced towards the end of the technology life cycle and usually only when forced to do so by competitor pressure.

Table 2. The Information and Communication Technologies (ITC) strategic orientation of the interviewees (Source: Own).

EU Respondents	ICT Strategy	Non-EU Respondents	ICT Strategy
Albania	Adapter	Croatia	Adapter
Bosnia & Herzegovina	Adapter	Greece	Adapter
Montenegro	Adapter	Italy	Adapter
Serbia	Reactor, Adapter	Slovenia	Adapter
Albania	Adapter		

Legend: ● Adapter; ● Reactor.

Mean values of the constructs: knowledge (C1), IT management (C2), effective system (C3), organizational culture (C4), managerial mindset (C10), and ICT capacities vs. exploitation (C11) are given in Table 3. It is obvious that all participants from both EU and non-EU maritime organizations highly appreciated knowledge, proper deployment of skills and roles mediated by top management, system effectiveness achieved via proper communications within the organization, with customers, and for the purpose of market exploring, as well as organizational culture highly. The control variable in all cases corresponded well to the level of intelligent use of ICT in that, in all cases, it had a relatively low level.

The interviewees from both EU and non-EU countries estimated the level of the rationality of using ICT within maritime organizations in which they work as relatively high. The results are given in Table 4. Consequently, all hypotheses in the model (H1–H8) were approved.

The obtained results were based on subjective assessments. However, when it comes to the number of ordinary and advanced ICT solutions employed [51] in the examined organizations, it became evident that maritime organizations in EU countries have considerably more ICT systems than those in the non-EU countries. The evidence is given in Table 5.

Table 3. The assessment of the independent, mediating, and control variables (Source: Own).

Country/Criteria	C1	C2	C3	C4	C10	C11
			EU respondents			
Albania	4.10	4.25	3.75	3.83	3.50	2.50
Bosnia & Herzegovina	4.50	4.00	3.00	3.00	3.00	3.00
Montenegro	4.40	4.90	4.80	4.90	4.80	2.50
Serbia	5.00	5.00	4.00	5.00	3.00	2.00
			Non-EU respondents			
Croatia	4.80	4.75	3.45	4.40	4.40	2.10
Greece	4.40	4.30	3.70	3.40	3.10	2.90
Italy	4.38	4.50	3.50	3.50	3.75	2.75
Slovenia	4.67	4.50	3.83	3.33	4.00	3.33

Legend: C1-Knowledge; C2-ICT management; C3-Effective system; C4-Organizational culture; C10-Managerial mindset (mediating variable); C11-ICT capacities vs. exploitation (control variable).

Table 4. The assessment of the level of intelligent use of ICT (Source: Own).

Non-EU Respondents	ICT Intelligent Use	EU Respondents	ICT Intelligent Use
Albania	🟡	**Croatia**	🟢
Bosnia & Herzegovina	🟡	**Greece**	🟢
Montenegro	🟢	**Italy**	🟡
Serbia	🟢	**Slovenia**	🟡

Legend: 🟡 Medium level; 🟢 High level.

Table 5. Availability of the ICT systems in examined maritime organizations (Source: Own).

Info-Communication System	Non-EU Countries				EU Countries			
	AL	B&H	MN	SR	CR	GR	IT	SL
Electronic Data Interchange (EDI)		1	1		1	1	1	1
Enterprise Resource Planning (ERP)		1	1		1	1	1	1
Customer Relationship Management (CRM) System	1	1	1		1	1	1	1
Electronic Logistics Marketplace (ELM)		1				1	1	1
THETIS (PSC—Port State Control)			1		1	1	1	1
Blockchain								
Automatic Identification System (AIS)	1	1	1	1	1		1	1
Long-range and tracking (LIRT)	1		1		1	1		1
Vessel Traffic Monitoring Information System (VTMIS)	1		1		1	1		
Sea Traffic Management (STM)	1				1		1	1
e-Navigation					1			1
e-Maritime					1			1
Common Maritime Communication Platform (CMSP)					1			1
Maritime Surveillance Services (MSS)	1				1			1
15. SafeSeaNet (SSN)			1		1	1		1
Maritime Single Window (MSW)					1	1	1	1
Automatic Guided Vehicles (AGV)								
Digital twins							1	
Remotely controlled vessels								
Unmanned area, sea or underwater vessels (UxVs)						1	1	
Earth Observation Services—SAR sensors					1	1	1	1
Earth Observation Services—Optical sensors					1	1	1	1
Satellite-based oil spill detection system at sea			1		1			1
Oil spill prediction modeling system			1		1		1	1
River Information Services (RIS)				1				
Score:	**6**	**5**	**10**	**2**	**18**	**12**	**13**	**19**

Due to the binary approach applied, where "1" means availability of the system, it is clear that maritime organizations in EU countries have a considerably larger number of available ICT systems: 19 (Slovenia—SL), 18 (Croatia—CR), 13 (Italy—IT), and 12 (Greece—GR). On the other side, the non-EU countries have a significantly lower score in this regard: 10 (Montenegro—MN), 6 (Albania—AL), 5 (Bosnia and Herzegovina—B&H), and 2 (Serbia—SR). This means that the non-EU countries have to reconsider their business development strategies and ensure funds for new ICT systems and the renewal of the existing ones. The non-EU maritime administrate and business organizations should follow actual trajectories and scenarios in efficient and effective digitalization through the available sources of relevant information [52]. The appropriate ICT systems and tools are an unavoidable part of ensuring sustainability in shipping, ports, and maritime logistics [53–55], which has to take into account maritime governance, development, and interventional plans at national, regional, and global levels. The proper use of contemporary IT/IS solutions (with subsumed "C") can contribute to increasing the visibility and industry stakeholders' understanding of the current situation in sustainability (tracking sub-standard ships, accidents, pollution, waste management, contingency plans, and measures, etc.). It can also assist them in designing appropriate managerial insights and help develop appropriate sustainable policies, along with implementation strategies and methods across maritime clusters.

Examining the Relationship between Independent and Dependent Variables

In an attempt to refine our quantitative analysis, we modeled a multiple linear regression functional relationship between the independent and dependent variables in the model. We used all responses from both EU and non-EU countries and obtained the results presented in Table 6. The analysis was realized in the Excel Module software embedded into Microsoft Excel on an Intel(R) Core(TM) i5 CPU@1.6 GHz and 8GB RAM PC. The simulation time was negligible, i.e., we almost instantly received the results.

Table 6. Multiple linear regression analysis results (Source: Own).

Intelligent Use of ICT	Knowledge	IT Management	Effective System	Organizational Culture
ai (i = 1, 4)	0.124	0.855	0.107	0.407
b			−2.700	
r			0.799	
R2			0.639	

Coefficients a1 to a4 (Table 6) correspond to independent variables in the model: knowledge, ICT management, effective system, and organizational culture, while b represents the regression line intercept. When independent variables are jointly regressed against the dependent variable (intelligent use of ICT) in an effort to explain the variance in it, the size of individual regression coefficients indicates how much an increase of one unit in the independent variable would affect the dependent variable, assuming that all the other variables remain unchanged. In this case, IT management has the highest impact on the dependent variable, i.e., intelligent use of ICT, then organizational culture, knowledge, and system efficiency, respectively.

The individual correlations between the independent variables and the dependent variable collapse in a regression coefficient multiple r or the square of multiple r, R-square, or R2, which is the amount of variance explained in the dependent variable by the predictors. The obtained regression coefficient (R2 = 0.639) indicated a strong relationship between the independent variables and dependent variable in the model. In other words, if R2 is 63.9%, it means that the value of the dependent variable 63.9% depends on the independent variables in the model and 36.1% on other factors (variables) that are not included in the model. This is a high correlation between the considered dependent and independent variables in the applied research approach.

4. Positive Experiences from Montenegro

Montenegro, as a non-EU country, has successfully implemented several info-communication systems imposed by international organizations, such as the International Maritime Organization (IMO), International Mobile Satellite Organization (IMSO), and European Commission (EC) and European Maritime Safety Agency (EMSA).

In early 2003, the Global Maritime Distress and Safety System (GMDSS) was deployed. The GMDSS was later renewed and upgraded in 2015.

In 2009, Montenegro successfully implemented Long Range Identification and Tracking (LIRT) by establishing the National LRIT Data Centre. This system enables Montenegro to use satellite-based tracking of vessels sailing under the flag of Montenegro worldwide. The positions of all ships are updated every six hours, or more often, if necessary. The system also provides information on foreign ships, which sail towards Montenegro's ports for the purpose of search and rescue at sea.

In 2013, Montenegro successfully implemented the CleanSeaNet (CSN) system previously approved by the EC and EMSA. The CSN is the European satellite-based oil spill monitoring and vessel detection service, developed and operated by the EMSA. The service analyses images, mainly from synthetic-aperture radars and optical missions. Montenegro was the first "developing country" that has joined the CSN system.

In 2015, the Vessel Traffic Monitoring Information System (VTMIS) center was officially opened in Montenegro. The sophisticated equipment for maritime surveillance, along with providing safety and security of sea traffic, was installed in three sites along its coast. The VTMIS center has required IT/IS equipment for sharing VTMIS data with respective stakeholders from Montenegro, as well as the EU partners. The personnel was trained to work as VTMIS managers and operators, as well as technicians, to maintain the system.

The aim of Montenegro is to improve the VTMIS system in the future by adding new types of sensors and new sites to cover blank spots. In addition, concepts and systems, such as augmented reality, Sea Traffic Management (STM), Common Information Sharing Environment (CISE), National Maritime Single Window (NMSW), are considered highly for the implementation. Now, the Administration for Maritime Safety and Port Management (AMSPM) is involved in several EU research projects where systems, such as CISE, unmanned aerial and underwater systems, NMSW, and STM, are subject of further research and improvements.

5. Discussions

The paper examined the level of rationality in using ICT solutions in selected maritime administration and business organizations in the non-EU and EU countries to identify weak points and countermeasures. The interviews were conceived to explore the employees' strategic orientation towards ICTs, along with their attitudes towards knowledge, IT management, system's effectiveness, organizational culture, and manager's mindset, while ICT was treated as a key perpetuator of sustainability in social, environmental, and economic aspects. Throughout the qualitative analysis, the following was found:

- All interviewees were Adapters when it comes to ICT strategical orientation. This means that emphasis was often on modifying rather than fundamentally re-configuring existing systems and applications;
- Only one respondent hesitated between the Adapter and Reactor. The latest meant that technology was not seen as strategic, with ICT platforms appearing weak and obsolescent.
- All respondents highly appreciated knowledge, the role of IT management, system effectiveness, positive organizational culture, and an open manager's mindset. The average assessments on the Likert scale (1–5) were above 3, while the majority were between 4 and 5.

- The respondents from two non-EU and two EU countries assessed the use of ICT in their organizations as highly intelligent, while the rest respondents assessed this key construct in the model as medium intelligent.
- Control variable in the model, which considers disharmony between the ICT capacities and exploitation, confirmed in all cases that responses negatively correspond to the level of intelligence in deploying ICTs. On the Likert scale (1–5), the control variable was between 2 and 3 for the corresponding values.
- Furthermore, there was a strong linear correlation between dependent and independent variables in the model. The value of the dependent variable of more than 60% depended on the independent variables in the model.

Through these analyses, the hypotheses (H1–H8) have been confirmed. However, when we came to the point of exploring the availability of contemporary maritime ICT systems in selected organizations, we faced the challenge of the lack of some key ICT systems for ensuring business success and sustainable development in the non-EU maritime environments. For instance, none of the non-EU examined maritime entities had strategies and plans for implementing e-Navigation, e-Maritime, maritime Cloud or CMSP, and blockchain technologies. This can be perceived as a discrepancy in implementing and adopting new strategies to increase safety and reduce the environmental impact in the marine ecosystem, which should function as unique since it is connected to the world oceans. This is the point where the EU, through its positive politics and practices, should provide recommendations and support to the non-EU maritime organizations to a larger extent.

Some positive practices in Montenegro, as a non-EU country, have been highlighted and further investigations should be oriented towards transferring these practices and positive experiences into other non-EU countries involved in sea/water transportation, in addition to the support that should be provided from the EU, at both strategical and operational levels.

6. Conclusions

This research has been based on the premise that the wise use of ICT in maritime enhances social, environmental, and economic dimensions of sustainability. Towards examining this premise, the employees in maritime administrative and business organizations in several EU and non-EU countries were interviewed. They had similar opinions regarding analyzed constructs connected to the intelligent use of contemporary ICT systems. Namely, they recognized knowledge, IT management, system efficiency, organizational culture, and manager's mindset as key enablers of rational and profitable use of ICT. It speaks in favor of their solid education and awareness about the importance of ICT systems and the environment in which these functions. When it came to ICT strategical orientation, they were cautious, i.e., not so prone toward taking risks in terms of investing in new ICT solutions and experimenting in the market. The applied multiple linear regression model confirmed a strong correlation between dependent and independent variables in the model. Notwithstanding, when it came to the availability of common and advanced ICT systems in the considered maritime organizations, it was shown that there were big differences between the EU and non-EU countries. For instance, maritime organizations in Slovenia had almost all the ICT systems listed in the questionnaire except blockchain or distributed ledger technology, AGVs, digital twins, UxVs, and RIS. Maritime companies in Italy had, for instance, digital twins and UxVs. Croatia and Greece also had quite extensive list of available ICT systems. On another side, examined non-EU countries were modestly equipped. The question is: what are the reasons for such differences, and how these can be addressed to avoid, in terms of sustainability, the lack of (corporate) social responsibility, disruptions in the maritime ecosystem, and negative economic implications in the future for the non-EU countries and their neighbors? This should be the subject of the following investigation in the field. In an attempt to conclude our study "optimistically", we presented some achievements that Montenegro has made regarding improvements in its maritime info-communication supra-structure. These include the renewal of GMDSS equipment ashore, implementation of LIRT, CSN, and VTMIS, working on the introduction of STM, CISE, and NMSW, along with the consideration of opportunities for deploying sea surface and underwater unmanned vehicles for environmental safety and security missions. However, it is evident that the EU supports Montenegro in ICT for environmental and safety purposes, but business-oriented ICT that can support economic growth and development are yet not in focus. Montenegro and other examined non-EU countries should make greater efforts in this regard in cooperation with EU countries.

It is expected that non-EU countries should follow positive practices from Montenegro or other developing countries to improve their maritime ICT systems' efficiency and effectiveness. This will support ensuring sustainability in maritime, in the region, and more widely, through smart adoption of contemporary ICT solutions in cohesion with all relevant examined constructs. Further research in the field should be oriented toward policies and recommendations for maritime organizations' digitalization management, including the needs of sustainable multi- and synchro-modal transport and logistics.

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Developing Countries' Concerns Regarding Blockchain Adoption in Maritime

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Abstract: This paper deals with challenges of implementing blockchain (BC) technology in maritime at developing countries, with a research focus on Montenegro and South Africa. Research design and categories analyzed in the paper are chosen due to the search of relevant secondary literature resources. Selected experts in Information Technology (IT) and maritime from aforementioned developing countries were asked about their perception of BC as disruptive technology, its implementation, and implications on maritime and other industries, through a questionnaire, which contains both quantitative and qualitative parts. The results should give the readers insights into the experts' standpoints concerning rational blockchain adoption in maritime and other industries in developing and transitional economies. The paper is organized into six sections: (1) introduction, (2) literature review on blockchain in maritime, (3) research problem and design, (4) results, (5) discussion, and (6) conclusions.

Keywords: blockchain (BC); adoption; challenges; developing environments

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1. Introduction

Blockchain is a new, transformative technology and business model based on digitalized, shared, distributed, and synchronized ledger. A ledger is comprised of unchangeable, digitally recorded data in blocks. Blockchain enables dealing with smart contracts, recording transactions, and tracking assets in both physical and virtual spaces. Assets can be tangible as money, land, properties, vehicles, etc.; and intangible as energy, patents, intellectual property, copyright, etc. Therefore, blockchain allows an untampered record of transactions over physical and virtual goods [1]. The network nodes within blockchain must validate and approve transactions before their packing into timestamped blocks, which form chains. This requires complex internodes communication and consensus mechanism [2].

Blockchain transforms business from centralized and human-based to a shared, algorithm-based system, which implies a new risk management paradigm [3].

The idea of blockchain arose in 2008 [4], and since then the discipline has been continuously evolving [5]. At the beginning, blockchain was a technological background for bitcoin. As a technology, blockchain can organize bitcoin transactions. Thereby, bitcoin is decentralized peer-to-peer crypto currency for exchanging goods and services virtually through sophisticated cryptography payment mechanisms. Due to the robustness of these mechanisms involved and consensus requirements, a bank as a third party is not needed. The nodes in the blockchain are anonymous, and as such, they can provide more security to other nodes to initiate and confirm the transaction. Besides cryptocurrency applications, blockchain is applied in healthcare, smart energy grids, and supply chains [6]. In healthcare, blockchain serves mostly for tracking medical devices and medicines, using patient biometrics for identification and for measuring and recording patient vitals. When it comes to smart energy grids, there is considerable interest in green and renewable energy sources, including bio-fuels, hydroelectric, solar, and wind energy. The availability of a local energy market implies that participants have a choice of using the local grid when its price is lower than that of the external grid. The blockchain dimension of this includes management of contracts and dynamically determining prices. It offers the opportunities to support the local grid and local renewable energy suppliers.

Besides healthcare and smart energy grids, blockchain finds its application in supply chains that are systems of organizations, people, activities, information, and resources involved in moving products or services from suppliers to customers. Manufacturing and trading of goods is becoming complex due to the increased number of intermediaries between the producer and the final consumer. Globalization and market expansion forced companies to expand their products and life cycle, to meet new markets and requirements [1]. Consequently, supply chain is an ecosystem that involves designing, engineering, manufacturing, and distributing products and services from suppliers to end-consumers worldwide [7].

There is a number of studies that focus on using blockchain technology in various application aspects, but there is no comprehensive survey on the blockchain applications in maritime shipping supply chain [8]. However, recently, Liu et al. [9] dealt with pilot initiatives of blockchain applications and pain points in maritime supply chain. In addition, Tsiulin et al. [10] dealt with block-chain based applications in shipping and port management through literature review towards defining key conceptual frameworks. Zhou et al. [11] considered key challenges and critical success factors (CSFs) of blockchain implementation in the maritime industry, based on studies conducted across Singapore maritime industry.

Since shipping provides mass, low-cost, efficient transportation services, it is the main form of global transportation. Maritime shipping services involve complex partners and deal with numerous transport documents, which can slow down delivering goods from one party to another [12]. Blockchain has been gradually introduced to the maritime shipping supply chain to improve efficiency through the digitalization of maritime shipping records, including keeping real time track of the status of cargos; improving visibility; and reducing consumers' clearance time, costs, and risks.

2. Blockchain in Maritime

Blockchain is designed to record and track transactions. It is very important to understand this technology to become capable to deploy it rationally across maritime clusters for containers tracking and tracing, near-instant logistics adjustments, automated risk management, insurance purposes, and more. Blockchain technology starts to build a block or individual blocks that become a chain, and that is a ledger. One can put information in a ledger, while all involved in the transaction can see that information. If a mistake is made, one has to build a new block that relies on the block before it. If one has multiple transactions, that person can build multiple blocks with multiple people and everybody can see the progression of whatever these multiple transactions are. This is a great advantage from a logistics, accounting, and risk-management perspective to be able to see all these.

One of the pieces behind blockchain technology is so-called Hyperledger. Blockchain programs are built on this platform or framework. The IBM has moved blockchain from in-house to Linux Foundation, and consequently all the code is open source, as a catalyst to move blockchain forward into different industries, including maritime [13]. Danish Maersk uses IBM-established collaboration through the TradeLens platform in 2017 to track container locations, cargo details, trade documents, and sensor readings [14]. The TradeLens offers the oversight control and automated risk management to every stakeholder in the supply chain: beneficial cargo owners, ocean carriers, ports, terminal operators, inland carriers including rail and tracking, shippers, freight forwarders, customs authorities, financial service providers, etc. The TradeLens uses Hyperledger Fabric permissioned blockchain to guarantee the immutability and transparency of trade documents [15]. It has a powerful Application Programming Interface (API) model, but it is easy to use web interface to deliver insights into equipment number, bill of lading number, cargo manifest number, booking number, and all-important information related to the container shipment. Key milestones that include hundreds of events can be followed up and down the supply chain, including near-instant logistics adjustments, so disruptions are kept to a minimum.

Currently, the platform handles 10 million events and more than 100,000 documents every week [16]. It is worth mentioning that there are 120 shipping events types [17]. Within this context, it is important to note that more than $16 trillion in goods are shipped across international borders each year. Approximately 80% of consumer goods used daily are carried out by the ocean shipping industry. By reducing barriers within the international supply chain, global trade could increase by nearly 15%, boosting economies and creating jobs [18].

Legacy data systems and manual document handling cause friction that costs both time and money for business and people throughout the supply chain. The TradeLens enables unprecedented transparency, collaboration, and efficiency in global supply chain. It provides control and management of shipping data and supplies innovative apps to every stakeholder. Access to shipping data and information is managed by the TradeLens' sophisticated permission model at each stage of shipment and provides a blockchain-encrypted audit trail of all critical actions. The TradeLens document store allows documents to be securely stored, viewed, and actioned by various parties. Documents can be uploaded and shared, as either structured or unstructured (scans or PDFs). The last allows information sharing between supply chain partners with disparate IT capacities. The TradeLens platform permits access to documents according to the permission matrix, so the right people can securely manage their supply chain in real-time. It breaks down longstanding data and processing silos that exist among some trading partners and simplifies the flow of documentation, which accompanies every shipment.

3. Research Problem and Design

Through this research study, we aim to collect the information relevant for blockchain adoption in maritime, in two developing countries, Montenegro and South Africa. As a research strategy, we used a survey as a system for collecting information from people to describe, compare, or explain their knowledge and attitudes towards using blockchain in maritime business. This strategy allows us to collect both quantitative and qualitative data and information. The survey was used for exploratory and descriptive purposes as a one-time or one-shot survey. As the survey instrument, we used self-administrated questionnaires that respondents completed on their own via the computer. After data were obtained through questionnaires, they were coded, keyed in, and edited. The questions were conceived after a detailed study of Upadhyay's (2020) study [5] on 'demystifying blockchain'. In addition, we used Rogers (2003), Lee & Kim (2007), Kapoor et al., (2014), Kim & Laskowski (2018), Kapidani et al., (2020), and Zhou et al. [11,19–25]. We applied triangulation of these various approaches and came up with the key dimensions of our questionnaire (Figure 1).

We used both closed and open-ended questions, while we were avoiding double-barreled, ambiguous, leading, and loaded questions [25]. Closed questions were conceived in a way that participants identify advantages or disadvantages of certain blockchain dimensions, and then chose one of the numerical values of Likert scale: 1, 2, 3, 4, or 5. Where, 1 represents the lowest level of agreement or disagreement, and 5 represents the highest level of agreement or disagreement with the statement. The rest of the offered numerical values are respectively in-between these two extremes. The open-ended questions allow respondents to express their opinion in free writing style. The respondents were selected among IT and maritime experts from Montenegro and South Africa. They are from maritime companies, agencies, research organizations, governmental bodies, insurance companies, and universities. They are from executive management level at industry and governmental bodies, and active researchers, professors and lecturers from universities. Responses were received back from 20 experts, of which 10 were from Montenegro and 10 from South Africa. The majority of the respondents from Montenegro are partners or external experts at several ongoing European Commission Horizon 2020 projects, while the respondents from South Africa are from universities and the biggest national multimodal transportation company in the country. After reception, the responses were edited, coded, and analyzed, while the obtained results are presented in the next section.

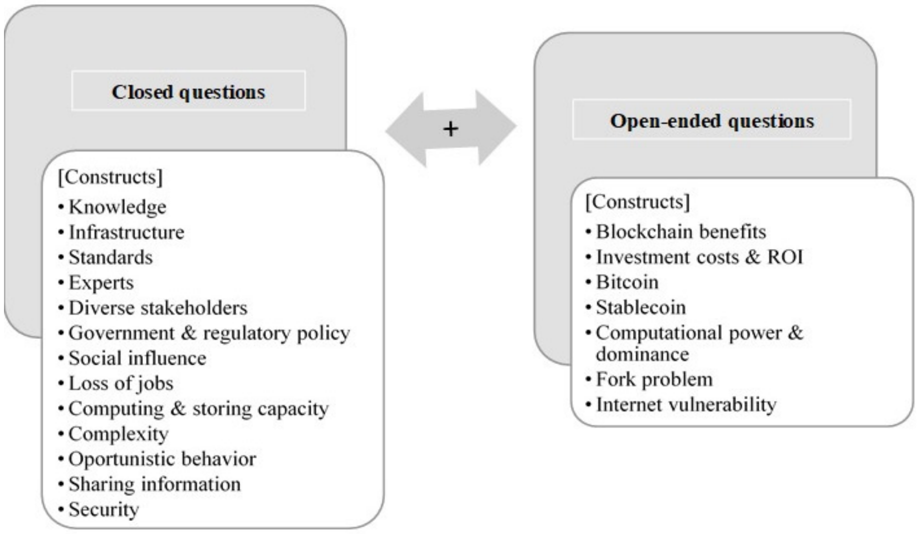

Figure 1. Survey structure and key constructs (Source: Own).

4. Results

All questionnaires sent back by the selected experts were meticulously filled in and there were no missing or 'wrong' data/answers. It was clear that the experts took their roles seriously and understood the importance of the conducted research.

4.1. Quantitative Analysis

The quantitative dimension of the survey analysis comprises average values assigned to "agree" or "disagree" attributes to each considered category within closed-ended questions. The summary of the data analysis is given in Table 1.

Five statements with the highest "agree" and "disagree" assessment rates are categorized in different PESTEL (political, economic, social, technological, environmental, and legal) dimensions, along with their rank (Table 2). The ranks and their connections with PESTEL dimensions will be discussed in the following section.

4.2. Quantitative Analysis

Regarding the qualitative part of the analysis, which was conceived and conducted through seven open-ended questions set around the categories shown in Figure 1, the following issues were considered, and some selected answers given as examples:

(1) Which benefits Montenegro/South Africa might have, for instance, of introducing blockchain solutions in maritime (shipping) industry?
Montenegrin expert: "Allowing tourists to spend their crypto currencies/coins during their stay in Montenegro would bring wealthier tourists. Also, it would bring tourists with crypto savings to spend more money than they planned to spend. The newest technology and tourism always comes together. Bringing wealthy and highly sophisticated digital nomads in and out of high season would bring Montenegro a significant raise in economy. Not to mention other gains like a longer season and employment of local IT experts with a significant raise of GDP. Tracking of tourists'

behavior such as spending and rewarding them with some usable tokens/coins would bring Montenegro tourism, which is dominantly connected with sea, growth, and development."

South African expert: "Blockchain can help by placing the crucial data in one place and creating a unique platform for solution providers, ports, and agents that operate along the supply chain. Allowing tracking cargo in real time using blockchain technology, shipping companies and ports can plan land procedures ahead of time, speeding up terminal works and cutting down costs. Maritime blockchain increases trading safety and transparency. Adopting blockchain technology would elevate the industry to the next level in terms of efficiency and would also impact positively mistakes being done on a daily basis by the personnel in maritime."

(2) It will have lot of cost in terms of time and money to change the existing system, especially when it is an infrastructure. We have to make sure this innovative technology not only creates economic benefits and meets the requirements of supervision, but also bridges with traditional organization, and it always encounter difficulties from internal organization, which is happening now. What do you think accordingly?

Montenegrin expert 1: "Montenegro needs a law that would regulate digital assets, together with crypto exchange and ICO (Information Commissioner's Office) regulation. Tokenizing big tourist investment via crypto would allow the crypto community worldwide to invest in Montenegro future projects."

Montenegrin expert 2: "Definitely, technology is advancing faster than human habits. Are our brains ready for all technological changes, and all that information delivered every day? Adoption is very slow; most of the people do not even use credit cards or e-banking services. It just needs decades, for new digital generations to come."

South African expert 1: "Blockchain technology will transform the maritime industry, as it is still struggling with high costs and a high level of pollution. Blockchain technology can help with both issues, by cutting down administrative costs and providing environment-friendly solutions."

South African expert 2: "Yes, changing from the old system to the new one will have a lot of financial implications for the organizations, but I consider it will be worth it, and ultimately will come with a lot of positives to the traditional organizations."

(3) Use bitcoin for example, the characteristics of the decentralized system will weaken the central bank's ability to control the economic policy and the amount of money, which makes government be cautious of blockchain technologies. Authorities have to research this issue, accelerate formulating new policy, otherwise, it will have a risk on the market. To which extent do you agree with this statement?

Montenegrin expert: "Bitcoin is unstoppable; its network is not censorable. There is no sanctions, no age, gender or any other restrictions. It is free for whole world to use it with the same rules for all. Banks will embrace bitcoin. It will become exchangeable in every bank as the dollar is today. Bitcoin is safeguarded against limitless money printing. It would not replace dollar or euro, but it could be complementary to gold, something as 'digital gold'."

South African expert: "Government will have to look at this system from all different angles in an attempt to find any serious loophole that might come with the system, especially in institutions like banks."

(4) Are you familiar with 'stablecoin'?—Can it assist regarding the previous challenge and in which way?

Montenegrin expert 1: "Local stable coin would bring to Montenegro the newest technology and long-awaited Easy Payment/PayPal-like options, which would for sure boost the Montenegro economy. If most merchants accept stable coin, this will lead to a significant Montenegro economy boost."

Montenegrin expert 2: "Major central banks are running pilot projects with stablecoins. The key question is how money laundering, tax heavens, and corruption will work with stablecoins that are more transparent than current financial systems. I guess we

shall have transparency for ordinary people, while big players will continue to hide their wealth."
South African expert 1: "I am familiar to a limited extent."
South African expert 2: "I am honestly not familiar with stablecoin."

(5) Even though it is an advanced technology, blockchain still struggles with some security issues. For instance, if someone has more than 51% computing power, then he/she can find nonce (number blockchain miners are solving for) quicker than others can, which means that he/she has authority to decide which block is permissible. What is your opinion concerning this issue?
Montenegrin expert 1: "There are several technologies developed, which practically make the 51% attack almost impossible to happen if applied correctly. Still, I always suggest using strong BC projects with huge hash power mining community—POW Blockchain networks, like Ravencoin, BitcoinCash, etc., or some reputable Blockchain netwoks—POS, like Etheraum, Ripple, etc."
Montenegrin expert 2: The 51% is really for smaller coins, but not for bitcoin. This is only a theoretical threat for the bitcoin network, and here is why. Firstly, it will cost billions in equipment to achieve that big hashrate with dubious benefits. The price of bitcoin will go sharply down. Bitcoin mining system is made that way to be more profitable to the honest miner. If an attacker could control the network for a longer period of time, the value of bitcoin would go down to zero, because trust in the bitcoin network would be zero. So, they would manage to get control of a lot of bitcoins that would be worthless. Not to mention worldwide storage of chips, such attack is not even possible right now."
The South African experts consulted from maritime industry were sincere and stated that this issue is beyond their scope of interest and expertise presently.

(6) Another issue is the 'fork' problem. It is related to decentralized node version agreement when the software is upgraded. Then, nodes are divided into old and new ones, and different problems of their mutual communication can appear.
Montenegrin expert 1: "It is democracy, who ever have 51% or more votes, it's a legit version of BC. There will be always one bitcoin, no matter how many times they fork it."
Montenegrin expert 2: "Some argue that while no technology is completely secure, no one has yet managed to break the encryption and decentralized architecture of BC. Decentralized networks can be much or less resilient to shocks, which can affect participants directly, unless careful thought is given to their design."
However, the majority of the consulted respondents are not familiar with this particular issue.

(7) Blockchain uses internet. Does it mean that it is prone at this instance to common internet attacks like 'botnets', for instance?
Montenegrin expert: "BC is not prone to classical botnet attacks, but there are similar ones. Especially when fees for transactions are low, multiple spam attacks are aimed to slowdown transactions and increase fees. Nevertheless, those people are just 'burning' their money, with increased fees; they increase the cost of the spam transactions also."
South African expert: "This is something we live with for all internet services. However, with proper implementation, monitoring, and improvement that would be made on the BC system over time, it would not be prone to any internet-related attacks."

Table 1. The assessments of considered blockchain (BC) adoption dimensions (Source: Own).

Statement	Agree	Disagree
1. The level of awareness and knowledge of BC affects its adoption.	4 + 5 + 5 + 5 + 5 + 5 + 5 + 5 + 5 + 5 + 4 + 5 + 4 + 4 + 5 + 5 + 4 + 4 + 5 + 4 = 9.30	-
2. The BC adoption is affected by the availability of the infrastructure and functionality to integrate and interoperate within and across the business ecosystem.	1 + 5 + 5 + 3 + 5 + 5 + 5 + 3 + 5 + 5 + + 5 + 5 + 5 + 5 + 5 + 5 + 5 + 5 + 4 + 5 = 9.10	-
3. Standardization and ensuring smooth interoperability is necessary, otherwise, BC can make things difficult instead of making them easier.	4 + 3 + 4 + 3 + 5 + 5 + 5 + 5 + 4 + 5 + 5 = 4.30	2 + 5 + 1 + 3 + 3 + 2 + 3 + 5 + 5 = 3.44
4. The BC adoption is affected by the availability of skilled and expert resources.	1 + 5 + 4 + 4 + 5 + 5 + 5 + 5 + 5 + 5 + + 5 + 5 + 5 + 4 + 4 + 3 + 5 + 4 + 4 + 3 = 8.60	-
5. The BC adoption is affected by a large number of stakeholders, with different mind-sets, organizational culture, and working habits.	3 + 4 + 4 + 5 + 3 + 4 + 4 + 4 + 4 + 4 + +4 + 5 + 5 + 4 + 3 = 3.80	1 + 1 + 1 + 2 + 1 = 1.20
6. The BC adoption is increased by favorable government and regulatory policies.	5 + 3+5 + 4 + 2 + 4+5 + 2 + 5 + 5 + + 5 + 5 + 4 + 4 + 5 + 5 + 5 + 5 + 5 + 4 = 8.70	-
7. Social influence positively affects the behavioral intention of using BC.	4 + 4 + 4 + 5 + 3 + 3 + 5 + 2+3 + 2 + + 4 + 3 + 4 + 5 + 2+3 + 4 = 3.53	2 + 2 + 3 = 3.50
8. A perception that BC implementation might lead to loss of jobs can be an obstacle in its adoption.	3 + 1 + 5 + 4 + 5 + 5+4 + 3 + 5 + 4 + + 3 + 4 + 4 + 5 + 5 + 5 = 4.06	2 + 5 + 1 + 5 = 3.25
9. Development in storage, computing, and cloud infrastructure will affect the BC adoption.	2 + 5 + 5 + 5 + 5 + 5 + 5 + 4+ + 4 + 3 + 5+5 + 4 + 5 + 4 + 4 + 4 = 4.35	2 + 2+1 = 1.67
10. The BC adoption reduces opportunistic behavior (opportunistic behavior means maximization of economic self-interest and occasioned loss of the other partners).	1 + 4 + 4 + 3 + 3 + 3+5 + 5 + 3 + 4 + 2 + 4 + 3 = 3.38	1 + 5+4 + 5+5 + 4 + 5 = 4.14
11. The BC adoption is reduced if the information is not shared by the partners, while some stakeholders are hesitant to share information considering it is a competitive advantage.	3 + 5 + 5 + 4+5 + 4 + 5 + 5 + 5 + 4 + + 3 + 4 + 5 + 4 + 3 + 5 = 6.90	1 + 3 + 5 + 1 = 2.50
12. Privacy and security of models and data need to be ensured, as BC technology is still immature and vulnerable.	5 + 5 + 4 + 4 + 3 + 4 + 5 + 5 + 4 + 4 + 5 + 4 + 4 + 3 = 3.9	2 + 3 + 3 + 2 + 1 + 1 = 2.00
13. Blockchain offers a high level of complexity and observability at the same time.	4 + 2 + 5 + 3 + 5 + 5 + 2 + 5 + 3 + 5 + + 4 + 5 + 4 + 4 + 5 + 3 + 2 = 4.47	5 + 4 + 4 = 4.33

Table 2. PESTEL quantitative analysis of selected constructs that affect BC adoption in developing countries: Montenegro and South Africa (Source: Own).

P **Political**	**E** **Economic**	**S** **Social**	**T** **Technological**	**E** **Environmental**	**L** **Legal**
Respondents "Agree"					
* Favorable government policies (rank 3)	* Hesitancy of sharing information (rank 5)	Awareness and knowledge about BC (rank 1) Skilled and expert resources (rank 4)	Infrastructure (rank 2)	* Hesitancy of sharing information (rank 5)	* Favorable regulatory policies (rank 3)
Respondents "Disagree"					
	Reduction of opportunistic behavior (rank 2)	Social Influence (rank 3)	Complexity and observability (rank 1) * Standardization (rank 4) ** Ensuring privacy and security (rank 5)	** Ensuring privacy and security (rank 5)	* Standardization (rank 4) ** Ensuring privacy and security (rank 5)

5. Discussion

As a result of summarizing the respondents' quantitative answers, divided into two categories: "agree" and "disagree", the ranks of five constructs assessed with the highest scores for both considered categories are additionally categorized into PESTEL dimensions, while the following can be drawn out:

- The respondents consider awareness and knowledge about BC as a social dimension of utmost importance for BC adoption in maritime and related industries. This is understandable, since knowledge is the biggest asset; the only one that grows with exploitation during the time. Second is infrastructure, which falls under technological dimension. This is reasonable, since without it, BC adoption is practically impossible. Third are favorable government and regulatory policies that fall under political and legal dimensions. This is of crucial importance, since in developing countries like Montenegro and South Africa, the economy and its development are controlled by the government (i.e., the reminiscence of socialism that was an actuality in Montenegro in the past, and which is currently tried to be developed in South Africa). Fourth is experts' knowledge, which belongs to social dimension of PESTEL model, and which is to a certain extent connected with awareness and knowledge, but it can be outsourced in the case of its lack, and under the assumptions that awareness and general knowledge about BC are present. Fifth is hesitancy of sharing information among the parties, and it falls under both economic and environmental dimensions of PESEL. This is understandable, since once BC becomes well-established, the impact of this issue will be reduced, and therefore the related statement is at the last position among selected constructs.
- The highest disagreement is observed regarding the 'simultaneous' presence of BC complexity and observability. The majority of respondents show suspicion regarding this paradox, which is logically understandable. Then, respondents do not agree with the statement that BC will reduce opportunistic behavior. Montenegro and South Africa are countries that for decades have been in a transition, and suffer from the permanent reproduction of crises and injustices. Consequently, their rather skeptical attitude towards this statement is completely understandable. Social influence is in third place. The respondents do not believe that society can impact the implementation of this advanced technology, and this belief is based on their experiences from transitional settings. The statement, which deals with standardization issue, is 'negatively' assessed, but it might be the case due to the experts' belief that standardization must be achieved and that it cannot as such diminish BC key advantages. Ensuring

privacy and security is negatively assessed, as well. This means that some respondents disagree with the statement that BC technology is still immature and vulnerable. Due to their response, one can conclude they believe that BC technology is at a high level of development, that it is less vulnerable, and that it can appear due its complexity and deployment at a global scale. This construct can correspond with technological, environmental, and legal PESTEL dimensions at the same time.

By analyzing the respondents' open-ended questions set around the constructs: BC benefits, investment costs, bitcoin, stablecoin, computational power and nodes' dominance, nodes interoperability, and internet vulnerability, we synthesized the following:

- Montenegrin experts see benefits in adopting BC for the cruising industry, mostly in terms of easier payment, attracting tourists, increased revenue, distributed development of cruise tourism, etc. Furthermore, due to the experts' opinions, BC could have an application in the management of passengers' flows, market analysis, provision of advanced software for cruise industry needs, etc.
- South African experts express positive attitudes in a way that BC can help by placing the crucial data in one place, while creating a unique platform for IT solution providers, ports, agents, freight forwarders, insurance companies, etc., that operate along the supply chain. The BC allows tracking cargo in real time, while shipping companies and ports can plan land procedures ahead of time, speeding up terminal work and cutting down costs. They believe that maritime BC increases trading safety and transparency. Due to their opinions, adopting BC would elevate the industry to the next level in terms of efficiency and affect it positively in terms of reducing the number of human errors.
- Regarding the costs of introducing BC infrastructure and impediments on changing organizational habits, the experts offered different opinions, but commonly, they believe it should be a part of a much needed and inevitable digitalization process. Changing from the old system to the new one will have many financial implications for the organizations, but ultimately it will come with many positives.
- Concerning the question of the central national banks as a regulatory body, Montenegrin experts see benefits, but in general agree that Montenegro central bank is the commercial banks' control body, rather than central bank. Montenegro does not have its own currency and no reason to consider decentralized crypto currencies as competition to other monetary flows. Of course, experts agreed Montenegro needs digital assets, crypto exchanges, and ICO regulations, which would disable eventual money laundering, frauds, or terrorist financial attacks. On the other side, South African respondents see government as the only entity that can put things under control. In general, South African eyes are usually directed towards the government as a central authority that can assist in solving key economic and social problems in the country.
- When it comes to stablecoin, computational power of BC, nodes interoperability, and cyber security, few Montenegrin experts are familiar with these topics, since they are involved in the EU projects, or work as external experts for foreign maritime institutions, or as adjunct professors at foreign universities. However, the lack of technological knowledge is commonly present in South Africa and Montenegro as countries in transition for more than 30 years. Therefore, strengthening technological knowledge transfer (not only ready-made technology) among developed and developing countries can assist considerably.

6. Conclusions

This paper presents the results of literature review regarding BC adoption in general and in particular in maritime industry and business. The literature sources are scarce and dominantly focused on extensive literature review with few papers that concern concrete applications and related issues. In this study, we screened the opinions of several experts from Montenegro and South Africa as developing countries, concerning the attempt to adopt BC rationally. The experts in general agree with the suggested benefits of BC examined through the quantitative part of the study. However, some oscillations in their assessments are noticed, but commonly there is an agreement with assumed benefits of BC implementation in maritime. The observed oscillations mean uncertainty due to the lack of knowledge and experience in blockchain implementation in emerging maritime economies. Through the qualitative part of the questionnaire sent to the experts and later analysis of their responses, we noticed again differences in opinions, which we considered in the discussion. The presence of lack of knowledge and confidence when it comes to some concerns has been noticed, as well. Due to our opinion, the first world countries have been planning and developing BC technology, while the third world countries need to invest more time and money in acquiring knowledge in this technology and respected organizational changes to become credible to determine the right directions for implementing this technology rationally, to protect their national interests, and ensure sustainable development. In this regard, closer communication with developers of this technology would be necessary, as well as exploring needs and preferences of the developing environments, more rigorously, longitudinally, and through larger polls.

Limitations and Recommendations

Since we collected only 20 survey responses, further research should include in-depth interviews or a survey upon a larger poll of experts and deeper discussion on the respondents' assessments, comments, and suggestions. In addition, following investigations in the field should include experts from other developing and transitional countries (besides Montenegro and South Africa), including longitudinal studies, too. The majority of consulted respondents are not familiar with botnets, how they can affect BC, and how such attacks can be prevented. Few are familiar with stablecoin, computational power, and nodes compatibility issues. Therefore, further investigations, building new, and transferring existing knowledge, primarily on BC technological, and then on political, economic, social, environmental, and legal dimensions are needed in developing countries.

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