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Vessel Traffic Services, towards e-Navigation

The role of Oceanic VTS in Global Maritime Surveillance

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To Sara Teixidó Vallés

Excellent mariner, master of seafarers, colleague, and friend for life.

In memoriam.

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“We cannot hold polluters accountable unless we can match them to their spills;
we cannot keep vessels from colliding if we don't know where they are;
we can't rescue survivors unless we find them.”

U.S. Coast Guard Admiral Brian Salerno.

“Veles e vents han mos desigs complir
faent camins dubtosos per la mar.
Mestre i ponent contra d’ells veig armar:
xaloc, llevant los deuen subvenir
ab llurs amics lo grec e lo migjorn,
fent humils precs al vent tramuntanal
que en son bufar los sia parcial
e que tots cinc complesquen mon retorn”.

Ausiàs March.

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Cuando presenté el proyecto de Tesis en la Facultad de Náutica, al finalizar, uno de los miembros del tribunal, el Dr. José Francisco González La Flor, se me acercó y me dijo: "bienvenida a la travesía del desierto". No entendí muy bien a qué se refería, pero me impactó. Ahora, terminada la tesis, he comprendido que me adentraba en el solitario mundo de alcanzar un reto personal. Una tesis es un largo camino de investigación que no depende de nadie más de lo que uno mismo quiera alcanzar. Evidentemente el director de la tesis está ahí, siempre acompañando, como un compás que te va indicando si vas por buen camino, pero la travesía te la trazas tú.

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El papel de doctoranda te sitúa en la constante intención de llamar a alguna puerta para solicitar ayuda. Personalmente, siempre me ha costado solicitar ayuda pues está entre el "no molestar" y el "dar a cambio". Un deber moral inevitable. Sin embargo, este recorrido también te enseña que hay personas dispuestas a ayudar generosamente sin esperar retorno.

Writing a thesis is a great challenge, perhaps the greatest I have faced so far, and in a language that is not my mother tongue. I thank Renata Whitewood for all the help and support, not just around the intricacies of English grammar but, also those of maritime vocabulary. She has been able to capture the special linguistic register that we sailors need when writing, with remarkable professionalism. Always available and in a good mood.

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Acabo fent el meu més sentit agraïment al meu marit, Antoni Batista, que també ha estat un referent de Doctor pròxim. Un exemple d'esforç i treball constant que admiro cada dia que passa. Sense el seu amor i constant suport, no hauria pogut fer aquesta tesi. La providència va fer que ens retrobessim, i des d'aleshores naveguem junts, ahir, ara i demà per sempre.

Abstract

This dissertation presents study and analysis of the Vessel Traffic Service (VTS) from its origins to the present, analysing future trends. Identification of various models of traffic management, systems operating specifically in the Spanish State and reflection on the diversity that prevails is also considered. Examining the current trend in terms of technologies that are being applied in the maritime sector, the dissertation focuses on the future to draw a new paradigm. A scenario at a planetary level, which follows a single global traffic management system, which would create a new model of the global VTS operator. A new assignment is proposed according to this third dimension, Port VTS being the first, the Coastal VTS second, and the Oceanic VTS is projected in the future. The foundation is based on EU projects, the most ambitious and currently underway being Sea Traffic Management (STM), with a scope greater than the European one, in the working groups of the IALA Committee regarding the future of the VTS and with recognition of what the IMO has been doing. New challenges to face are those such as maritime communications and digital technology in the context of e-Navigation, which will provide emerging tools and a paradigm on a planetary scale for VTS around the world.

Keywords

Vessel Traffic Services, e-Navigation, Satellite, AIS.

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List of Acronyms

AAPP	Autoridades Portuarias
ADSS	Automated Dependent Surveillance System
AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable
API	Application Programming Interfaces
ASM	Application Specific Messages
ATC	Air Traffic Control
BIMCO	Baltic and International Maritime Council
BOE	Boletín Oficial del Estado
CBA	Cost Benefits Analysis
CIRM	Comité International Radio-Maritime
CMDS	Common Maritime Data Structure
CNIS	Channel Navigation and Information Service (Coastguard UK)
COLREG	Convention on the International Regulations for Preventing Collisions at Sea
COMSAR	Sub-Committee on Radiocommunications and Search and Rescue
CSSA	Common Shore-based System Architecture
CVTS	Cooperative Vessel Traffic Services (between countries)
ECDIS	Electronic Chart Display and Information System
EEZ	Economic Exclusive Zone
EIS	European Index Server
EMSA	European Maritime Safety Agency
EMSN	European Maritime Simulator Network
ENC	Electronic Navigational Chart
ENUW	e-Navigation Underway
FAL	Convention on Facilitation of International Maritime Traffic
FSA	Formal Safety Assessment
GHG	GreenHouse Gas
GIS	Graphical Interface SafeSeaNet / Geographic Information Systems
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IAPH	International Association of Ports and Harbors
IEC	International Electrotechnical Commission
IGS	Código Internacional de Gestión (ISM)
IHO	International Hydrographic Organization
ILO	International Labour Organization

IMCO	Inter-Governmental Maritime Consultative Organization (Ex IMO).
IMDG	International Maritime Dangerous Goods
IMO	International Maritime Organization
IMPA	International Maritime Pilots’ Association
IMPA	the International Maritime Pilots' Association
IMSO	International Mobile Satellite Organization
INS	Information Service (VTS)
ITU	The International Telecommunication Union
IWRAP	IALA Waterway Risk Assessment Programme
JIT	Just-in-Time
LPEMM	Ley de Puertos del Estado de la Marina Mercante
LRIT	Long-Range Identification and Tracking
M2M	Machine to Machine
MAREP	Maritime Reporting System (Strait of Dover)
MAS	Maritime Assistance Services
MASS	Maritime Autonomous Surface Ships
MAtoN	defined as a non-fixed or un-moored AtoN
MCP	Maritime Connectivity Platform
MCPC	Maritime Connectivity Platform Consortium
MCTS	Marine Communications and Traffic Services (Canada)
MIR	Maritime Identity Register
MITMA	Ministerio de Transoprte, Movilidad y Agenda urbana
MMS	Maritime Messaging Service
MMSI	Maritime Mobile Service Identity
MONALISA	Motorways and electronic navigation by intelligence at sea
MRCC	Maritime Rescue Coordination Centre
MRN	Maritime Resource Names
MS	Maritime Service
MSC	Maritime Safety Committee
MSI	Maritime Safety Information
MSP	Maritime Service Portfolios
MSR	Maritime Service Register
MTC	Marine Traffic Control
MTR	Marine Traffic Regulations
NA	Nautical Assistant

NAS	Navigational Assistance Service
NAVTEX	Navigational
NCSR	Sub-Committee on Navigation, Communications and Search and Rescue
NMs	Notices to Mariners
NUC	Vessel not Under Command
OCIMF	Oil Companies International Marine Forum
OOW	Officer On Watch OOW, officer of the watch
OPPE	Organismo Público Puertos del Estado
PAS	Port Advisory Services
PAWSA	Port and Waterways Safety Assessment
PCMF	Port Call Message Format
PDCA	Plan Do Check Act
PIANC	Permanent International Association of Navigation Congresses
PKI	Public Key Infrastructure
PNT	Position, Navigation and Timing
PortCDM	Port Collaborative Decision Making
PSSA	Particularly Sensitive Sea Areas
RADAR	Radio Detection and Ranging
RCO	Risk Control Options
RDV	Rendezvous Service
RTCM	Radio Technical Commission form Maritime Services
RTZ	Route Exchange Format
S2SREX	Ship To Ship Route Exchange
SAR	Search And Rescue
SASEMAR	Sociedad de Salvamento y Seguridad Marítima
SC	Service Consumer
SeaSWIM	Sea System Wide Information Management
SESAR	Single European Sky ATM Research
SHS	Ship-handling simulator
SIP	Strategy Implementation Plan
SIRA	Simplified Risk Assessment
SITRES	SafeSeaNet Tracking Information Relay and Exchange System
SMCP	Standard Marine Communications Phrases
SMCV	Standard marine Navigational Vocabulary
SMTP	Simple Mail Transfer Protocol

SOAP	Simple Object Access Protocol
SOTDMA	Self Organised Time Division Multiple Access
SP	Service Provider
SPM / SBM	Single Point Mooring or Single Buoy Mooring
SRS	Ship Reporting System
SSN	Safe Sea Net
SSS	Short Sea Shipping
STCC	Sea Traffic Coordination Centre
STCW	Standards of Training, Certification and Watchkeeping for Seafarers
STCW-F	Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel
STM	Sea Traffic Management
SUA	The Suppression of Unlawful Acts Against the Safety of Maritime Navigation
SWIM	System Wide Information Management
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TAG	Training Advisory Group (VTS Canada)
TDMA	Time Division Multiple Access
TDMS	Traffic Density Mapping Service
TOS	Traffic Organization Service
TS	Technical Service
TXT	Text Message Format
UN	The United Nations
UNCLOS	The United Nations Convention on the Law of the Sea
UNCTAD	United Nations Conference on Trade and Development
URN	Uniform Resource Names
USCG	United States Coast Guard
VDE	VHF Data Exchange
VDL	VHF Data Link
VHF	Very High Frequency
VIS	Voyage Information Service
VPN	Virtual Private Network
VTIS	Vessel Traffic Information Service
VTMIS	Vessel Traffic Management and Information System
VTS	Vessel Traffic Service(s)
WMO	World Meteorological Organization
WRC	World Radiocommunication Conference

WWA	World Wide Academy
XML	Extensive Markup Language

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INTRODUCTION

Who is unaware of the role of an air traffic controller (ATC)? However, the same is not the case with maritime traffic controllers (VTS). This thesis seeks to place on the map the figure of the VTS operator and clarify the training, necessary qualifications, tools used, scope of their functions and consolidation of the system. The VTS has an assured future.

It should be noted that this thesis has been divided into three clearly differentiated parts, but these three parts also intersect throughout. In this way, the research work, which has, as its final objective, the preparation of the Doctoral Thesis, has been based on:

a) The compilation of written material in the format of regulations, rules, laws, papers, reports, news, books and magazines related to the subject, to generate an in-depth bibliographic study and to locate the evolution of the VTS. Also included is a compilation of VTS management systems at the level of the Spanish Administration. A VTS centre is analysed as an example to illustrate the tools used, the dynamics of the system with its strengths and weaknesses, preparing a statistical record.

b) The participation and direct involvement in the main projects of the European Union (EU) that wanted to take advantage of the potential of the digital age and satellite technology applied to the maritime sector. It includes conferences, seminars and workshops related to the role played by the VTS system and what is being done around the e-Navigation concept, always with the aim of obtaining direct information and increasing the level of involvement and understanding. Also included is participation in webinars (promoted as a result of the pandemic) organized mainly by the IALA.

c) The third distinct section that allows projection of future directions. An assessment that includes over 10 years of experience as VTS, extensive training and professional experience of the author, which, when integrated with a) and b), results in a reinforced dissertation.

Once these studies have been carried out, where a) and b) are quantitative analysis and qualitative analysis, the research is developed from the implication and replication of these parameters, reciprocal terms of text and context, which support a thesis developed from the method of pure science, but also result in the ability to achieve the praxis of an applied science, which can create an optimisation of all the systems within reach: Obviously, the new ones, but also the established ones that perhaps have not been able to reach the maximum development of their potential benefits, although the new technologies contribute to their subsistence. For all these reasons, this thesis has its foundations in "field work" to cover all the aspects under study. The research voyage, then, has not only been undertaken administratively, but it has also included active and direct participation and involvement, therefore, the results of this entire dissertation are included here.

This thesis has navigated, as it appears in the academic record, throughout the European project Sea Traffic Management (STM), docking in 2017 in Venice in its Midterm conference (STM Midterm Conference) with respect to the general program and subsequently following it, via Valencia in its work sessions, to London, where the final conference was held at the IMO headquarters. The last conference (recorded in this thesis), held around the STM commanded by the Baltic region, was on June 3, 2021, now available online. The STM, in its validation phase (Validation Project) included amongst its activities, testing the European Maritime Simulator Network (EMSN), integrating centres equipped with ship bridge simulators and VTS-type centres in a common virtual platform and, in addition, equipping ships with STM-services to exchange information with shore centres. The author participated in four sessions, two at the Jovellanos Integral Maritime Safety Centre (CESEMI), and two at the Faculty of Nautical Studies of Barcelona (FNB).

The author of this thesis has also crossed the seas of IALA first by participating in the working sessions of the EU's EfficienSea2 project, held at its headquarters in Saint-Germain-en-Laye, France. Subsequently attended the seminar on the revision of the latest IMO guidelines for VTS also from its headquarters, in its VTS47 sessions and participated in the “workshop on VTS Training and qualifications, 2020 beyond”, held online by IALA VTS Committee. The author has also assisted in the e-NAV26 IALA Committee, focusing on the tools of the future for VTS, including VDES (VHF Data Exchange System).

Through incorporation as a member of IALA in its meetings of the VTS Committee, specifically in its VTS50 session, and including the author in the working groups, the “future VTS” and in the group dedicated to “MASS ships from a VTS perspective” (Maritime Autonomous Surface Ships), they have placed themselves in a privileged position of being at the forefront, with participation in international conferences on e-Navigation: “e-Navigation Underway” (ENUW) and “Digital@Sea” and a total of 9 attended webinars, whose topic consistently revolved around the VTS.

It can be agreed, in view of the latest academic trends, in permanent relocation, that the methodology of the thesis presents a multifunctional factor of analytical constellation, which gives the necessary specificity and specialization of each corpus a greater depth of field, a holistic perspective. A depth of field that, on the subject of navigation, safety and protection of the environment, is absolutely essential.

It must be added to these methodological considerations that the field work carried out to compile and systematize what could be called the history of the corpus, due to its breadth, it could constitute an academic contribution in itself, on which to draw other lines of research, in addition to that presented here. Finally, the intrinsic value of the methodology that, on occasions, can itself be a thesis, needs to be highlighted. Marshall McLuhan coined that "the medium is the message" (Understanding Media: The Extensions of Man, 1964) and paraphrasing him, it could be stated that, the methodology, in itself, is also a thesis.

1. Thesis topic and justification.

The idea of doing a thesis on the system, the figure and profession of the Vessel Traffic Services (VTS) Operator was born after more than a decade of professional experience in the Maritime Safety and Rescue Agency (SASEMAR) in Spain. Therefore, it could be said that the starting point of this Thesis is empirical knowledge, the basis of the scientific method. It therefore begins, not as a linear continuity of degree studies, but with the added contribution of those hardcover notebooks in which predecessors and referents wrote down their research, to then build on quantity the theoretical building of quality, stating a hypothesis and trying to prove it, culminating in thesis.

In this sense, during this time, the author has been able to observe how the functions of the VTS have been developing under the influence of new technologies and, additionally, how the growing concept of a globalized world has surpassed the globe itself and is already being analysed with spatial vision. In the last four intense years in which working life has been combined with research, through the evaluation of future trends, a new approach has been detected, which will be necessary for future maritime traffic services. The maritime sector, particularly slow by nature, faces new challenges, new technological and conceptual paradigms. The present thesis, with a view to anticipating questions about future developments within the nautical world, raises global maritime traffic services and proposes, for the first time, the creation of a new VTS figure, according to this dimension, the figure of the Oceanic VTS. This approach will consider the creation of an Oceanic Vessel Traffic Service, where all personnel would exchange information, without state borders, between ships and onshore centres worldwide. This also raises the issue of how a new technological paradigm will fare against archaic barriers of legislative scope. To arrive at the thesis, the hypothesis follows the history of the VTS to future trends, focusing on the role of the VTS operator, regulations that surround it, scope, tools, and services to be provided.

Vessel Traffic Services (VTS) operators can monitor vessel movements in local coastal areas and also have the technological capability to track vessels internationally, as all merchant vessels are currently equipped with global tracking systems. Digital information processing and satellite communications are powerful tools that the industry is always eager to take advantage of around the three maxims: safety, efficiency, and environmental protection. Parallel to this dissertation towards the global figure in terms of management, the need to unify and standardize the terminology of these professionals is also considered, including defined acronyms and names that will not lend themselves to confusion, regardless of where one might navigate on the planet, taking as a reference the agreed universal language, English.

The practice of VTS Operator in different Maritime Rescue Coordinator Centres (MRCC) as well as the training in the different management systems that are carried out in each port where this service is provided, has led the author to discern that, in general, it operates under a functional amalgam. This individual functionality is not due to the size of the port, the volume of operating vessels, or the gross tons, much less latitudes or longitudes. It solely and exclusively obeys the internal contracts that each authority signs between the different actors in the port. What can be understood as a traffic control system, in conceptual terms of unity, in reality is divided into numerous sections, according to the participating entities of the maritime sector.

During the year, situations of confusion, risk or critical points directly related to the apportionment of functions have been detected. There have been incidents and even serious accidents in waters near the ports, which are well controlled. Thus, it is detected, (i) in the lack of unity of the figure and the management of the VTS operator in favour of safety, but also of operability, which includes efficiency and environmental protection, and (ii) in framing the context in which this standardization will be carried out, under what system it is housed and in what spatial dimension. Finally, it is pertinent to highlight that, in the VTS scenario, there are two main actors that exchange information, a sender, and a receiver or vice versa, located in different habitats, that is, one on land and the other at sea. If the practice as a VTS Operator has allowed the author to identify a potential improvement of this system, their roots as a seafarer predispose them to the complicity of the ship. The author is well aware of the conditions and different situations that underly making a report to the VTS Centre. Therefore, having both points of view first-hand increases and represents a valuable plus for this research, but it would also emphasise the profession of the VTS Operator.

This dissertation, aims to enhance the training and qualifications of the VTS operator and identify what future tools and new challenges will have to be faced, such as VDES or the new generations of MASS ships. The maritime world is moving towards common digitization and the integration of satellites will be greater and greater. All this reinforces the initial thesis and therefore, “quod erat demonstrandum” (Q.E.D).

2. Research objectives.

This research aims to investigate the role the Vessel Traffic Services has played in the maritime world, since the beginning, studying the present, with a future perspective.

The final result that is proposed is to define a new concept related to the VTS, taking into account its scalar magnitude. Given the current trend of growth and evolution of new technologies, it is beginning to be perceived that their applications will require new forms of organization, new ways of managing. The maritime sector, traditionally conservative in nature, is not exempted from this revolution. Maritime traffic flows began to be controlled over a long distance through a screen with AIS technology but, with satellite launching, the intention and future reality is that they will be controlled on a planetary level. We are facing a unitary module that goes in a horizontal direction, in a forward direction, towards the future, and its point of application is from now, the present moment. It will be necessary to anticipate what the extension of its numerical value will be. The control of world maritime traffic will therefore require a global maritime traffic system. The implementation of a single, robust, independent and multi-spectral maritime traffic control system is the key formula for its ongoing proper functioning, so that it can be recognized and identified anywhere in the world in a way similar to that registered by air traffic controllers. The objective is also to find the best formula to define the new parameters needed for global VTS.

The more detailed objectives are the following:

1. To place the VTS System historically within the maritime sector and show its exponential importance over time, how it started and how it expanded and evolved. To detect the emergence of a new profession, the VTS Operator, the jargon that it has acquired and is currently acquiring and define which would be the most appropriate for global clarity. Also, to outline regulations that have been forged.
2. To compare the VTS with the air traffic system, identifying similarities they share and what differences over time. Between both new acronyms and related nomenclatures, the objective is to identify the need for standardization. In addition, to establish a language or seme, and specific acronyms that are exclusively identified within that scenario that would colloquially be called terrestrial, because of the land, although in reverse synecdoche, it is more maritime, because of the sea.
3. To describe the different existing VTS control systems and the agents that participate, to show the variety and diversity that converge, particularly in Spain. To define the competence limits of each of these agents, paying special attention to whether there is any type of overlap or duplication of procedures. To illustrate, using real examples, the most complex situations directly related to maritime traffic services. (No line break needed here.)

To present the current work tools typical of VTS centres and the environment the VTS Operator operates in.

4. Identify the type of model developed in Spain, based on the coexistence of various contractual relationships, whose competencies are intertwined, ensuing certain operations to be redundant. The constellation of maritime traffic control will require a harmonization more adapted to new technologies, aimed at optimizing operations. A further objective is to identify how the terms of safety, efficacy and environmental protection are key to this new approach.

5. Analyse the trend in terms of new technologies applied to the maritime sector. The digital era means promoting the concept of IMO e-Navigation so the VTS will also be involved. Identify the role of drift towards globalization and digitization and which legislative framework would conflict with this new paradigm of the numerical-zero-point era.

6. Study the projects that work on e-Navigation. Specifically, study and analyse the Sea Traffic Management (STM) project, which covers the European level, but also the non-EU level, which must conceive a computerized data exchange system that will change the way in which ships are interrelated with each other, with the shore sector and vice versa. Identify the role of the VTS within the STM project, how it will be located in the technological organization chart, what functions it is expected to provide and with what tools it will work, and whether they are already defined in this project.

7. To determine a new concept of the VTS system, in the line of conceiving it as unique and universal, and therefore applicable, globally. A concept with a future projection regarding e-Navigation technology, for a globalized future, that tends to monitor maritime traffic on a planetary scale, thanks to satellite technology. To demonstrate that the essence of the acceptance and success of any innovation lies in the support from international organizations such as IMO and IALA, among others.

8. To highlight the role of the professional VTS, also global, which should be consistently recognisable in any port, especially community and, therefore, whose qualifications and training will be established as suitable to work in any area that offers this service, the control of maritime traffic. When proposing an innovation, in this case, a new paradigm for the professional dimension of the VTS centre, it is necessary to consider how it should be named. There are two possible ways to achieve this: a new word or neologism or adding a new meaning to an existing word. It is from this binary axis that dictionaries have grown. The proposal is based on a noun with sufficient weight and dimension: the ‘ocean’ that would give rise to the Oceanic VTS and that could be included in a global VTS Manual. Therefore, the objective is to demonstrate the need for a new concept object

9. In this way, to contribute to a greater understanding of the VTS within a world that is progressing and offer an adaptation of the VTS, according to the future. Assessing the future of the new

profession of the Oceanic VTS controller implies defining what dimensions it will encompass, which tools and interactions and in which legislative areas it will move. A standardized figure that can compete and adapt to any VTS system in the world is needed.

The objectives listed above are resolved by various means. **Objective 1** is solved by studying, in depth, the historical process of the VTS, regarding international regulations and standards referenced to the VTS. Also, by considering, for scientific reference, the literature for evaluation and matching the opinions. **Objective 2** is resolved by extracting, from the two systems, the main acronyms that they acquire and the operation of each one. **Objectives 3 and 4** are resolved by explaining the current VTS system in Spain, giving examples of the different organizational options. **Objectives 5 and 6** are resolved by re-analysing specific international regulations and standards on the concept of IMO, e-Navigation, and the projects that have worked to introduce it to the maritime sector. **Objectives 7 and 8** are resolved through applying the methodology of the investigation. After identifying the subject, framing it historically, and justifying it, the issue can be detected, a void in the future, and the new hypothesis can be proposed. **Objective 9** is resolved by showing results and personal contribution obtained from active and direct involvement (described in the introduction of the thesis) in the proposal of the new concept and drawing final conclusions.

3. The structure of the thesis.

The thesis has been structured across three-time scales. Starting from foundations, when the first VTS was born in the past, it continues with the present and projects into the future. Establishing it as a triptych, a triple present, the present connects with the past and the future from the here and now. Past, present, and future by themselves, consecutively, can be independent. With this triple concept, the present is at the intersection of three sets.

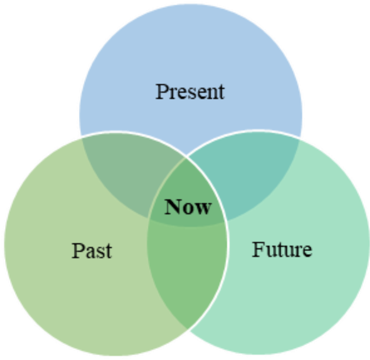

Figure 1. Triple Present. Own elaboration

The concept of "triple present" was coined by Dr. Isabelle Garcin-Marrou, Professor of Political Science at the University of Lyon, as a formula for analysing complex realities –in her case, subjects of various types of violence, from terrorism to gender- which, for correct appreciation, needs to connect the present with the antecedents and project it to its eventual consequences. The complex present is thus shown, not as a self-referential system in the conventional line of Luhman[1] , but as an intersecting set of present, past, and future (Isabelle Garcin-Marrou, “L’evenément dans l’information sur l’Irlande du Nord”, en “Réseau. Communication, technologie, societé”, number 76, March-April 1996).

As part of the presentation of a proposal and to better understand the evolution and trend of VTS, this concept has been chosen to establish the three methodological phases in the contexts of past, present, and future tense as Part I, Part II and Part III respectively for this thesis.

Part I, present-past, corresponds to the origin of the VTS concept that began after the Second World War and its evolution over the following 50 years, with the essential support of IMO and IALA. It consists of a compilation and analysis of the main conventions, resolutions and academic references around the maritime sector that connect to the birth of the VTS system, from its earliest beginnings, in 1948, to the first guidelines for VTS, published by the IMO in 1985. It identifies changes that have taken place, new guidelines that have been added and how the path towards the consolidation of the VTS system was being forged when the concept of routing and the ship reporting system appeared. The

[1] Niklas Luhmann. Systems Theory. Sistemas sociales: Lineamientos para una teoría general (1992) ISBN 84-7658-493-8.

analysis consists of the detection, over fifty years, of the flaws that have crept in over time and what future trend is beginning to be glimpsed, always around the figure and system of the VTS.

Part II, present-present, begins with the first guidelines for VTS revoked in 1997. The changes made and the new contributions after 12 years are analysed in depth. The VTS system has been consolidated during this stage with important international support. Being the part corresponding to now, what currently comprises a VTS is analysed and, as an example, a VTS centre in Spain is described. The new tools that allow greater control of maritime traffic are outlined, and how, at a European level, procedures and agreements have been established to coordinate it.

Part III, present-future, presents the new guidelines for VTS, already accepted by the IMO, but still in the publication phase, (perhaps, while this thesis is being finished and defended, the new resolution will have come to light). The main projects at European and international levels that work on the concept of e-Navigation and how the maritime sector faces new digital technologies are also identified. The STM Project is considered in depth, since it is the longest and most important within the EU. Finally, the future trend is analysed where the digital age also reaches the oceans, opening a new scenario, a scenario as extensive as the Earth's surface. New challenges will need to be solved, in order to move towards new technologies within the entire maritime sector and, for the scope of this thesis, also VTS Centres globally. Here a deficiency has been detected, which is why a new concept is proposed, the Oceanic VTS.

Each of parts I, II and II ends with a brief outline as an extract and, additionally, some final conclusions in constructing and clarifying the concept that this thesis proposes.

The last part corresponds to the final conclusions, which include the previous conclusions of each of the parts, to complete the justification of the investigated topic.

PART I

PRESENT – PAST: The origin of the VTS system.

1946 – 1996 (50 years)

Introduction: This first part begins with the study of the origin of the VTS system, how it started and where, and how, its applicability became more and more widespread in coastal areas and in different parts of the world. This includes the type of Centres that were being implemented, the necessary equipment, the functions that were being covered, which personnel undertook this work and which legislations were created to support and regulate the maritime sector. Additionally, from which sources the VTS grew and what criteria were established. This period has been covered from its beginning, with a single shore Centre interacting with ships in its vicinity, until the penultimate guidelines for VTS endorsed by the IMO emerge.

Chapter 1. Origin of the VTS.

1.1. Prehistoric context to the VTS.

Starting by citing the origin of the Earth may seem somewhat out of context, it is true. However, there is something that has always helped the author to understand and position the changes that occur over time, and that is the scalar reference. This reference will be a constant in this thesis since it is part of all reflections, analysis, and conclusions. To think that the origin of the Earth dates back to 4,467 million years ago, that it took more than 100 million years to form and that life on this planet dates back to 4,000 million years ago, numbers so vast that it is difficult to comprehend when the human can only experience, at best, an average of 90 or 100 years. Nine zeros separate them, that is, one 0.00000025 parts. At first, Earth was covered by a gigantic mass of water. The earth's surface was born in the Archaic period through the flow of heat that gushed out from the core. The crust was very unstable, and collisions of asteroids and meteorites occurred.

At the end of the Paleozoic Era and the beginning of the Mesozoic, the different land masses were united into a supercontinent, called Pangea. However, 200 million years ago, the solid mass fractured into pieces that separated, forming the continents, until reaching the position with which they are currently known. Whether from Africa, Asia or Greece, the point is that, until now, the origin of the homo species on Earth has been scientifically attributed to around 300,000 years, (the millions have disappeared and the thousands have appeared). The date of the first sea voyages by the original humans is not exactly known, If it is assigned to the origin of the ship concept, it is estimated that it comes from ancient Egypt, more than 11,000 years ago. Between 300 and 11 thousand, it is possible that someone climbed on a floating log, letting themselves be carried away, thus experiencing their first "ship" voyage.

The evolution of ships is not the subject of this thesis, it is to cite the first navigation aids that are attributed to geographical signals, to recognize natural features, such as capes and inlets. The first aids to navigation (AtoN) were coastal beacons and lights, followed by the introduction of buoys. Over the years, these aids have been constantly improved with increased visibility and range and the addition of audible signals. As discussed later, AtoN will cover a broader concept that includes electronics (e.g. MOB with AIS) and the human factor (e.g. a VTS).

The lighthouse, the oldest of which is commonly cited as the Pharos of Alexandria, a tower built in the Third Century in 270 B.C. (Dickens 1971) also began to be developed. As a side note, it did, however, take much longer to be officially appreciated. The celebration of "World Marine Aids to Navigation Day" was first approved on July 1, 2019 (the same day that IALA officially began in 1957). This was an initiative of the IALA and Spain led the pilot experience, through State Ports with, among other activities, an open day in the lighthouses of the national territory that, due to the peninsularity and insularities of the coastline, has the largest number of installations in Europe. It has taken 2,289 years to realize that navigational aids are well worth a day of annual celebration. Since this is a thesis on VTS, the author wonders how many thousands of years it will take to establish the International Day of the VTS Operator, (just as air traffic controllers have been celebrating, every October 20, the International Day of the Air Traffic Controller since 1961). They have been celebrating it for more than 60 years and the VTS have been operating for more than 70 without being able to celebrate.

The sea is currently the main route of world trade, the percentage is around 80% of the volume of international trade in goods, according to UNCTAD[2]. It has been the main route for centuries, resulting in nations aspiring to the safe and efficient navigation of ships, for greater success of commercial transactions.

However, the management of maritime traffic is relatively recent. It was born in the contemporary history of humanity, at the end of the 19th century and developed in the second half of the 20th century, after the two "World Wars": The First World War (1914-1918), also known as 'the Great War', and World War II (1939-1945). This means, on the one hand, that for thousands of years ships have freely navigated the oceans and seas, with no limitations, other than those imposed by the type of vessel, the expertise and courage of their crew and the prevailing weather conditions. On the other hand, that the world at the organizational level began to change after these two great tragedies. It could be said that everything began with the creation of the United Nations Organization in San Francisco, California, in 1945, ratified by 50 Member States. After this date, the most important international conventions in the maritime sector began to emerge and will be considered in this 50-year Chapter.

1.2. The birth of the VTS, 1948.

The first reference that is linked to a traffic surveillance system is associated with tests that were made through the installation of marine radar (Radio Detection And Ranging) equipment on land in 1946. The British Admiralty conducted radar screen experiments in the port of Liverpool, UK. The development of radar during World War II made it possible to accurately monitor and track maritime traffic, and its civilian applicability is first placed at Douglas, at the end of Victoria Pier, Isle of Man, on February 27, 1948[3]. Months later, in July, a stationary radar was installed in the same port of Liverpool, equipped with radio communications to be able to assist the pilots, especially in conditions of poor visibility, thus becoming the pioneer European port in VTS (Hughes 2017). In this way, a traffic surveillance system was achieved, which allowed the exchange of information in real time between the ships and the shore. This type of service was seen to be especially useful as an aid for other ports that also often suffer from adverse weather conditions due to fog, such as Long Beach in California, which established a radar and a VHF to facilitate port operations in 1951. Le Havre established another system and thus, gradually, radars were installed in other European ports, such as Amsterdam in Holland, Southampton in England and Halifax in Nova Scotia.

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[2] Review of maritime transport. Available at: https://unctad.org/topic/transport-and-trade-logistics/review-of-maritime-transport

[3] Background to VTS. Retrieved from: https://web.archive.org/web/20161015201020if_/http://maritime-vts.co.uk/background.html

The photograph of the first Harbour control by radar, in the world of maritime transport, deserves to appear in all historical references about VTS. This has also been considered by the IALA, publishing the image in various editions of the VTS Manual, including 2012, 2016 and 2021. Therefore, in this thesis, the image could not be omitted either and, by way of comparison, a more recent image of the same dock has been located. As can be seen, it has changed very little and is, still, almost identical. Some places in the maritime world, remain unchanged by time Figure 3: Harbour control by radar – Douglas harbour installation by Richard Hoare[4].

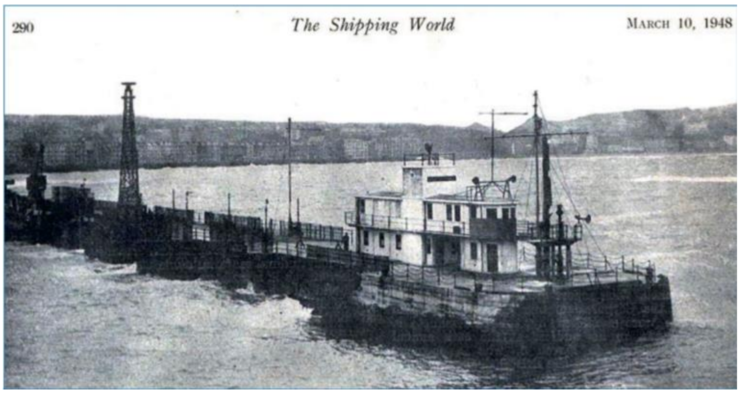


Figure 2. Pier Victoria in 1948. Harbour control by radar. Douglas harbour installation by Cossor Ltd

Figure 3. Pier Victoria in 2016

The combination of land-based surveillance of maritime traffic through radar, with the transmission of messages by radio, regarding navigation in real time is what is formally understood as a VTS system[5], and it was immediately seen as a powerful tool to increase safety, facilitate operations, reduce delays and increase the efficiency of port traffic flow.

[4] Retrieved from: https://www.geograph.org.uk/photo/4879154

[5] The development of VTS. Retrieved from IMO: https://www.imo.org/en/OurWork/Safety/Pages/VesselTrafficServices.aspx

But it was during the conference, held in Scheveningen (one of the eight districts of The Hague, Netherlands) in 1955, when it was proposed to officially standardize aids to navigation systems worldwide and create a Permanent Secretariat, based in Paris. The organization created would not depend on national governments, it would be exclusively for technical purposes and would be non-profit.

It would acquire the name Association Internationale de Signalisation Maritime, (AISM), or International Association of Lighthouse Authorities (IALA). This proposal was sent on July 31, 1956, to all navigation authorities of the World and its subsequent approval by 20 countries, gave rise to the IALA that was officially established in 1957. However, it is not the IALA that is known today. Over time, more countries were added, and functions and objectives were expanded, as will be described later but, at that time, it was not related to the VTS system. VTS becomes AtoN later.

In 1956 a series of 7 remote stations were built along the 20 km of the New Waterway River that reaches Rotterdam, to be able to assist, mainly, pilots in poor visibility conditions. These remote stations, through the portable VHF, could establish communications with the radar operators. The centres that were installed allowed both radar and visual control of the area, in the style of air control towers. This is an important piece of information to consider, since technology tends to dispense with visual control, which should never be lost. More than ten years of professional experience has reassured the author about the reliability and relevance of this empirical method.

In 1959, the Thames Navigation Service was created in London, to control the 95 navigable miles of the River Thames, from Teddington to its mouth (García Fernández et al. 2004).

By the 1960s there were centres scattered throughout Europe and North America, and in Japan by the 1970s. Today, forms of VTS are found, although they are not standard, across the globe, on the coasts of all continents: China, Egypt, Hong Kong, South Africa, all European countries including the coasts of the Baltic Sea, Atlantic and Mediterranean, countries around the Arabian Peninsula, some of the Black Sea, including Romania and Ukraine, the United States and Canada.

1.3. Air traffic control as convergence.

Air control towers and, therefore, the Air Traffic Controllers (ATC) were born virtually at the same time as commercial aviation. The first plane dates from 1903, the Wright Flyer, invented by the Wright brothers in the south of Kitty Hawk, North Carolina[6], and the air traffic control towers began to develop in the 1920s. Firstly, aerodromes were built, and, consequently, it began to be necessary to relay information from the ground to the pilots, mainly about the situation of the runway, weather conditions such as wind direction or other aircraft movements. This assistance used flags, flashing lights, and radio communications. The quick growth of air traffic made it necessary that air traffic controllers not only

[6] Retrieved from: https://www.natca.org/wp-content/uploads/2019/12/NATCA_ATC_History.pdf

gave information to pilots, but gave instructions when they took off or landed, in order to avoid possible collisions[7].

The same did not happen with the ships, since the navigation of these vessels began much earlier. From the approximate date when the first ship emerged, to the maritime control centre in Douglas, there is a jump of about seven thousand years. There is thus the paradox that, today, sea navigation, vastly predating air traffic, is now fixed on its control towers and even reproduces them architecturally. This paradox is common in linguistics since the hegemony of English, in such a way that today we understand the word "domestic" (domestic flight) as a neologism of English, when in reality the etymology is "domus", the Latin for 'house'. In addition, air transport has taken advantage of the nautical language to navigate, in such a way that both sectors share many words, starting with 'navigation', so aviation copied many words from the nautical world, but, when the VTS appeared, it in its turn, copied air traffic control. In brief, aviation copied many words from the nautical world but, when the first VTS started, it was the VTS that copied the air traffic controllers, which is why the convergence process between the two is included within this section.

It seems obvious to say that, in the ocean, there are only two dimensions of space, while in the air there are three but, unlike in the air, at sea, stops are possible and encounters are almost always satisfactorily dealt with through the use of radar ships and direct vision, but it is still necessary to establish routes.

Several studies have compared the two systems over the last fifty years and their results have been reported in the literature by different authors. It has been well established that maritime and air navigation can learn from each other. Maritime traffic has a history of following aviation in adopting some routes and control, (Proctor 1973). Aviation established mandatory airways and routes and, many years later, so did the maritime sector. In areas with higher traffic density, routing and control by sea has been necessary, establishing the VTS system that controls routes and reporting protocols from a "tower". With the expansion of commercial aviation, the number of control towers increased, but the need for safety reasons is also associated with them, after air accidents. The increase in VTS is not associated so much with the growth of the merchant fleet but with safety reasons, also following numerous maritime accidents.

In Part I, where the VTS system is born, a metaphor might say that the seaman has arrived at the port, the role of a new profession for seafarers is born. This is the VTS Operator, in the form of a counterpart at sea. However, this is not a Controller but an Operator. The Air Traffic adopted the Air Traffic Controller, whereas the Vessel Traffic adopted the Operator, as defined in the first guidelines for VTS. Prior to this resolution, the VTS role had caused confusion and other formulas had been used to refer to it.

[7] Retrieved from: https://www.usca.es/en/profession/history-of-air-traffic-control/

Experts from the maritime sector, with the purpose of disseminating discussions and studies, have published hundreds of referenced articles. The figure of the VTS is associated with the Marine Traffic Control (MTC) when the Marine Traffic in the Upper Bristol Channel is described (Corbet 1975).

Describing the VTS system as a system of control was also used. A study that analysed the VTS system, hierarchically divided the level of involvement with traffic into three, high, intermediate and low, where the low is the direct control over shipmasters executing VTS directives even as to course and speed. (Buller et al. 1986).

Operator versus *Controller*, collocated adjectives to "VTS", are two nouns with considerable history. The current formula officially uses "operator" and indiscriminately "controller”. However, "operator" has its etymology in the Latin voice "opus-operis", which means "work", and more precisely in the plural "works". Its neutral gender in Latin helps the amplitude of derivations it has had, to begin with the word "opera", the most popular musical manifestations, but, its semantic benefits are wide, from "opera" to "operator". It has the meaning and value given to it firstly through telephony, based on the appropriation that English made of Latin. The telephone system was originally interconnected through operators, hence its immediate transition to radio, and probably without leaving Guglielmo Marconi. (It might also be noted the inventor of wireless technology dates back to 1895). Its current definition in the RAE, Royal Spanish Academy of the language, defines the "operator-oris" as "the one who does", "the one who operates" and continues to focus on telephony as the "person who takes care of establishing the non-automatic communications of a telephone exchange”. But it also gives it cinematographic attributions such as "person who handles the projector and sound equipment for films", or of formal science that "denotes a set of operations" and finally appears in business, as "tour operator". All of them have little to do with maritime navigation, perhaps that is why the maritime world has its own dictionary. However, it seems that "controller" better specifies the functions to be carried out. Air traffic controllers have not hesitated to call themselves “controllers” in their control towers ipso facto, continuing with the Latin. But the "controller" has a marine etymology related to navigation. A possible etymology of control dates back to Venetian merchants, of course transacted by sea. The Castillian aspect limits it to the role of navigation, since it traces the word to the Spanish galleons of the 16th Century, which carried gold and silver to Seville, where customs control of pecuniary metals was exercised: the “Torre del Oro” and “Torre de la Plata. The receipt was extended "against gold", hence the Romanic evolution "contraloro" and, by syncopation and apocope, the definitive "control".

Currently the RAE gives it directly the noun, "those controls", in application to computer science as "to the program that allows a computer to handle the components that it has installed", but the masculine or feminine noun, is directly for the "air traffic controller", the "specialized technician who, from the ground, guides, orders, monitors and supervises the take-off, flight and landing of aircraft." The maritime lexicon has been essential in the creation of all the languages of most subsequent roaming systems. The Greek etymology of the maritime vocabulary, very rich since Homer recorded Ulysses's sea voyage in literature, has been applied to aviation and interplanetary flights, and it can be seen how it now also works for computer communications: people navigate by internet because they have internet navigators, they connect, or dock, their USB devices to ports. From the 8th Century B.C. to the 21st century A.D, sailors have helped to infuse old words with new meanings, they have supplied neologisms and ultimately, they have contributed to the cultural heritage. It is time to use this heritage for the maritime service, to renew the tradition of creating language based on the latest communication trends, which derive from an accommodation of English, due to its internationalization, and from the proliferation of acronyms and acronyms, that condense, in syllabic brevity, so many meanings.

Thus, the idea of the controller, who provides air navigation, agrees more with the role announced, simultaneously enriching the semantic transfer between maritime and air navigation, whose lexical balance is clearly favourable to maritime and, in this case, would help to balance the exchange.

Returning to the Resolution, the guidelines for VTS could be worked out in an international framework for VTS, in a similar fashion to the framework for Air Traffic Services (ATS), which includes aspects such as standard definitions, establishment of ATS authority, objectives and criteria to determine the need for ATS, designation of areas, coordination between ATS authorities and third parties involved, operation of ATS, scope of traffic information, methods used in the provision of traffic information or requirements for communications. In short, VTS and ATS basically have the same objectives (Bootsma and Polderman 1987).

In this first Part I, the comparison between ships and airplanes has been made from they inception, to when each one had its first controllers on shore.

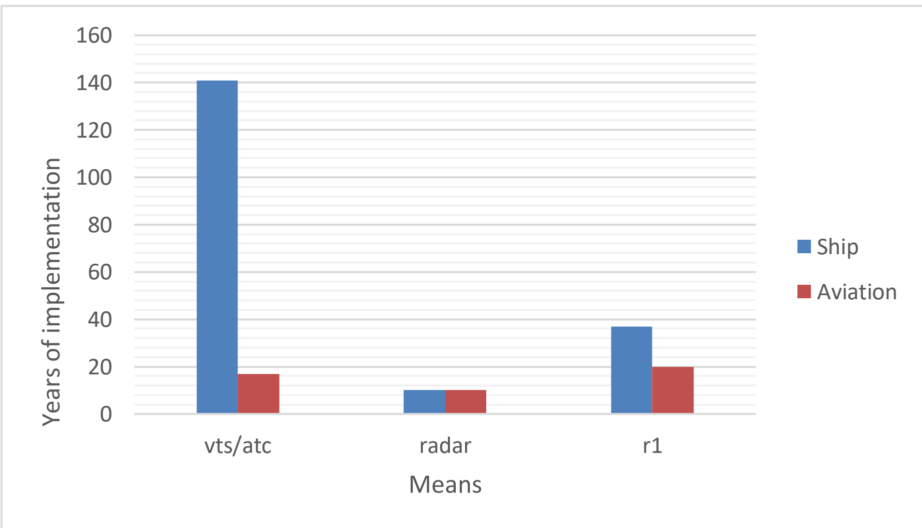


Table 1. ATC vs VTS. Own elaboration

The graph above shows the years that the same "means" has been implemented on ships and airplanes. For “means”, VTS and ATC systems, radar and the first regulations have been chosen.

As can be seen, radar was implemented at the same time in both carriers. The beginning of radar dates back to around the 1930s and 40s. By the middle of the Second World War, it was already used in ships and airplanes, so it had taken about 10 years for the technology to be installed on board.

In the case of what is understood as "control towers", it took planes only 17 years to implement a control tower after the plane was born, while ships (taking the first steamship as a reference in 1807) took 141 years.

In reference to r1, it represents the first international regulation recognized by both services. In the case of aviation, it took 20 years but, in the case of ships, 37 years. It can be stated that there is a correlation between the speed of each carrier, and the implementation of new features.

Chapter 2. VTS system landing.

The VTS system landing is a metaphor for its implementation since, although it is at the service of the sea, it is located on land. Before the recognition of the VTS system, two parallel concepts were born, which, in the end, were included and became part of the VTS system. A clear perception is that the parallelism crosses at infinity, but in this case, the crossing came earlier. These are: the routes of the ships that give rise to the Traffic Separation Schemes (TSS) and the Ship Reporting System (SRS).

The VTS system, as studied in this thesis, is an entity in itself that is gaining prominence throughout history and has a hopeful future, assured, at least, as long as ships continue to navigate the world and transport the majority of goods. The system exists within a profession and as a profession, in which it performs various functions. One of these is to organize the traffic, the Routeing System (RS) another, to interact with the traffic (SRS) and, as will be seen, it will acquire new functions in the future. It indicates the increase in functions and importance of VTS around the world.

2.1. The Routeing Ships (RS).

The oldest practice of following predetermined tracks is attributed to the North Atlantic geographic area in 1898, where passenger ships, going back and forth, avoided head-on situation zones. It stands in stark contrast to the fact that, for thousands of years, ships sailed freely, without following definite routes, as noted above. Indeed, the first attempt to separate traffic flows to avoid the turnaround situations encountered was in the 20th century, in the Strait of Dover. It soon spread to other parts of the world.

The purpose of the ship routes is: “to improve the safety of navigation in converging areas and in areas where the density of traffic is great, or where freedom of movement of shipping is inhibited by restricted sea-room, the existence of obstructions to navigation, limited depths or unfavourable meteorological conditions” (IMO 1985a).

2.1.1. Routeing Ship system voluntary (1967).

The Strait of Dover and its approaches form one of the busiest and congested sea lanes in the world. But it was already the case, even in the early 1960s, when it was estimated that some 300,000 ships passed, each year, along a route just 5 miles wide, between the Varne and the English Coast, regardless of whether they were traveling in a north-easterly direction or south-west. Between 1956 and 1960, there were 60 collisions (Squire 2003), indicating that it was becoming the scene of a large proportion of collisions and groundings in the world. The 1960 SOLAS Convention covered ship route distribution measures in busy areas on both sides of the North Atlantic, and Contracting Governments used their influence to induce the owners of all ships crossing the Atlantic to follow the recognized routes and ensure compliance with such routes in convergence zones, to the extent that circumstances allowed. However, analysis of casualty statistics showed that ship-to-ship collisions were becoming a worrying cause of accidents, especially on congested waterways and in foggy conditions.

In 1961, the Institutes of Navigation of Great Britain and France, with their German counterparts, Deutsche Gesellschaft für Ortung und Navigation, formed a working group (Richey 1966) to address the issue of traffic regulation in converging areas at sea, with special reference to the Strait of Dover.

The Group's Report, which was published in October 1962, made certain proposals for routing traffic in the area, which were accepted, in April 1964, by the Maritime Safety Committee (MSC) of the Inter-Governmental Maritime Consultative Organization (IMCO) and endorsed by the publication of the Resolution A.90(IV) of 1965 (IMCO 1965). Its implementation as a recommended Traffic Separation Scheme - the first in the world - was in 1967. Although the Collision Regulations were already in place, it was done independently of these regulations (Irving 1981,1982) but was predicated on the principle of ships keeping to the starboard side of the channel, broadly in accordance with Rule 25 of the 1960 Collision Regulations (COLREGS), today Rule 9.

The figure 4 depicts the Separation of Traffic at Sea, to advise, in Sailing Directions, Notices to Mariners, and alterations to charts, following certain recommended tracks. At that time, the possibility

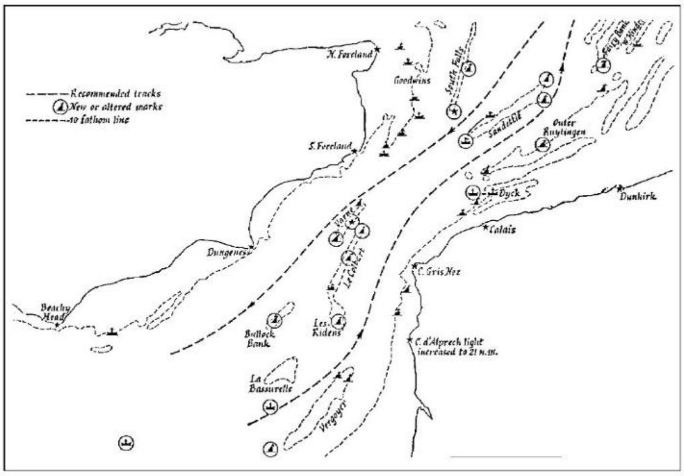


Figure 4. Recommended tracks proposed for the Dover Strait, 1967. (Richey 1966 and Squire 2003)

of making the routes mandatory could not be considered, as it was considered that some circumstances could make them impractical. These recommendations from the Strait of Dover represented the first restrictions for captains navigating freely by selecting their own routes on the high seas. However, a survey revealed that it was a proposal widely accepted by captains around the world (of 3755 replies received only 107 were against routeing) (Richey 1966), which meant 2,84 of replies received were against routeing. The research clearly indicated that the overwhelming majority of captains around the world viewed routing as favourable.

It should be said that, although the Traffic Separation Scheme (TSS) in the Dover Strait began in 1967, International Regulations for Preventing Collisions at Sea (Collision Regulations) have existed, in one form or another, since 1863, (Irving 1981). When steam-powered ships were introduced at sea, they encountered sailing vessels with different power systems for manoeuvring. The wind limited the manoeuvrability of the sailing ships, but it did not do so with those with engine, so new conventions and regulations were necessary that took both into account.

2.1.2. Routeing Ship system mandatory (1971).

After introducing recommendations in the Strait of Dover, several studies were carried out on the accidents that subsequently occurred. Although a decrease was recognized, collisions continued to be recorded two years after the scheme was implemented in 1967, statistical data was published in the article "Two Years of Routing in the Dover Strait" (Beattie 1969).

In 1971 a report was presented to the IMCO with the results of a forum held in London, with the participation of a committee of experts, to address the issue of recent collisions whose rate, in the Dover Strait, for the 44 months before and after routing, was about constant, although the average collisions per fog day had been reduced. The causes of accidents were attributed to an involved meeting situations. In the majority of these cases, one ship was in the wrong lane so a percentage of ships were still not observing the recommendations (Richey 1971).

The Resolution A.228 (VII), Observance of Traffic Separation Schemes, adopted on 12 October 1971, published a recent survey (at that time) which indicated that around 5% of the ships observed by radar were moving in the wrong lane, and that there were still collisions in this area where about 600 ships sailed daily (Richey 1971). The IMO, at that time, IMCO, recognizing the need to improve the safety of life at sea, published amendments to the 1960 SOLAS convention via Resolution A.205 (VII). Among them, recorded in Annex VI, are those which referred to Chapter V, Regulation 8 on "Routeing" (IMCO 1971a:9). But the Organization's attempt to publish new Resolutions continued to eradicate the phraseology. Recalling that the Organization was recognized as the only international body to establish and adopt measures at the international level regarding routes and areas to be avoided by ships or certain classes of ships, it urged Contracting Governments to use their influence to ensure proper use routes adopted, and to do everything in their power to ensure adherence to the provisions adopted by the Organization, in relation to the route of ships. Only in the section (e) of the Resolution A.205(VII), are government indications given, while, when one-way traffic lanes are specified, ships using these lanes must advance in the specified direction of traffic flow. Additionally, ships crossing the lanes will do so at right angle as far as possible.

Subsequently, the resolutions referring to the Traffic Separation Schemes, (TSS), will be given with references to the nautical charts and the limits in coordinates. Examples are Resolution A.227(VII), System of TSS in the Dover Strait and adjacent areas, or the Resolution A.226 (VII) Traffic Separation Schemes (IMCO 1971b,c) from different parts of the world. Impractical and laborious systems that are reminiscent of those who still navigated and corrected the navigation charts by hand with pencil and marker on the bridge. Electronics will also put an end to this system, "Notices to Mariners" (NMs).

With the arrival of COLREG in its 1972 version, until their, entry into force on July 15, 1977[8], the TSS were clearly recognized, and the obligations derived from their use by ships were clearly defined in Rule 10. This rule was included in the Steering and Sailing Rules section and gave guidance to determine the safe speed, the risk of collision and the conduct of vessels when navigating in or near the TSS. Its exclusive enforcement led to conflict with other Rules and, also, with common sense (Irving 1982). Mainly rules such as, at that time, Rule 3: Vessels constrained by their draught (today Rule 28) or Rules, 15 and 17.

However, this controversy is something that has lasted over time, as explained below, being the object of study by other experts who have tried to shed light on the behaviour of ships using a TSS, in reference to the rest of the rules. However, despite some amendments to the Collisions Regulations, it remains static in this regard.

2.1.3. Routeing System standardized (1973).

In 1973 the IMCO adopted the general provisions pertaining to Ships' Routeing, a detailed resolution that followed the previous effort to describe TSS from several parts of the world by latitude and longitude, the Resolution A.161(ES.IV) in 1968 (IMCO 1968b).

The International Organization recognized that the use of the routing measures adopted contributed to the safety of navigation, by reducing the risk of collisions and strandings, and therefore continued to revoke previous resolutions, in order to improve, whilst indicating that this need is in harmony with the International Regulations for Preventing Collisions at Sea. That is why Routeing was also included in the SOLAS V in Regulation 8 (at that time, later it was moved to Regulation 10).

The revised general provisions for adoption, terminology, symbols, methods and general principles of ships' routeing arrived with the Resolution A.284(VIII), adopted on 20 November. An extensive document, a total of 66 pages, that contains, in its Annex I: 9 definitions, 14 symbols and 5 figures; and in Annex II: TSS of the whole world, including deep water routes and areas to avoid, given in coordinates, latitude, and longitude. But the six specific areas of the world described are Baltic Sea, Western Europe waters, Mediterranean area, Indian Ocean and adjacent waters, North America - Atlantic Coast and Pacific Coast, Australasia. However, if only the theoretical part regarding routeing, is counted, it is 11 pages (IMCO 1973).

Nevertheless, the most interesting thing about this document is, on the one hand, that the Organization compiled the SR graphics, giving them colour (mainly magenta) and the first definitions. Elements that form the basis for organizing traffic, not only in coastal areas, but also in entrances and exits to ports, narrow passages, archipelagic sea lanes, areas to avoid and international waters. On the other, that the bases were forged so that the routes for the ships to follow, in certain areas of the world, were

[8] Retrieved from: https://www.imo.org/en/About/Conventions/Pages/COLREG.aspx

standardized, although the positions were illustrative and were not to be used for navigation, as recommended at the beginning of each area described: [sic] “Mariners should consult the appropriate nautical publications and charts for up-to-date details on aids to navigation and other relevant information”.

The 9 defined terms include: Routeing, Traffic separation scheme, Separation zone or line, traffic lane, Roundabout, Inshore traffic zone, Two-way route, Track, and Deep water route.

The 5 graphic from this Resolution are a description of routes, using very simple drawing, simply to give an explanation of their functions. The schemes were designed after careful consideration of local conditions, traffic density, prevailing hydrographic and meteorological conditions, available space for manoeuvring and, in general, their length was to be the minimum necessary. Thus, the methods used were: “By separation zones or lines (…), By natural obstacles and geographical defined objects (…), By inshore traffic zones (…), By sectors at approaches to focal points (…) and by roundabouts”.

With the COLREG of 1972 just adopted, this resolution was limited in its naming by notation in its rules 1 (d) and 10. Some areas had been examined that same year, as it was observed that some rules could conflict with the schemes, although, in the resolution, there are detailed explanations of the use of routeing systems but even so, time will bring more controversies to light.

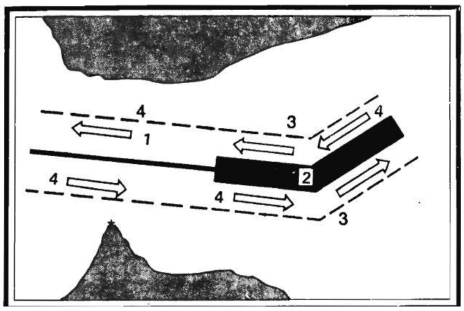
2.1.4. General provisions on Ships' Routeing (1985).

The establishment of procedures for the adoption of traffic separation schemes and other routeing systems jumped 12 years to adopt a new resolution, the Resolution A.572 (14) adopted on 20 November 1985 as general provisions on ships' routeing were reduced by half, from 66 to 33 pages. It presented more definitions (from 9 to 14), up to 25 detailed symbols and 18 figures, this time, with explanations of each one. All of Annex II disappeared with the global TSS described using coordinates for its location, which meant that the theoretical part was tripled, with respect to the previous one.

The 5 definitions added were: Recommended route, Precautionary area, Area to be avoided, Established direction of traffic flow and Recommended direction of traffic flow. There appears to be an attempt to clarify terms, with a view to increasing safety, given the controversies and accidents that continued to occur, so terms such as "recommended”, “caution”, “precautionary”, or “avoid" were included within the newly added definitions.

Regarding the 6 added drawings, these correspond to more sophisticated traffic junctions: (6) Separation of traffic at a crossing, (7) Separation of traffic at junction, (8) A junction, showing a separation line substituted for a zone, where there will be crossing traffic, (9) Precautionary area at a focal point, (10) Precautionary area with recommended direction of traffic flow around an area to be avoided, and (11) Precautionary area at a junction, with recommended direction of traffic flow. In addition, 7 other routeing methods were considered: Deep-water route (two-way); One-way deep-water route (within a traffic lane); Recommended directions of traffic flow between two traffic separation schemes; Two-way route (with one-way sections); Recommended routes; Recommended tracks (in black) and an Area to be avoided.

The matching Routeing infographics of the old and new resolution, after more than a decade, had hardly changed. Figure 1 of each from each is shown as an illustration.



1- Separation lines.
2- Separation zone.
3- Outside limits of lanes.
4- Arrows indicating main traffic direction.

Figure 5. Traffic separation by separation line and zone. (1973)

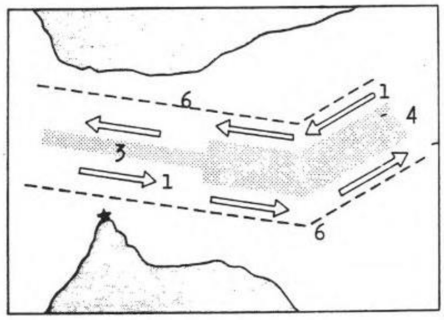
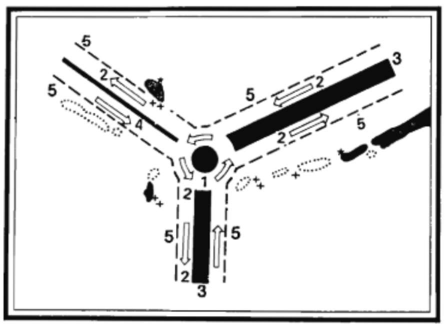


Figure 6. Traffic separation by separation zone line. (1985)

The main differences lie in the fact that the references to deep-water route were expanded, to avoid the problems that vessels limited by draught could suffer when navigating these areas, and the new traffic junctions drawn showed that the traffic flow had been considered in a more complex way. In 1973, the traffic junctions drawn were at three, while, in 1985, crossing at four were included.

As an example of the evolution and refinement of routeing, the following figures are presented. A traffic junction area with recommended directions. The previous resolution did not show any caution symbols with an exclamation point within a triangle. This type can be found, for example, in the Strait of Gibraltar.



1- Circular separation zone
2- Arrows indicating traffic directions
3- Separation zone
4- Separation line
5-Outside limits of lines

Figure 7. A roundabout where several traffic separation schemes meet (Figure 5 form 1973)

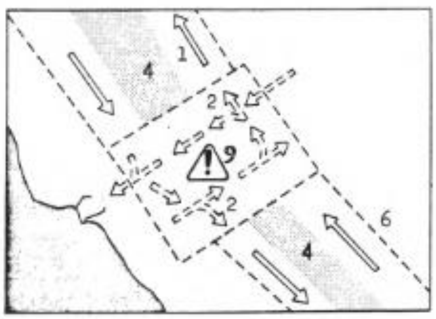


Figure 8. Precautionary area at a junction, with recommended directions of traffic flow. (Figure 11 from 1985)

All these extensions to the resolution show that the routeing system is complex, despite already having a consolidated maritime traffic code. The COLREG, on the one hand, and the IMO, on the other, both trying to clarify and qualify what the Collision Regulations leaves as an open subject.

The need for the IMO to publish its responsibilities and, at the same time, indicate that which Governments have, was reflected in an ample section of this resolution. Evident concerns regarding how to interpret the symbolisms are reflected in the descriptions of each figure. How to propose the implementation of a routeing system is described in four sections that cover topics on design criteria, how to apply temporary adjustments to traffic separation schemes, the use of routeing systems and the representation of the type of symbols on charts. Note the immense effort on the part of the IMO to try to specify, detail, or clarify the resolution, always in favour of safety, encouraging governments to comply with recommended practices.

The resolution holds extensive references to COLREG, 8 years after it had come into force, in its rule 10, (the world "collision" appears 17 times) but also giving attention to the areas where intense crossing situations occur, such as in the English Channel and the Strait of Dover, with an increased risk of collision in these areas. Why does this need arise? COLREG, as a manual of rules for traffic at sea, for all "vessels" and not "ships", carries various ambiguities in its purely technical purpose. Historically, the roots of the current regulation developed when merchant vessels were equipped with an engine, leaving behind sail propulsion, a conjunction that occurs in the early 19^{th} century. Thus, a legal need arises that has to do with the engine, although the Regulation refers to all types of ships, including sailing vessels. It is one of the most important instruments that navigators have, but nonetheless, it is interpretive. The Regulation does not prevent collisions by itself, although it has been conceived for prevention. Seafarers who interpret it correctly are able to avoid them but, if the interpretation is not the same between two ships, it can result in an accident, although both have interpreted the same Regulation. The disparate interpretation is what gives it ambiguity. This matter has been studied in depth by various professionals in the maritime sector. The COLREG was defined as: "A Sacrosanct System based on Specious Logic" (Corbet 1992:428) where the weaknesses of the Rules are reflected in the article.

The whole Convention was analysed, rule by rule, in the book "Los abordajes en la mar"[9] (Salinas 2004b), a book that sheds light on the regulations and this should be available to all sailors, since it finds all the answers to the questions that arise in the prevention of collisions, with practical examples and analysis of real accidents that have happened.

The wording is an interpretive text, full of conditionals, where it is not fully clarified to which conditions they refer " if the circumstances of the case admit". There are 13 "ifs" out of 41 rules in the versions amended up to 2018 (Hossain 2020).

[9] "Collisions at Sea".

The routeing system encounters Rule 9, "Narrow Channels" when, as an example, at the mouth of the port, on occasions, a fishing boat or a sailboat asks the merchant ship by radio to manoeuvre it just because they are minors[10]. Also, ambiguities in the rules 8, 10 and 15, when a vessel follows a TSS and another minor wishes to cross starboard, there is a solution that is not based on the length of the crossing vessel, "not impede the safe passage and keep out of the way, because they are not synonymous" (Salinas 2002).

The final analysis leads to the observation that it is important to highlight that the TSS of this Resolution have a broader concept of what schemes they are, with respect to the Convention on the International Regulations for Preventing Collisions at Sea. The COLREG only refers to the TSS approved by the IMO, while this Resolution includes much more, such as two-way roads, recommended tracks, areas to avoid, coastal traffic zones, roundabouts, precautionary areas and deep-water routes. Passive measures as they do not require reporting but must be respected (Salinas 2004b:65-9).

Despite these controversies between the rules and the routeing system, TSS is credited with a 50% reduction in boardings over the last 40 years, in addition to the improvements that have been made to the bridges of the ships (Salinas 2004b:20). And the IMO, through the SOLAS V, reminds the masters that the intended voyage plan shall take into account ships' routeing systems in its Regulation 34.

Up to this point, with all that routeing entails, and with VTS services running for over 30 years, there is no reference to it.

2.2. Ship Reporting Systems (SRS).

The reporting action is linked to radio contact between ships and shore stations, but in the primary sense that the report goes from ships reporting ashore. The beginnings of this act are associated mainly with the year 1979**,** in two respects.

One, the reporting system was initially identified for the purpose of facilitating Search And Rescue (SAR) operations. The 1979 Convention, the International Convention on Maritime Search and Rescue (SAR) of the IMO contains Chapter 5, for Ship Reporting Systems (SRS). However, when SRS were included in SOLAS V (Regulation 8-1 in 1994 but currently in Regulation 11), they were associated with contributing to the safety of life at sea, safety and efficiency of navigation and/or protection of the marine environment. Thereby the purposes of the SRS were distributed in both agreements[11].

Two, in the Strait of Dover, after the routeing system became mandatory, a Ship Movement Reporting scheme (MAREP) was introduced (Squire 2003), thus began the requirements for ships to report their movements ashore but on a voluntary basis.

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[10] Retrieved from: https://www.practicosdepuerto.es/es/colegio-federacion/publicaciones/derecho-de-paso-en-las-bocanas-de-los-puertos

[11] SOLAS V. Regulation 11 Ship reporting systems*: This regulation does not address ship reporting systems established by Governments for search and rescue purposes, which are covered by chapter 5 of the 1979 SAR Convention, as amended. pp. 361-2.

All ships, whether certain categories of ships or ships carrying certain cargoes, may use the SRS, in accordance with the provisions of each system adopted. Ship Reporting Systems (SRS) contribute to the safety of navigation and the purpose and objective is to monitor maritime traffic. However, it is not difficult to envisage that, if there is a reporting system and an incident occurs, the procedure SRS goes into alert mode. For distress and safety purposes, the system makes it possible to provide information (to another system, if the rescue service is delegated) on navigational hazards, medical advice, or to direct the nearest ship to the ship in distress and define the search area. The same happens with pollution incidents, so the SRS was also linked to the framework agreement (MARPOL). The ship's report is a precondition for providing assistance.

The SRS formula becomes voluntary or mandatory, depending on the legal stipulations of each Government and zone. Ships submit their reports, following the same predetermined forms, on regular deadlines or in some other agreed manner. But the IMO will establish specific resolutions for mandatory reports in different parts of the world.

As an example, the first part of the world to implement a routeing system, had a mandatory ship reporting system in 1999. At 0000 hours UTC on 1 July, the Ship Reporting System in the Strait of Dover[12] entered into force (IMO 1999), that is, 28 year later.

2.2.1. General principles for Ship Reporting Systems, SRS (1983).

Resolution A.531(13), adopted on November 17, 1983, addresses the general principles for the Ship Reporting Systems (SRS) (IMO 1983b). It is noteworthy that, although maritime traffic services (VTS) had not yet been formally adopted by the IMO, they were already cited in numerous resolutions (although not in this one). The analysis of this resolution resides in detecting the points that are related to the premise of this thesis.

On review, as it predates the first IMO VTS Guidelines, it was recognized for the first time that, in the absence of general but specific SRS procedures and reporting formats, this could cause confusion to captains of vessels navigating areas that provided different reporting services. Thus, Member Governments were urged to comply with the principles specified in the Annex to the Resolution.

The SRS was presented as a conjunction of accessing and collating diverse information. Considering the SAR convention, the use the Standard Marine Navigational Vocabulary (IMCO 1977) and the International Code of Signals is encouraged. It was established that the radio reports referring to search and rescue, traffic services, weather forecasting and prevention of marine pollution should comply, as far as practicable, with 15 principles. It was only for the exchange of essential information, the minimum possible, without overloading communications, which would be useful in an emergency. The next 5 points under study are highlighted:

[12] Resolution MSC.85(70) Mandatory Ship Reporting Systems adopted on 7 December 1998.

1. The resolution recognizes the need to establish an international agreement to unify procedures and reporting formats and thus not cause confusion to ships sailing in different areas of the world. Today, in 2021, it continues to be a key principle within the maritime sector.
2. In Principle number 7, it is considered that the system, therefore, the action of the vessels to be reported is labelled as being a system in itself, and the basic information, such as ship data, facilities and equipment on board, amongst other information, should be reported only once, kept in the system and updated by the ship, when changes occur in the basic information reported. This point is important since, currently, after nearly 40 years, it remains unresolved: in systems where several stations coexist in the same area, the same information is being requested from ships, so that ships are under the obligation to repeat the same information several times to shore. As will be shown later, digitization will solve this matter (see Part III).
3. Ship reporting systems should preferably use a single operational radio frequency (principle 13); When additional frequencies are needed "the number of frequencies should be restricted to the minimum required for the effective operation of the system". The discussion is in the "number" and in the "effective" term. The "minimum required" is a vague term, how many are minimum to be effective? Linking with the previous point, if several stations coexist in the same area, there will be different channels to tune in to and this can also cause confusion, as will be seen later (see Part II).
4. The ship notification system should provide for special reports from ships on defects or deficiencies, with respect to their hull, machinery, equipment or manning or on other limitations that may adversely affect navigation, and also provide for special reports on incidents of marine pollution (principle 15). History has shown that the information to be reported is dynamic and must be contemporary, examples are incidences and extent of terrorism on board, through the International Ship and Port Facility Security Code (ISPS) or the health status of the crew in terms of contagious diseases, such as Ebola in 2014 or Covid-19 in 2019.
5. One of the report formats includes the navigation plan. This provides information on the planned route precisely, giving the latitude and longitude of each track between two points, with the date and time to pass. Knowing from land the navigation plan of a ship is part of the extension of powers for the VTS, which will be discussed later (see Part III).

2.2.2. Guidelines and criteria for Ship Reporting Systems, SRS (1994).

The General Principles for SRS from 1983 to 1997 were expanded to "General Principles for Ship Reporting Systems and Ship Reporting Requirements, including guidelines for reporting incidents involving dangerous goods, harmful substances and/or marine pollutants" with the Resolution A.851(20). All the subsequent resolutions revoking the previous ones, continued to generically name vessel traffic services without further specification. There is discussion of radio reports between ships and coast radio station (CRS), the nearest coastal State, shore establishment or shore station. The Resolution A.531(13) was revoked by A.598(15), this was revoked by Resolution A.648(16) and this was revoked by the Resolution A.851(20). The following table shows the minor evolution, even after 14 years.

Year	Reference	Title	VTS reference
1983	Resolution **A.531(13)**	General principles for Ship Reporting Systems	traffic services (once) CRS
1987	Resolution **A.598(15)**	General Principles for Ship Reporting Systems and Ship Reporting Requirements	vessel traffic services (once) CRS
1989	Resolution **A.648(16)**	General principles for ship reporting systems and ship reporting requirements, including guidelines for reporting incidents involving dangerous goods, harmful substances and/or marine pollutants	vessel traffic services (once) CRS
1997	Resolution **A.851(20)**	General principles for ship reporting systems and ship reporting requirements, including guidelines for reporting incidents involving dangerous goods, harmful substances and/or marine pollutants	vessel traffic services (once) CRS

Table 2. IMO Resolutions evolution with VTS reference

Between 1989 and 1997 a major amendment to SOLAS appeared. In 1994, the Resolution MSC.31(63) included amendments to SOLAS 1974, and the SRS was added as a new regulation for Chapter V, Regulation 8-1 on the Ship Reporting System with 12 subsections (a-l). (This currently has 11 subsections).

This amendment to the SOLAS V generated a new resolution, 7 months later, the Resolution MSC.43(64), adopted on 9 December 1994 as "Guidelines and criteria for Ship Reporting Systems". This meant that the Guidelines and criteria for Ship Reporting Systems, tenuously linked to the VTS, came with a resolution from the Maritime Safety Committee of the IMO "Ship reporting systems (…) may or may not be operated as part of a vessel traffic service". Additionally, when it refers to the personnel who will be in charge, reference is made to VTS Operators.

- 1994 Resolution MSC.43(64). Guidelines and criteria for Ship Reporting Systems. The beginning of SRS linked with VTS

Later on, this resolution will gain force when it appears within the Guidelines and criteria for VTS, together with the IALA VTS Manual. (See Part II).

2.3. In conjunction, RS and SRS.

Organizing traffic by tracking routes and establishing a reporting system, when they are used, it is logical that both systems converged in normative term. The two systems will be part of the international SOLAS V Convention and reference resolutions will link them.

- In conjunction in the SOLAS V:

The IMO is recognized for both Ships' Routeing systems and Ship Reporting System, as the only international body for developing guidelines, criteria and regulations on an international level. Governments can establish their own SR and SRS systems and submit, or not submit them, for IMO approval but, if either of the two is not submitted to IMO for adoption, the guidelines and criteria developed *shall be taken into account.* Only in the case that more than one Government shares an area, must they reach agreement and formulate joint proposals.

In 1995, Resolution MSC.46(65) included the adoption of amendments to SOLAS 1974. It was included in Chapter V, Regulation 8 as Ships' Routeing, with 11 subsections (a-k), because it had already been included previously in 1971 as "Routeing" also included as Regulation 8. (This currently has 10 subsections).

SOLAS V		
1971	1994/5	
Regulation 8	Regulation 8	Ships'Routeing
	Regulation 8-1	Ship Reporting System

Table 3. SOLAS V evolution

The two SOLAS Regulations[13] will have in common some features, as indicated in the definition of each described in the first point:

<table>
<tr><td>Ships' routeing</td><td rowspan="2">contribute to safety of life at sea, safety and efficiency of navigation and/or protection of the marine environment.</td><td>Ships' routeing systems are recommended for use by, and may be made mandatory for, all ships, certain categories of ships or ships carrying certain cargoes, when adopted and implemented in accordance with the guidelines and criteria developed by the Organization</td></tr>
<tr><td>Ship reporting systems</td><td>A ship reporting system, when adopted and implemented in accordance with the guidelines and criteria developed by the Organization pursuant to this regulation, shall be used by all ships or certain categories of ships or ships carrying certain cargoes in accordance with the provisions of each system so adopted.</td></tr>
</table>

Table 4. RS vs SRS

[13] SOLAS, v3 (2004). pp.359-363.

Both are included in the SOLAS V but not linked. Where they are linked is in resolutions.

- Linked in Resolutions:

In 1997 the “headline” of a resolution put RS and SRS together. This was the Resolution A.858(20) “Procedure for the adoption and amendment of Traffic Separation Schemes, routeing measures other than traffic separation schemes, including designation and substitution of archipelagic sea lanes, and Ship Reporting Systems”.

The time that both systems took to appear in the same resolution is shown chronologically, the two systems intrinsically related to maritime traffic. (Table 5).

RS			SRS
RS Voluntary		1967	
R.A.205(VIII)		1971	
R.A.184(VIII)		1973	
		1983	R.A.531(13)
R.A.572(14)		1985	
	14 years	1994	MSC.43(64)
MSC.46(65)		1995	
		1997	R.A.851(20)
R.A.858(20)		**1997**	**R.A.858(20)**

Table 5. RS vs SRS from 1967 to 1997

Chapter 3. The beginnings of the VTS system.

At the beginning of the VTS system, there is more discus1971sion of the regulations around recognition by the IMO, via Resolutions and amendments to SOLAS V, than of new technologies and infrastructures. As will be seen later, this trend will be reversed, leaving the "legal paperwork" part of the framework refracted, while the VTS system grows and is equipped with new means to carry out its functions.

3.1. First international recognition, (1968).

The first official recognition of the information exchange system between ships and shore authorities for the increase of safety of navigation[14] by the IMO did not happen until 1968. At the time, the Inter-Governmental Maritime Consultative Organization (IMCO) adopted, through the Assembly of the Maritime Safety Committee, the Resolution A.158 (ES. IV) Recommendation on Port Advisory Services (PAS) and this recommendation was received by ports as a valuable contribution to port safety and its approaches (IMO 1968a). In this sense, it promoted two points addressed to governments in favour of safety: one, which is particularly relevant for oil terminals or dangerous goods, and the second being the use of the estimated time of arrival (ETA), which also helps to manage the arrival of ships, contributing to efficiency. The birth of the principles that have been maintained to support the VTS services can be

[14] Available at: https://www.imo.org/en/OurWork/Safety/Pages/VesselTrafficServices.aspx

seen: to contribute to safety, increase efficiency and protect the marine environment. Although, in 1968, the word “efficiency” still does not appear implicitly and the protection of the marine environment is only specified for cargo operations in oil terminals, with noxious or hazardous substances.

A decade after the development of this new shore service, aimed at ships, a series of serious accidents occurred between the 60s and 70s, with ships sailing near the coast, causing profound damage to the environment and the sea. One of the main references is the Torrey Canyon oil tanker, the first of the large supertankers, capable of carrying, at that time, a load of 120,000 tons, which struck the Seven Stones Reef off Land’s End, off the southwest coast of England, on March 18, 1967, spilling more than 100,000 tonnes of crude oil and causing disastrous consequences. Another, the Very Large Crude Carrier, VLCC Metula, had an accident and ran aground while crossing the Strait of Magellan in southern Chile, with 206,000 tons onboard. She spilled over 50,000 tons of Saudi Arabian crude oil and 2000 tons of bunker on August 9, 1974. Others include the Amoco Cadiz, which sank off the French coast spilling almost 230,000 tons of oil, on March 16, 1978, and the Atlantic Empress, which spilled 287,000 metric tonnes of crude oil into the Caribbean Sea, after colliding with another oil tanker, the Aegean Captain, on July 19, 1979. This happened 18 nautical miles east of the island of Tobago, at the time, not controlled. Today, however, it is within the reach of a VTS.

All these accidents caused ecological disasters.

On 11 January 1971, a major accident occurred in the Strait of Dover, denoting that unregulated navigation in a traffic zone was not safe and neither was the voluntary report. Perhaps the most notorious incident was the collision between the freighter Paracas and the motor tanker Texaco Caribbean. The Texaco Caribbean exploded, split in two and sank, causing the spill of 600 tons of bunker. Unfortunately, there were 9 casualties among the crew members[15] but, fortunately, it was in ballast. However, accidents are always a concatenation of events, and the Texaco Caribbean was no exception, becoming a wreck that, although it was marked, was hit, the next day, by the freighter Brandenburg, which sank minutes later. At that time visibility was 1-mile, due to thick fog. There were 21 lives lost. And a month later, on February 27, another ship, the motor vessel Niki, also sank after running aground on the wreck and 22 people (21 crew and one passenger) died.The following table 6 indicates the main oil tanker accidents; all spills were crude oil. The objective was to see at what distance in nautical miles from the shore, accidents occurred. Of the 27 registrations, 10 were out at sea, the rest near shore.

[15] Retrieved from Centre for Bibliographical Studies and Research. Available at: https://cdnc.ucr.edu/cgi-bin/cdnc?a=d&d=DS19710111.2.16&e=-------en--20--1--txt-txIN--------1

	Year	Ships	Location	Shore	Tons	Cause
1	1967	Torrey Canyon	Isles of Scilly	15	119.000	Grounding
2	1968	World Glory	Durban, South Africa	65	52.900	Broke up
3	1969	Hamilton Trader	Liverpool Bay, England	Inshore	700	Collision-Hannes Kuppel
4	1971	Wafra	Cape Agulhas, South Africa	4	30.000	Collision-Paracas
5	1972	Sea Star	Gulf of Oman	700	115.000	Collision-Horta Barbosa
6	1974	Metula	Strait of Magellan	Inshore	53.000	Ran aground
7	1975	Jakob Maersk	Leixoes, Portugal	Inshore	88.000	Grounding
8	1976	Urquiola	A Coruña, Spain	Inshore	108.000	Grounding
9	1977	Hawaiian Patriot	Honolulú	300	99.000	Broke hull
10	1978	Amoco Cádiz	French coasts of Brittany	Inshore	227.000	Grounding
11	1979	Atlantic Empress	Tobago	10	287.000	Collision-Aegean Captain
12	1979	Independenta	Bosphorus, Turkey	Inshore	94.000	Collision-Evrialy
13	1980	Irenes Serenade	Navarino Bay, Greece	Inshore	100.000	Explosion
14	1983	Castillo de Bellver	Saldanha Bay, South Africa	34	257.000	Explosion
15	1983	Sivand	Humber estuary, England	Inshore	6.000	Collision-Jetty
16	1983	Assimi	Muscat, Oman	55	53.000	Explosion
17	1985	Nova	Off Kharg Island, Gulf of Iran	90	70.000	Collision-Magnum
18	1988	Odyssey	Off Nova Scotia, Canada	700	132.000	Explosion
19	1989	Khark 5	Atlantic coast of Morocco	120	80.000	Explosion
20	1989	Exxon Valdez	Prince William Sound, Alaska	Inshore	37.000	Grounding
21	1991	ABT Summer	Angola	684	260.000	Explosion
22	1991	Haven	Genoa, Italy	Inshore	144.000	Fire/explosion
23	1992	Katina P	Maputo, Mozambique	Inshore	72.000	Broke/grounding
24	1992	Aegean Sea	A Coruña, Spain	Inshore	73.500	Grounding
25	1993	Braer	Shetland Islands, UK	Inshore	85.000	Grounding
26	1996	Sea Empress	Milford Haven, UK	Inshore	72.360	Grounding
27	2002	Prestige	A Coruña, Spain	155	64.000	Hull failure

Table 6. Major oil tanker accidents

The pressure on Government Authorities increased, and various studies highlighted that traffic surveillance would be one of the factors that could help reduce these accidents, so efforts to further expand the use of radar surveillance were doubled. At the international level, ports, captains, and pilots soon reached accord in this discipline of accepting the regulation of traffic from shore, in favour of safety and protection of the environment. The VTS concept as a system, began to navigate.

3.2. Main international maritime conventions, until 1982.

The recognition of the VTS system by the IMO through a Resolution did not arrive until 1985, 17 years after that first international recognition, in 1968, and 37 years after those first tests in port with a radar and a radio. But, before this great step for VTS, it should be noted that during this period, notable international agreements regarding navigation and safety emerged, the great maritime pillars were formed and are still considered essential. All of them have some connection with the VTS, in that they form part of the training of all sailors and, by extension, of the VTS operator. The main international maritime conventions were, in chronological order, follows:

- In 1957, the International Association of Lighthouse Authorities (IALA) was established, or Association Internationale de Signalisation Maritime, (AISM). Nowadays this is the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA).
- In 1958 and 1960, the United Nations Conferences on the Law at Sea was held in Geneva (which evolved into UNCLOS).
- In 1965, the Convention on Facilitation of International Maritime Traffic (FAL) was adopted to facilitate international maritime traffic. The main objectives of the Convention are to avoid unnecessary delays in maritime traffic, to aid cooperation between governments and to ensure the highest possible degree of uniformity in formalities and other procedures. This agreement is interesting since, despite its age, it will be connected with future technologies in the search for the digital "Single window", a concept analysed in Part III. The maritime sector, international maritime transport, is one of the activities most subject to numerous regulations, the effort to simplify it continues.
- In 1966, the International Convention on Load Lines (LL) was formed. This agreement, although it was initiated based on the principles of reserve buoyancy (in 1930), is related to the limitations on the draught of the ships, limits that are given in the form of freeboards, ensuring adequate stability and avoiding excessive stress on the hull as a result of overloading, also connected with the pilot ladder type. Concepts related to the VTS and this will eventually become part of the MARPOL and SOLAS conventions.
- In 1972, on October 20, the Convention on the International Regulations for Preventing Collisions at Sea (COLREG) was adopted and entered into force on July 15, 1977, replacing the Collision Regulations of 1960[16].
- In 1973, the International Convention for the Prevention of Pollution from Ships (MARPOL) was activated. It was modified in 1978, MARPOL 73/78, an agreement that has been growing and adapting to ongoing developments, according to the changing, yet constant demand for environmental protection[17].
- In 1974, the International Convention for the Safety of Life at Sea (SOLAS) was adopted and entered into force in 1980, although the first version was adopted in 1914, after the Titanic disaster in the early hours of April 15, 1912. Today it has a full Chapter (the Chapter V) referred to the safety of navigation, but it also covers various aspects of ship safety, including minimum standards for the

[16] Available at: https://www.imo.org/en/About/Conventions/Pages/COLREG.aspx

[17] Available at: https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

construction, equipment and operation of ships. In this first version, there was no reference to vessel traffic service, VTS. This inclusion would come 23 years later, in 1997, through Regulation 12 (IMO 2004, 363), as indicated below (Part II).

- In 1976, the Convention on the International Maritime Satellite Organization (IMSO)[18] was adopted and entered into force 3 years later. The IMSO is part of the Global Maritime Distress and Safety System (GMDSS) with Inmarsat and Iridium, and the Long-Range Identification and Tracking of Ships (LRIT). The launch of the world's first telecommunications satellite, Telstar, was in 1962 and, since then, space has been filling with satellites to improve maritime communications. The IMSO (later subdivided into Inmarsat) is an intergovernmental organization but, due to the process of liberalization and privatization of global and regional satellite communications services, more options are fast developing.

- In 1977, the TSS of Dover became mandatory, with the inclusion of traffic separation schemes in the COLREG in its rule 10 (IMO 1972).

  That same year, the IMCO established the Standard Marine Navigational Vocabulary (SMNV), (IMCO 1977), amended by the IMO in 1985, which has been known, since 2001, as the Standard Marine Communication Phrases (SMCP), through the Resolution A.918(22).

- In 1978, the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW) was held (ITF 2010:11) and entered into force in 1984, with major revisions arriving in 1995 and 2010.

- In 1979, the international conference in Hamburg brought the International Convention on Maritime Search and Rescue, (SAR), ensuring that, no matter where an accident occurs, the rescue of people in distress at sea would be coordinated by a SAR organization or, where necessary, through cooperation between neighbouring SAR organizations. The "obligation" of assistance, although it seems somewhat unnatural to regulate something as natural as helping, is legislated at sea by Chapter V of SOLAS, Regulation 33 "Distress messages: obligations and procedures" (IMO 2004:384). Regardless of this, the obligation of ships to go to the assistance of vessels in distress has been enshrined in marine tradition for centuries. Following the adoption of the Convention, the IMO's Maritime Safety Committee divided the world's oceans into 13 search and rescue areas, in each of which, the countries concerned have delineated the search and rescue regions for which they are responsible. Recommendations on the establishment of ship reporting systems for search and rescue purposes[19] were included, noting that ship reporting systems could provide adequate

[18] Available at: https://www.imo.org/en/About/Conventions/Pages/Convention-on-the-International-Maritime-Satellite-Organization.aspx

[19] Described in Chapter 2. Section 2.2 Ship Reporting Systems of this Thesis.

information for search and rescue purposes in a given area. The Convention entered into force in 1985 (IMO 2006:3).

- In 1982, the totem of totems arrived, considered one of the most important multilateral treaties in history: the United Nations Convention on the Law of the Sea (UNCLOS 1982). After the important agreements mentioned previously, which set clear mandatory guidelines for member countries in the maritime field, the UNCLOS’82 is the cornerstone that defines the jurisdiction of the coastal states, endowing them with the power to adopt laws for the safety of navigation and regulation of traffic.
- In 1982, the International Maritime Organization (IMO) changed its acronym[20]. The former Inter-Governmental Maritime Consultative Organization, (IMCO), was established, after the agreement that emerged at the United Nations conference held in Geneva, from February 19 to March 6, 1948. Since its founding, it has been working in maritime safety and cooperating between various States and the shipping industry. In 1959, it began to introduce measures in the form of Conventions, Recommendations and other fundamental instruments for the safety of navigation.

3.3. The first Guidelines for VTS, (1985).

The Resolution A.578(14) of the IMO adopted on November 20, 1985, as "Guidelines for Vessel Traffic Services" represents, in terms of the Guide, the former historically. Moreover, this meant that maritime traffic surveillance systems were gaining international recognition. It was a definitive stage for the vessel traffic services, where the need for ships to report ashore was highlighted, when approaching a port and within territorial waters, including narrow channels, in areas of heavy traffic, when dangerous goods are involved or in sensitive areas. In general, operational procedures and VTS planning were outlined. The IMO recognized that the areas provided with VTS had made a valuable contribution to the safety of navigation, had improved the efficiency of traffic flow and also reduced the risk of pollution, so the responsibility of the Member States was linked to the provision of the VTS service itself. In this way, the IMO included the VTS within the regulations and guidelines related to maritime safety, the prevention and control of pollution of the sea by ships, but also attributed to them the purpose of improving traffic efficiency when it described them.

This new resolution referred only to the first recognition in 1968, (17 years earlier), and to Resolution A.531(13) on general principles for ship reporting systems (SRS) of 1983. Therefore, without having defined who would be in charge of the SRS, at this point, they were attributed to the VTS. In turn, the Resolution on General Provisions RS (1985), referring to the routes of the ships, did not make any mention of the VTS or who should ensure that the ships comply with the TSS. However, it was mentioned here that the VTS would provide information on the routes and even offer information on

[20] Available at: https://www.imo.org/en/About/HistoryOfIMO/Pages/Default.aspx

alternative routeing[21], also the authority to establish routes to follow and speed limits to be observed[22]. Therefore, another function was attributed to the VTS.

The structure of this document begins with statements from the IMO Assembly, common in this type of document. It includes an Annex as a preamble to describe the VTS guidelines and two Chapters. Chapter 1 is dedicated to the objectives and procedures and divided into 7 sections. Chapter 2 is concerned with how to plan a VTS. A total of 17 pages of which is worth highlighting and analysing:

a) It is recognized that the lack of standardization in the use of different procedures by VTS may cause confusion for captains moving from one VTS area to another, thus the aim is for international uniformity. In Chapter 1, Item 4, the VTS functions are described, including: information, navigation assistance and traffic organization (the acronyms INS, TOS and NAS are not used) but, as will be seen later (Part III), this attempt to standardize its functions will require a rethinking of them.
b) The Annex begins with a Preamble. From Point 2, the concept that ships sailing beyond the Territorial Sea can use the VTS service on a voluntary basis is subtracted. Currently, the limits of the VTS, and what will happen beyond the waters whose states have jurisprudence, are still being studied.
c) A VTS is any service implemented by a competent authority[23]. The "VTS Authority"[24] "is the authority operating a VTS. It may include a governmental maritime administration, a single port authority, a pilotage organization or any combination of them". This definition will conflict with two important premises: one, it will not be understood by all countries in the same way; and two, inclusion or combination tends to disappear as specialization increases.
d) When the elements of a VTS[25] are defined including VTS organization, vessels and communications, it seems to understand the hole VTS system.
e) When the resolution refers to the means that the VTS operator needs to exercise its functions, this resolution indicates to "be equipped with communications facilities (…) have surveillance radar and other equipment", which involve VHF radio links which can be duplicated or complemented, for example with traffic signals since generally, the first contact between the vessel and the VTS is by radio, and this may be assisted by "technical means such as shore-based radar or VHF direction finder (DF)". The VTS Operator may collect data from "hydrological and meteorological sensors, radar, VHF direction finder, etc". An essential element of this thesis is the study the means that the VTS use. In this first resolution, in synthesis, radio and VHF are included, and it remains open what are "others" or "etc".

[21] Resolution A.578(14) Guidelines for Vessel Traffic Services. Chapter 1. Section 4. Functions of a VTS. 4.4 Information service. p.9.
[22] Ibid.Sect.4.6.
[23] Resolution A.578(14) Guidelines for Vessel Traffic Services. Chapter 1. Objectives and procedures. Section 1. Vessel traffic services. p. 5.
[24] Ibid. Section 2.1.
[25] Ibid. Section 3.

f) The "VTS Operator" is defined as the duly qualified person who performs the functions of the VTS and who has received specialized training and complies with the linguistic requirements, since English and the use of the Standard Marine Navigational Vocabulary are invoked.

g) The information requested from ships should be presented only once[26], (as also indicated in R.A.531(13) SRS) to avoid unnecessary repetitions of information, but even so, these repetitions are still not resolved.

h) To identify the status of message[27] addressed to ships, it is specified "Any VTS message directed to a vessel should make it clear whether it contains information, advice, or instruction". This two-way radio communication is eventually identified as "message markers" and evolves over time, using eight markers (IMO 2001c).

i) Back then, a sailing plan[28] "normally consisted of the estimated time of arrival in the VTS area or departure from a berth or anchorage in the VTS area. (…) In exceptional circumstances the sailing plan may be amplified at the request of the VTS centre. (…) The VTS centre may advise changes to the sailing plan to take account of the traffic situation or special circumstances. (…) After the sailing plan is agreed between the vessel and the VTS centre the vessel is permitted to participate in the VTS and should, as far as practicable, try to maintain the plan. (…) If special circumstances or the safety of traffic so require, the VTS centre may request the vessel to follow a changed sailing plan, indicating the reasons for its request. (…) when the VTS operator has the authority, a vessel may be instructed to maintain a specific sailing plan or implement changes to the sailing plan". It is very important to highlight all these citations, since they form part of the basis and principles on which the EU STM project is based (Part III), a navigation plan that will acquire all its dimension, in the exchange of a complete navigation plan between ships and shore.

j) A VTS area can be divided into sectors, but these should be as few as possible[29]. Without focussing on the ambiguity generated by the "as few as possible", the trend, as analysed in this dissertation, is that the VTS area will be understood as a whole, without divisions.

a) VTS centres in an area or sector should use a name identifier. When the number of different identifiers that the maritime sector has been applying is collected, this can even be confusing to the ships themselves (Hughes 2009), as will be seen in Part II.

In the way of comparative analysis, the following table depicts the points chosen from the Resolution on the first Guidelines for VTS that will be counteracted later with the subsequent ones.

[26] Ibid. Section 5.1.5.
[27] Ibid. Section 5.1.7.
[28] Ibid. Section 5.3.1.
[29] Resolution A.578(14) Guidelines for Vessel Traffic Services. Chapter 2. Planning a VTS. Section 4.

1st 1985 Resolution A.578 (14) Guidelines for Vessel Traffic Services
17 p. Annex, 2 Chapters
Requested by Governments and international organizations
Lack of standardisation*
R.A. 158(IV) PAS
R.A.531(13) SRS
SOLAS IV & V**
VTS Authority
Types of VTS: not specified
Types of VTS functions: information, organization, assistance
VTS procedures: information, advice or instruction
VTS Operator: appropriate qualifications and training
Use SMNV
VTS area can be divided into sectors
Equipment: VHF + Radar (+DF) and other equipment

Table 7. Highlights Resolution A.578 (14)

*RECOGNIZING ALSO that the use of differing vessel traffic service procedures may cause confusion to masters of vessels moving from one VTS area to another.
**SOLAS IV and V made reference only from the perspective of the ships: Vessels using a VTS.

With this resolution published, VTS was understood as the term adopted by the IMO to describe the range of systems operated by coastal states over specified areas of sea, adjacent to their ports or coasts, under which ship traffic is subject to the supply or exchange of information or the giving of advice or, possibly, of instructions by coastal stations, with a view to enhancing the safety and efficiency of that traffic (Plant 1990). It is clearly demonstrated that the VTS system is a compendium of three, where routes, communications and surveillance are located.

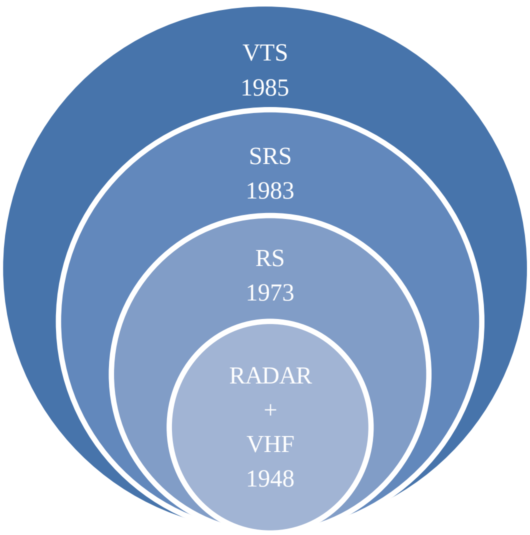

Figure 9. VTS system compendium. Own elaboration

Conclusions and recapitulation PART I

The recognition of the VTS by the IMO was essential for the acceptance and consolidation of the system at an international level. Over the last 50 years, through resolutions and amendments to SOLAS, the VTS has been gaining prominence. The international agreements signed during this period highlight the importance of the maritime sector worldwide. The Guidelines also highlighted the importance of pilotage in a VTS, and the importance of reporting procedures for ships passing through an area where a VTS operates.

This great step also represented the beginning of what would be a new profession, the internationally recognized VTS Operator. Their training is based on having received specialized qualifications and training, appropriate to their tasks within the VTS and also on the necessity that they meet the English language requirements, "if necessary" and are able to use the SMNV. It is also understood that the candidate should know how to handle the radio and radar systems.

Here is the point at which the Operator will be able to give information, organize traffic and provide assistance, and even instruct a ship to maintain a specific navigation plan or implement changes in its route, although the navigation plan is limited only to knowing the ETA or ETD, and whether the ship will go to anchorage or into berth, on arrival.

From its beginnings on the Isle of Man, with a VHF and radar, to this resolution, 37 years have passed. The following table 8 chronologically illustrates, in summary, the main international conventions and named resolutions, taking as reference the first steps with radar and radio equipment as VTS, until the publication of the first guidelines for VTS.

The following table summarizes the strengths achieved in the context of the VTS system:

International Conventions		Years	About VTS
The United Nations		1945	
IMCO		**1948**	**RADAR+VHF**
3rd SOLAS		1948	
		1950	VTS Centres
		1957	IALA Established
4th SOLAS		1960	COLREG
		1965	FAL
Load Lines (LL)		1966	
		1967	TSS Dover-voluntary
		1968	R. A.158 (ES.IV)
	37 years	1972	COLREG
MARPOL		1973	
SOLAS, as amended		1974	
		1976	Convention (IMSO C)
SMNV		1977	TSS Obligatory
STCW		1978	MARPOL 73/78
		1979	SAR
IMO		1982	UNCLOS
		1983	R.A. 531 (13) SRS
		1985	**R.A.578(14) Guidelines for VTS (1st)**

Table 8. The strengths achieved in the context of the VTS chronologically 1945-1985

Remarks Part I:
The first Guidelines for VTS (17p.)
The VTS service is recognized as a value for safety, efficiency, and the environment
Types of VTS: not specified
Mandatory in territorial waters, voluntary beyond
Lack of standardization is recognized
Specific equipment for the VTS: Radar and VHF
Functions: information, organization, and assistance
VTS area can be divided into sectors

Table 9. Remarks Resolution A.578(14) Guidelines for VTS

PART II

PRESENT – PRESENT: The consolidation of the VTS.

1997 – 2017 (20 years)

Introduction: This section begins by stating that the current situation of the VTS system will be evaluated, also called the "state of the art", but in no case, what the "estado del arte" means in the Spanish. If this thesis had been written in Spanish or Catalan, the state of the art for any university describes current knowledge about the studied matter. But, from the Faculty of Nautical Studies, as the mariners that they are trained to be, if they were to talk about the state of the art, they should deviate from the topic and begin to describe how fishing tackle is developing. Since the literal meaning of the "state of the art" is fishing nets for seafarers. It is thus suggested from this point, that it be taken into account for future theses or lines of marine research.

Having said this, this second part, correlative to the first part chronologically speaking, has been limited to 20 years. It starts from the publication of the Guidelines for Vessel Traffic Services (the second version) by the IMO in 1997, until 2017, when drafts were being made for a further new version. During this period, important events occurred that will be examined later. Here is shown the consolidation of the VTS and the profession of the VTS Operator with the support of the IMO but, above all, the IALA which, over time, has acquired a fundamental role. In addition to analysing the evolution of the reference documentation, the tools used by the VTS will be examined with a comparative perspective. This second part includes above all, 10 years of experience of a VTS Operator who has become an Instructor.

Chapter 4. The consolidation of the VTS system.

From the first guidelines for VTS until they were revoked, considered in this dissertation as the second, 12 years have passed, that is from 1985 to 1997, and the following is worth highlighting:

- The Global Maritime Distress and Safety System (GMDSS), introduced in 1988, but entering into force on February 1, 1992, amending SOLAS Chapter IV[30].
- IALA publishes the first edition of the VTS Manual in 1993, validated and renewed every 4 years.
- With the new Resolution for Vessel Traffic Services, the maritime traffic, and the acronym VTS will appear linked for the first time in the SOLAS V, Rule 12.

This last direct resolution of the IMO in Resolution A.857(20) format, added two annexes, some technical criteria on VTS and addressed, for the first time, the hiring, qualifications and training of the personnel operating in the VTS. However, it is a fact that the VTS system turned 71 in 2019, and the last definition continued to be that of 1997, so the lack of revision for 22 years more than justified its urgent revision. And this was recognized by the IALA in 2017, in its 43rd Session of the VTS Committee[31], where a draft was prepared, currently with the IMO for submission to the IMO-Sub-Committee on Navigation, Communications and Search and Rescue (NCSR) and in its final approval phase.

The increase in traffic, the increase in tonnage that makes its length inversely proportional to its manoeuvrability, and the advancement of modern technologies, reinforce the increasing need, in increasing regions of the world, to equip VTS systems on shore. It is estimated that, up until 2016, (IALA 2016) there were more than 500 types of VTS service, distributed globally among all 155[32] independent coastal States. However, at present, despite the consolidation of the VTS, the exact number of centres operating throughout the world is approximate. In 1999, the IMO wanted to promote the "World VTS Guide" via MSC/Circ.586/Rev.1. The Maritime Safety Committee, at its 71st session (May 19-28, 1999), noted that the VTS World Guide, produced by IALA, the International Association of Ports and Harbors (IAPH) and the International Maritime Pilots' Association (IMPA), was already available on the Internet, as well as in a printed publication. The Guide was intended to provide shipmasters and ship navigators clear, concise, schematic, information, in writing, on operational and navigation requirements for VTS centres around the world. The intention was not only to know the number of VTS centres in the world, but also in which area or sectors they operated. An access website was also established for this[33], where the Maritime Safety Committee, considering that the guide was a useful publication for navigation safety purposes, invited Member Governments to participate. In the Annex to the Circular, there was even a survey on whether the International Hydrographic Organization

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30 Retrieved from: https://imso.org/gmdss/

31 Retrieved from: https://www.iala-aism.org/e-bulletin/vts43/

32 Data from International Compliance, IALA Standards, World-Wide Academy. MBSHC 2019 p. 27.

33 The internet web page was: http://www.worldvtsguide.org/ but it is no longer active.

(IHO) should become a full member of the VTS World Guide Governing Board or should continue to participate as an observer.

It should be noted that Spain does not appear on this list, despite the fact that the Spanish Safety and Rescue Agency was founded in 1992, although it did not officially acquire the functions of VTS until 2011. (See Chapter 5). However, the result was that, on December 19, 2016, the IMO Subcommittee on Navigation, Communications and Search and Rescue reported the cessation of the development of the World VTS Guide via NCSR 4/27/2. IALA argued that, given the maturity of online technologies and the development of e-Navigation, the information of each VTS can be obtained through other authorized sources, so the guide had become redundant. The section of Resolution A.857(20) (the Guidelines for VTS) where reference was made to the World Guide, was also invalidated. There are possibilities that, in the future, it may be accessed again, given the tendency to share information and interconnect VTS centres around the world (See Part III).

4.1. The Second Guidelines for VTS (1997).

In 1997 the Resolution A.578(14) was revoked by the Resolution A.857(20), Guidelines for Vessel Traffic Services. This meant that they were updated by the IMO after 12 years and that, therefore, second guidelines were published. This new resolution was generally broader and more precise, went from having 17 pages to 22. Two annexes were added, some technical criteria concerning VTS and, addressed for the first time, the hiring procedures, necessary qualifications, and training of the personnel that operates within the VTS centres.

This was adopted after other important publications, including the first edition of the VTS Manual, from IALA in 1993. So the resolution included, for the first time, the IALA Manual, as a complement to the guidelines of the resolution itself. Also, consistent with any new resolutions, it began by referring to the previous resolutions, in this case the first recognition of the port advisory service (R.A.158(ES.IV)), and the two resolutions regarding SRS (that of 1994 and 1997)[34], and, this is essential, the guidelines were associated with SOLAS V. For the first time, after the amendments to SOLAS, the VTS were included in the agreement. The Resolution MSC.65(68) was adopted on 4 June 1997, only 5 months before these new guidelines, where VTS appeared in Regulation 8-2. Note also, that the VTS does not appear as a new Regulation but as a subdivision of Regulation 8.

Any amendment must improve performance in three key areas: increased safety of lives at sea, efficiency of navigation and protection of the marine environment, another constant that the IMO remembers and also in this resolution.

[34] R.A.851(20) and R.MSC.43(64).

After 12 years, it continued to be recognized that the lack of standardization of VTS services and procedures caused confusion for ships navigating from one VTS area to another, and Governments and international organizations continued to request guidelines on VTS.

Because this thesis analyzes the evolution of the resolution in its three temporal phases, (1982, 1997 and 2019) it has been able to follow the main points susceptible to modification. For this reason, it can be inferred that the main points that will be subsequently modified are those that have been considered over the years obsolete or superseded, overly detailed, unclear, misunderstandings or open to differing interpretation. With these parameters, seven out of ten definitions, according to Annex 1, point 1, will need to be modified. The Vessel Traffic Service, VTS is defined at point 1.1.1 as: “a service implemented by a Competent Authority, designed to improve the safety and efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and to respond to traffic situations developing in the VTS area”.

The Competent authority in 1.1.2 is “the authority made responsible, in whole or in part, by the Government for safety, including environmental safety, and efficiency of vessel traffic and the protection of the environment”. 1.1.3 defines VTS authority: “the authority with responsibility for the management, operation and coordination of the VTS, interaction with participating vessels and the safe and effective provision of the service”. 1.1.4 defines VTS area: “the delineated, formally declared service area of the VTS. A VTS area may be subdivided in sub-areas or sectors”, depending on factors such as traffic density, traffic patterns, type of service requirements and surveillance. In 1.1.6, the VTS Operator is defined as: “an appropriately qualified person performing one or more tasks contributing to the services of the VTS”. 1.1.10 defines Allied services as “services actively involved in the safe and efficient passage of the vessel through the VTS area”.

Within point 2, General considerations for Vessel Traffic Services, the services that are rendered by a VTS (described before in point 1.1.9), the three types of services identified as; The Information Service, INS, the Traffic Organisation Service, TOS and the Navigational Assistance Service, NAS (those now appear with acronyms in this resolution) are linked with two types of VTS. That means, three services for two types. It also describes them as a clear distinction: Coastal VTS as mainly control the maritime traffic in a determined area, which includes traffic in Traffic Separation Scheme (TSS), regulated by the IMO, which can be found in Spain, for example, as the Finisterre VTS which controls the Finisterre TSS, which is beyond the territorial sea (between approximately 21 and 40 nautical miles from the coast). Additionally, ii) Port or Harbour VTS as mainly dedicated to port entry and departures. It may be the case that the same VTS centre exercises Coastal and Port control. The information services (INS) are attributed, "usually", to the Coastal VTS, while TOS and NAS to the Port or Harbour VTS.

The term “control” is pointed out because, although it is not in these definitions, it appears several times in this resolution referring to traffic. However, in the first resolution, it appeared twice, concerning pollution, but not at all, in relation to traffic. Within VTS functions, it appears as routine control[35] of vessels and manoeuvres to avoid collisions.

The Annex 2, titled "Guidelines on recruitment, qualifications and training of VTS Operators" is an extensive annex that occupies more than half of the resolution (12p) in order to establish the needs and standards that are required for operators in a VTS service. The authority that provides the VTS service should have "sufficient staff, appropriately qualified, suitably trained and capable of performing the tasks required, taking into consideration the type and level of services to be provided".

The resolution notes that during the last few years there has been a rapid expansion of VTS, which is why the number of VTS Operators has also increased. Research indicated that the preparation of the personnel was diverse, from personnel with experience in at sea (merchant mariners) to those with no nautical background, so it was necessary to establish standards, defined on a world-wide basis (never done before).

The resolution contains 20 detailed definitions, objectives, prerequisites and parameters for the system where the VTS Operator in short, has to be "an appropriately qualified person". It is beginning to be seen that a supervisor figure for training, or an instructor, is required to achieve a level of learning. Nevertheless, the flaw of this proposal (as with the resolution) is that the system is under the management of the Authorities, so a system that gives its own certifications is judge and jury.

Hence the importance of an external body such as IALA, in charge of standards with internationally recognized certifications, but this would come later, since the first issue is from 1998 and the first edition from 2005 as IALA Recommendation, "Standards for training and certification of VTS Personnel" (IALA 2017k). At the end of the Annex 2 there is a figure "Analysis of traffic management functions into skills and knowledge components for VTS Operators" as an organigram.

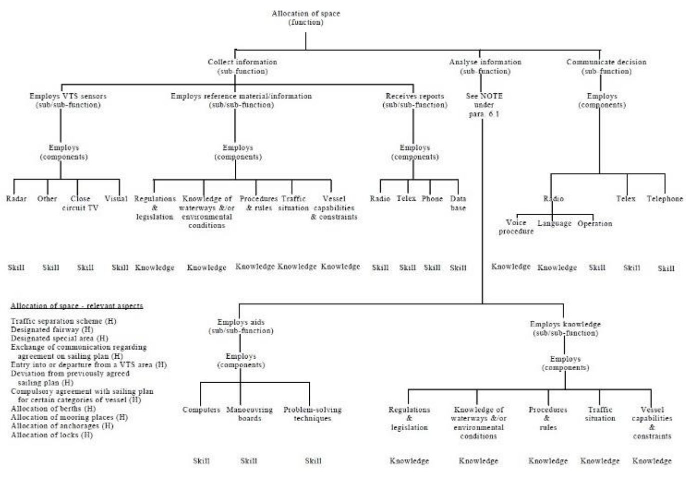

Figure 10. Resolution A.857(20) p. 22

[35] Annex 2. Section 1. Definitions. 1.2.18. VTS functions. p.13. and Section 6. Determining skill and knowledge requirements associated with VTS functions. 6.4. p.19.

From this can be deduced the equipment or tools used by a VTS Operator. Curiously, in the previous resolution, the basis of the VTS system, radar and VHF equipment, appeared (VHF named 5 times and radar 3) but, in the present resolution, there is no mention of VHF or radar in the organigram. Point 6, in the skills that an operator should have, includes operate communications and surveillance equipment (most likely radio and radar) and ability to operate ancillary equipment such as telephones, telex, tide and meteorological equipment. Additionally, it refers to English, not as SMNV, but as the current SMCP. But, observable from the organization chart, are; radar, radio, close circuit TV, visual, computers and boards, in addition to one "other". In 1997, equipment that would be part of the VTS for the next 20 years had not yet been developed, so this "other" has been supported as a reference to new applications such as AIS, or mobile, among others.

By way of comparative analysis, the following table shows the points chosen from the second Resolution on the same first Guidelines for VTS which will be counteracted later with the subsequent resolution.

2nd 1997 Resolution A.857 (20) Guidelines for Vessel Traffic Services
22 p. 2 Annexes
Requested by Governments and international organizations
Lack of standardisation*
R.A. 158(IV) PAS
R.A.854(20) SRS
Revokes R.A.578(14) Guidelines for Vessel Traffic Services
SOLAS IV & V. Rg.8-2
IALA VTS Manual 1st Edition
VTS Authority
Type of VTS: Port or Harbour and Coastal
Types of VTS services: INS, TOS, NAS.
VTS procedures: information, advice or instruction
VTS Operator: appropriate qualifications
Use SMCP
VTS area can be divided into sectors
Equipment: Radio + Radar, Computers, telephone, phone, telex, circuit TV, visual, other

Table 10. Highlights Resolution A.857(20)

*RECOGNIZING ALSO that the use of differing vessel traffic service procedures may cause confusion to masters of vessels moving from one VTS area to another.

4.2. Air Traffic Control as divergence.

With the consolidated VTS system, numerous studies began to analyse the differences between ATC and VTS. Analysis revealed that, although both systems shared common goals and were responsible for promoting the safe, fluent, and efficient traffic movements, there were huge differences in how safety was achieved (Praetorius et al. 2012). Obvious differences in the medium in which each travel, air or sea, and their speeds were set aside.

The premises were based on the fact that the main function of an ATC service is to control the air traffic network safely between airport and airport and that airplanes are completely dependent on ATC. On the contrary, VTS is a service limited to coastal areas or at most to territorial waters, where the monitoring starts when the ships report at the border of the VTS area and are not dependent on the VTS in that, although Operators can give instructions, the ultimate decision and responsibility always remain with the shipmaster. The VTS does not take control of the vessel (Westrenen and Praetorius 2014).

In aviation, procedures are centralized internationally, and it is a somewhat inflexible system, while in the maritime sector there are organizational variables that depend on local administrations and the system is more flexible. This generates differences in terms of training, ATCs are governed more by standardized procedures, while operators have responses that depend largely on previous experience as mariners. There are no objective safety margins for VTS, and the general lack of standardization allows for a wide range of responses that also depend on educational background and work experience of the VTS Operator. Some, with previous education of a navigation officer, have had experience from sailing at sea, whereas others have had no navigational education or no previous maritime experience, as was found in a study referring to the working practices of VTS Operators in six VTS centres in Finland (Nuutinen 2005). In this sense, it could be inferred that the more standardized and procedural a VTS system is, the more it will resemble an ATC (see Part III).

Airspace is divided into controlled and uncontrolled space in most countries. In the controlled, entry is prohibited (only those authorized) so neither a plane, nor a balloon, for example, can invade that space. On the other hand, at sea, the space is "free", with freedom of transit or the right of innocent passage[36] (UNCLOS 1982) and anyone has rights of navigation, even within a controlled area. In a VTS zone, sailboats, and other small boats, for example, are allowed to navigate (under local regulations restrictions).

Resolution 857(20) established that the skill and knowledge level of the operator candidate should have a master mariner or top-level air traffic controller base, but, in the end, the requirement of the training level falls on each authority that provides the service. In this temporal comparison, training is a differentiating feature, in that Air Controllers are required to meet standards through continuous training,

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[36] According to the meaning of innocent passage. PART II. Territorial Sea and Contiguous Zone. Section 3. Innocent Passage in the Territorial Sea. Subsection A. Rules applicable to all ships. pp.30-3. and PARTIII. Section 3. Innocent Passage. Article 45. p.39.

practices and evaluations, while VTS Operator training is initial and remains open to the degree of assigned functions. (Although, as will be discussed in the next part, this is already changing).

One of the essential differences between VTS and ATC in terms of equipment is that the VTS radar antenna does not detect small vessels that the navigating vessel can observe, so the Operator would not be able to best direct a vessel from its position observation deck, relative to the vessel's bridge.

When the IMO publish the Guidelines for VTS in 1985, it adopted for the system the term "Vessel Traffic Services". But, in the first draft of the resolution A.578(14), it appeared as "Vessel Traffic Control System" which is similar to Air Traffic Control (IMO 1985b). The reason for rejecting the term VTCS was that it would have suggested a mandatory control of maritime transport movements in all cases. "And in practice most VTS is restricted to the exchange of information" (Plant 1990:71). This means that there is a clear difference in the degree of control of ships and aircraft.

The summary table depicts the traits that have been chosen for differentiation but is subject to imminent change.

	ATC	**VTS**
dimensionality	3D	2D
network	airport to airport	arrivals and departures
space	controlled/uncontrolled	free
environment	empty	restricted
speed	~500 Mph	0-40 knots
system	centralised	distributed
reliance	totally	part of
voyage plan*	shared	not shared
scene	full	partial (area)
performance	procedures	experience
training	standardized / continuous	Semi-standardized / at intervals

* In the same sense as in airplanes.

Table 11. ATC vs VTS

With the specialization of VTS Operators and the maturation of the system, their role is increasingly essential in the stipulated terms of traffic safety and efficiency, taking into account that, due to the increase in port activities, the demand is also greater.

Monitoring traffic, ensuring separations, following routes, and planning the area under surveillance are the essence of both professions, VTS and ATC. If spatial boundaries are a differentiating feature, the next discussion will bring them closer together.

4.3. All in conjunction, RS, SRS and VTS.

Resolutions amending SOLAS brought the three systems closer together in such a way that the three reflected in the agreement would end. First, as if one depended on another, but later, separately. Thus, after the 1997 amendments were accepted and entered into force[37], SOLAS V was as follows:

- In conjunction in SOLAS:

SOLAS V

	1971	1994	1997
Ships‘ Routeing	Regulation 8*	Regulation 8	Regulation 8
Ship Reporting System		Regulation 8-1**	Regulation 8-1
Vessel traffic services			Regulation 8-2

*As Routeing in 1971.
**Accepted in 1995 and entered into force in 1996.

Table 12. Changes in the SOLAS V regarding RS, SRS and VTS 1971-1997

The inclusion in 1997 of the VTS in the SOLAS was determined with 5 divisions. These 5 sections are literally the same as the subsequent amendments to the SOLAS agreement, those of the year 2000 (one minor change of a plural to a singular, ‘flags’ to ‘flag’, since ships only fly one flag, as long as they belong to a state[38]). On December 5, 2000, the Resolution MSC.99(73) arrived, with further amendments to SOLAS 1974, and these referred to Chapter V, Safety of Navigation, putting the three systems in order. Each one now remained in separate Regulations; Regulation 10 for Ships’ Routeing, Regulation 11 for Ship Reporting Systems and Regulation 12 for Vessel Traffic Services, (IMO 2000b:122-4) and in accordance with the latest version of SOLAS.

SOLAS V

	1971	1994	1997	2000
Ships’ Routeing	Regulation 8	Regulation 8	Regulation 8	**Regulation 10**
Ship Reporting System		Regulation 8-1	Regulation 8-1	**Regulation 11**
Vessel traffic services			Regulation 8-2	**Regulation 12**

Table 13.Changes in SOLAS V regarding RS, SRS and VTS, 1971-2000

[37] In 1999 unless, prior to that date, more than one third of the Contracting Governments to the Convention or Contracting Governments the combined merchant fleets of which constitute not less than fifty per cent of the gross tonnage of the world ' s merchant fleet, have notified their objections to the amendments. Resolution MSC.65(68) p.1.

[38] On June 15, 2021, from the MRCC Tarragona I saw the Bulk Carrier UNISON MEDAL moored, flying two flags at the stern, one below the other on the same mast. One was from China and the other from Hong Kong. Then I understood why, Hong Kong is special Administrative Region of the People's Republic of China.

The RS are passive measures, since communication is not necessarily a factor, the navigator interprets them through nautical charts, but it can be monitored from the shore. The three SOLAS Regulations[39] have some features in common, three of which stand out. Those, which are also the main axis as far as VTS is concerned, are safety, efficiency, and protection of the marine environment. The first point of each one is defined as follows.

Ships' routeing		Ships' routeing systems are recommended for use by, and may be made mandatory for, all ships, certain categories of ships or ships carrying certain cargoes, when adopted and implemented in accordance with the guidelines and criteria developed by the Organization
Ship reporting systems	contribute to safety of life at sea, safety and efficiency of navigation **and/or** protection of the marine environment.	A ship reporting system, when adopted and implemented in accordance with the guidelines and criteria developed by the Organization pursuant to this regulation, shall be used by all ships or certain categories of ships or ships carrying certain cargoes in accordance with the provisions of each system so adopted.
VTS	contribute to safety of life at sea, safety and efficiency of navigation **and** protection of the marine environment	adjacent shore areas, work sites and offshore installations from possible adverse effects of maritime traffic.

Table 14. SOLAS V. Regulations 10, 11 and 12. Section 1

In the initial statements in Regulation 10 (R.10) and Regulation 11 (R.11), the three contributions can each be applicable, but, with the disjunctive conjunction, it can include or exclude any of them. However, in Regulation 12 (R.12), the copulative conjunction ensures the conditions are inclusive only and, therefore, the VTS acquire a greater rank, in analysis of how important these services are.

Even so, it must be said that both paid great attention to the environment. The Resolution A.851(20) clarifies that incidents involving dangerous goods, harmful substances and/or marine pollutants must be reported. And the same resolution appears in other Regulations of the SOLAS, expanding the sense of importance to other chapters[40].

Once included in SOLAS, each rule referred to the Resolution already mentioned above.

[39] SOLAS, v3 (2004). pp.359-363.

[40] SOLAS. CHAPTER VII. Part A. Carriage of dangerous goods in packaged form. Regulation 6: "Reporting of incidents involving dangerous goods" and Part A-1. Carriage of dangerous goods in solid form in bulk. Regulation 7-4: "Reporting of incidents involving dangerous goods". pp.405-7.

		Refer to (v.2004)
R. 10	Ships' routeing	Resolution A.572(14)
R. 11	Ship reporting systems	MSC.43(64), as amended by Resolution MSC.111(73) Resolution A.851(20)
R. 12	VTS	Resolution A.857(20)

Table 15. Regulations vs Resolutions

However, Regulation 10 and Regulation 11 were susceptible to various clarifications over time. The IMO was informed that the guidelines and procedures were not being followed correctly in some areas, following the various amendments published to clarify concepts or make qualifications. There are some 23 SRS adopted by IMO in the world[41].

The IMO published, on January 6, 2003, the MSC/Circ.1060 circular, "Guidance note on the preparation of proposals on Ships' Routeing Systems and Ship Reporting Systems for submission to the Sub-Committee on Safety of Navigation". The purpose of this document was to provide information to Member Governments in the development, drafting and submission of proposals to the IMO for RS and SRS systems. In this sense, governments that wish to establish traffic organization measures in their waters must adhere to the principles established in the IMO Ship's Routeing Publication and make their proposals to the Subcommittee on Navigation Safety (NCSR) for subsequent final adoption by the Maritime Safety Committee (MSC).

In 2019, the IMO, through the NCSR, published another circular, the MSC/Circ.1608, since some RS and SRS (especially with regard to RS, the R.A.572(14)) did not conform with the criteria outlined. However, new resolutions had previously emerged, the MSC.419(97) for RS in 2016 and the MSC.433(98) Guidelines and criteria for ship reporting systems, in 2017.

Regarding the study of the VTS system that is the objective of this thesis, it is important to note the points that SOLAS deals with, for an in-depth analysis. Of course, in all three systems it is taken into account that nothing will prejudice the rights and duties of Governments under international law or the legal status of straits used for international navigation and archipelagic sea lines. In the three systems, Governments are encouraged to follow the guidelines developed by IMO "wherever possible".

But while R.10 and R.11 can submit proposals to the IMO for approval, R.12 cannot. VTS is a system that has to follow the guidelines developed by the IMO, and whether or not to establish a VTS is a matter of "opinion"[42] of the contracting Governments. This issue is analysed in the next Chapter.

- In conjunction with the UE.

[41] IMO presentation "The Global Approach to Automated and Standardized Ship reporting. Straits e-navigation Alliance Conference 2015" by Ashok Mahapatra. Senior Deputy Director. Available at: https://www.mpa.gov.sg/web/wcm/connect/www/d32866e9-cee9-441d-a454-faaab309476b/mahapatra_global_approach_ship_reporting.pdf?MOD=AJPERES

[42] SOLAS V. Regulation 12. Section 2.

In the EU, a less broad international framework when compared to the IMO, the three systems also appear together through the Directive 2002/59/EC[43], “establishing a Community vessel traffic monitoring and information system” which include articles such as; Article 7: “Use of ship's routing systems”, Article 8: “Monitoring of the compliance of ships with vessel traffic services” and Article 9: “Infrastructure for ship reporting systems, ships' routing systems and vessel traffic services”. It even includes special measures in case of pollution from ships. This was an important step, at European level, to coordinate ship surveillance services. So, since 2002 within Europe, work was being done to implement mandatory SRS, RS and VTS systems. Curiously, within their definitions, the “operator” is not the VTS Operator but means the owner or manager of a ship[44].

Directive 2009/16/EC of the European Parliament and “of the Council on Port State control”, introduced more robust regulations on the inspection of shipping and included obligations that could involve port authorities on notification of the arrival of ships.

Directive 2010/65/EU of the European Parliament and of the Council “on reporting formalities for ships arriving in and/or departing from ports of the Member States” and repealing Directive 2002/6/EC was then introduced.

- In conjunction in the COLREG?

Definitely not. The COLREG only included the TSS.

	COLREG (1972)	**SOLAS V (1997)**	**IMO**
RS: Routeing System TSS	Rules 1d) and 10)	Regulation 10 and 34	R.A. 572 (14)
SRS: Ship Reporting System	x	Regulation 11	R.A. 851 (20)
VTS: Vessel Traffic Services	x	Regulation 12	R.A. 857 (20)

Table 16. Rules vs Regulations vs Resolutions

4.4. IALA, the first VTS Manual and beyond. (1993)

From the beginning of the creation of the IALA, officially in 1957, until today, 2021, it has changed and evolved remarkably. Not only because of the addition of more countries, but also because of the roles that it has acquired and assumed over more than 60 years. It was initiated in order to bring together maritime signaling services from all countries, to study technical issues of nautical interest. When it was created, IALA had only 20 National Members and, at present, has 87[45].The world map, when shaded in blue with the National Members, shows practically the whole world coloured[46]. IALA has different

[43] Amended by Directive 2009/17/EC.

[44] Article 3. Definitions. (b) L 208/13.

[45] Data collected from the webinar organized by IALA on December 17, 2020. Session 2 “Transforming IALA from NGO to an Intergovernmental Organization (IGO) by Francis Zachariae. There were 85 attendees online.

[46] IALA Navguide 2018. Figure 1. p.5.

types of membership; National, Associate, Industrial and Honorary. In 2015 it comprised 79 national members, 124 industrial, 55 associated and 44 personal honorary members.

However, the true beginnings go back to a fair, held in Paris, on maritime structures, coastal lights, buoys and maritime signals in 1889. Hence the need to create permanent commissions to address maritime matters, which is why, a decade later, the Permanent International Association of Navigation Congresses (PIANC) was created. The Congress, held in London in 1926, was where the perception that the Aids to Navigation (AtoN) needed to be treated separately originated, since different buoyage systems were in use around the world, with rules in complete conflict with each other, which caused problems. So, in 1929, a specific congress was organized as the "The London International Lighthouse Conference". As mentioned at the beginning of the thesis, the World Wars literally stopped the world, in one way or another, so international conferences were resumed in 1955. Below, important dates are highlighted very briefly[47]:

- IALA is granted consultative status at IMCO, in 1961.
- IALA published its 1st Recommendation in 1966.
- IALA Maritime Buoyage System Agreement signed in 1982[48] (A, port is Red, and B, port is green).
- IALA was more involved in the organisation of the VTS Symposia in 1992.
- The World-Wide Academy (WWA) was established in 2012. The Academy works closely with IMO and IHO.

The IALA headquarters was established and is still based in Saint-Germain-en-Laye, France, despite plans, at one time, to change the location.

The first IALA aim was to harmonise standards for aids to navigation systems worldwide and the first IALA manual was the "Aids to Navigation Manual" called Navguide in 1990. It was well received in terms of providing administrations with assistance in planning Aids to Navigation systems (Bole 1991). Publications were scheduled every 4 years, to provide updates from the working committees and, in the same way, a schedule was established for the **VTS Manual,** whose first publication was in 1993, that is 45 years after the VTS system started, at intervals that can be observed in its published editions:

Edition:	1st	2nd	3rd	4th	5th	6th	7th	8th
Navguide	1990	1994	1998	2002	2006	2010*	2014	2018
VTS Manual	**1993**	1998	2002	2008	2012	2016	**2021**	

*: Importantly, the 2010 Navguide focused, for the first time, on e-Navigation, recognizing that the new concept was expected to play a key role in the future.

Table 17. Navguide and VTS Manual editions

47 Webinar IALA (2020): "The history of IALA in a few clicks. 1889-2020". Session 1.

48 IMO SN/Circ.120. 8 May 1984. 56 Lighthouse Authorities became Parties to the Agreement. The document "on the IALA Maritime Buoyage System (Paris, 15th April 1982) and Rules annexed thereto" was publish in French and English and included 7 Articles and the signature of the representatives of the countries in agreement. Spain does not appear.

The purpose of the manual was to assist AtoN authorities in the harmonisation of marine AtoN by providing a first point of reference on all aspects of providing such a service. VTS services were included, since the IALA considers them AtoN, as they satisfy the definition itself. A marine Aids to Navigation is an external aid to the ship that consists of a device, system or service designed and operated to enhance safe and efficient navigation (that is different from an on-board navigation aid for the purpose of assisting navigation). But the increasingly important role of VTS in the maritime sector necessitated separate consideration in the Navguide[49] and, three years later, a separate Manual (IALA-AISM 2010, 27).

The first IALA Manual was released in 1993 and prepared, as in its later versions, by the VTS Committee formed in 1981 (IALA 2012). The Committee has evolved in recent years in such a way that, at present, its members represent the majority of the main national maritime authorities in the world, whose delegates are mariners, with extensive experience and VTS professionals, but also have the support of international sister organizations. This ensures that the Committee can speak to the international authority on VTS matters and, more importantly, develop new procedures to meet the emerging needs for modern traffic management and improve maritime safety. In this way, IALA is an example of impartiality with multiple abilities.

Each new version of the manual, updates the guidance and advice provided in previous editions, to help authorities considering implementing a new VTS or updating an existing service. The later versions of the IALA VTS Manual show a decrease in the number of pages, an example of progress towards simplification and concretization. In 2008 it had 195 pages, in 2012, 176, in 2016 130 and in 2021, 38. The seventh modern edition becomes a document that was published online, in accordance with current times. From the manual that included the IMO resolutions, it has progressed to a manual with web links to access to publication Standards, Recommendations and Guidelines via Internet. The VTS manual is a reference for all VTSs, but also provides other references to more detailed published documents in standard, recommendations and guidelines format, manuals and even model courses. The links to Standards, Recommendations and Guidelines access more than 300 documents[50]. This translates into a huge effort and constant work, not only in providing specific documentation, but also in updating them.

The IALA VTS Manual Edition 6th 2016, included, for the first time, among the acknowledgments, the Spanish Maritime Safety Agency (IALA 2016c). Since its involvement as an associate member, it has increased its involvement to such an extent that it currently participates actively in the VTS IALA Working Groups (WG), of which there are three: WG1-Operations, WG2-Technology, and WG3-VTS Training. IALA has four Committees in total, which are; Aids to Navigation Requirements and Management (ARM) (previously Aids to Navigation Management (ANM)), e-Navigation (ENAV),

[49] IALA Navguide 2018. Chapter e-Marine Aids to Navigation pp.24.

[50] Retrieved in 2019: Standards:7; Recommendations: 83 and Guidelines: 144. Total: 234. Retrieved in 2021: Standards:7; Recommendations:199 and Guidelines: 164. Total: 370.

Engineering and Sustainability (ENG) (previously Engineering, Environment and Preservation (EEP)) and Vessel Traffic Services (VTS). Although this edition was prepared by the VTS Committee, other committees were also consulted, especially ARM and ENG, since modern systems involve and interconnect them all.

This version of the IALA Manual includes three types of VTS, when only two are referred to in the IMO Resolution 1997. In addition, it makes reference to supplementary material.

	IMO R.A.857(20) 1997	**IALA** VTS Manual 2016	Reference
Types of VTS		VTS in Inland Waters	Recommendation R0120 (V-120) * Guideline 1166
	Port / Harbour VTS	Port / Harbour VTS	
	Coastal VTS	Coastal VTS	Guidelines 1071

*IALA Recommendation R0120 (V-120) “Vessel Traffic Services in Inland Waters”. Edition 2 December 2013. Edition 2.1 September 2020. Note: Prefix: ‘V’ indicates a recommendation produced by the VTS Committee.

Table 18. Types of VTS considered

What can be noted from the table above is that, from the resolution of the IMO to the IALA publications, there are differences in time and concepts. IMO resolutions require a certain time for their approval and adaptation. However, the IALA recommendations and guidelines are more effective. From the IMO, two types of VTS are contemplated while, from the IALA, the spectrum is broadened from the innermost to the outermost, that means, from "inland" to "beyond territorial seas”, in other words, to the open sea.

Inland waters include rivers, lakes, or other stretches of water, whether linked to the sea or landlocked, which, by natural or man-made features are suitable for navigation (IALA 2013c). Due to differences between seawater and river waters, it may be that state jurisprudence depends on different administrations but, in any case, both require a VTS.

A VTS beyond the territorial sea should be on a voluntary basis, except in the international straits (TSS), but this is the beginning of considering a long range VTS.

In relation to the means of the VTS, those that were considered within the IMO Resolution have been mentioned. In terms of resolution, as stated above, the main equipment included are radio, radar, computers, telephone, phone, telex, circuit TV, visual and other, and nothing is specified in SOLAS V Regulation 12. However, in SOLAS V Regulation 19, “Carriage requirements for shipborne navigational systems and equipment”, AIS was considered as “AIS shall provide automatically to appropriately equipped shore stations” (…) “exchange data with shore-based facilities” and “as a VTS tool” in 1998[51]. From this, the provision of IMO for AIS in the VTS system can be deduced.

[51] Resolution MSC.74(69) adoption of new and amended performance standards. Annex 3.p13.

IALA always take under consideration further developments that influence the maritime sector, in terms of safety, efficiency and new technologies. Therefore, the AIS is also included with what would be equipment for the VTS, or what is described as sensors. IALA recognizes that the most commonly used surveillance equipment is still radar, although other systems, such as AIS, are used to good effect. The first Guidelines were "IALA Guidelines on the Universal Automatic Identification System (AIS)" in 2002 (IALA 2002) and the Recommendation R0123 (A-123)[52], "The Provision of Shore Based Automatic Identification System (AIS)", whose first edition dates from the same year (IALA 2007b).

Although, at the beginning, only the IMO existed as a reference for international regulations referring to VTS, now the IALA is part of the pyramid of the regulatory and legal framework regarding VTS. IALA has been requested by the IMO to develop reference documentation and guidelines, thereby engaging governments to follow IALA procedures. To guarantee the safety of life at sea and protection of the marine environment, the states have the responsibility of promulgating laws and regulations according to the superior instruments, therefore, the following pyramid is shown inverted. Although local laws must comply with at least those of higher rank, so they might be stricter laws but in no case, less strict.

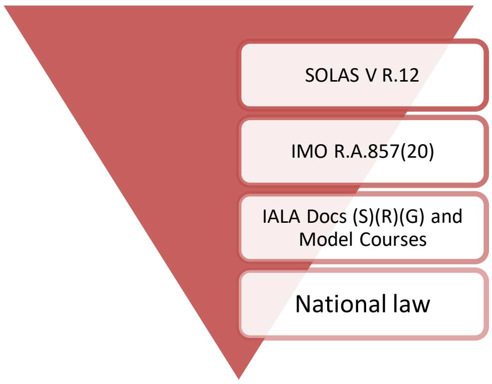

Figure 11. Graphical representation of legal, regulation and guidance hierarchy associated with establishing VTS (inverted)

SOLAS states that for VTS, following Regulation 12. in IMO Resolution gives the Guidelines for VTS and encourages Member States to accept and implement this into their national law. IALA developed a document structure, Standards (S), Recommendations (R), and Guidelines (G), that is used as a framework for the harmonization of technologies and services related to the development, implementation, and operation of VTS. National laws operate, for example in Spain, which stipulate who is in charge of VTS services[53].

As for the new profession that emerged from the VTS system, VTS Operators, IALA began as a mere training orientation for VTS Operators and is now leading a world academy. It issues its own certificates and recognizes other training centres around the world, which have been duly accredited by their

[52] Prefix: 'A' indicates a recommendation produced by the AIS Committee.

[53] Royal Legislative Decree 2/2011, of September 5, approving the Consolidated Text of the Law on State Ports and the Merchant Marine.

respective Competent Authorities, to be certified under their standards. The accredited training organisations delivering IALA VTS model courses under Recommendation-103 are “Accredited Training Organisation”. In 2020 there were 35 accredited centres in 22 countries around the world (IALA 2020c). The accredited Training Organization in Spain is CESEMI, as listed and under national law, BOE 178 (Ministerio de Fomento 2011b)[54].

The Academy fosters the accreditation process in accordance with the IALA Recommendations and associated model courses. The World-Wide Academy (WWA) was established in 2012 but there also exists a Recommendations for training and certification of VTS personnel, dated 1998. This means that it has been promoting the training of VTS for more than 20 years and this has translated into the development and specialization that the profession of VTS Operator has reached.

The first IALA Recommendation on “Standards for Training and Certification of VTS Personnel” dates from May 1998 as V-103[55], updated in 2020 (IALA 2020d). Then the IMO, through the MSC/Cric.952 “IALA Standards for Training and Certification of Vessel Traffic Service (VTS) Personnel” of 2000, was already considering three course models (IMO 2000a). Two years later, there were four in consideration after the IMO circular MSC/Circ.1065 and, in 2018, it was superseded.

Year IMO	IALA Model Courses
2000 MSC/Cric.952	V-103/1 VTS Operators; V-103/2 VTS Supervisor; V-103/3 On-the-job training (OJT);
2002 MSC/Circ.1065	V-103/1 VTS Operator V-103/2 VTS Supervisor V-103/3 On-the-Job Training (VTS Operator and VTS Supervisor) V-103/4 VTS On-the-Job Training Instructor
2018 MSC.1/Circ.1065/Rev.1	V-103/1 VTS Operator; V-103/2 VTS Supervisor; V-103/3 On-the-Job Training; V-103/4 VTS On-the-Job Training Instructor; and V-103/5 Revalidation process for VTS Qualification and Certification.

Table 19. Evolution of IALA Model Courses

In 2016, the complete revalidation system was considered for the 5 models[56] by IALA, as they are currently known (IALA (2016b). The training and certification of vessel traffic service personnel follows the format used by IMO for the training of shipboard personnel, the STCW Code (STCW95) and subsequent amendments (1998 and Manila 2010). The inclusion of the VTS in the agreement

[54] Resolution of July 6, 2011, of the General Directorate of the Merchant Marine, by which the Comprehensive Maritime Security Center "Jovellanos" of the Maritime Rescue and Security Society is delegated to teach courses.

[55] Webinar IALA: “VTS Guidance Documents” by Jillian Carson-Jackson, president of The Nautical Institute. February 23, 2021.

[56] IALA Model course. V-103/5 The revalidation process for VTS qualification and certifications- Ed.1 2016.

directly links the profession of Operator with that of the seafarer. The first V-103 course is the STCW II/1 Officer of the Watch (OOW) Deck, so mariners can embark on the VTS profession.

Note that these certifications do not classify the VTS according to their functions but according to their degree of experience, therefore they are all part of the same area of training knowledge. What indicates the different functions or features that a VTS Operator can perform is described in Chapter 4 and, in Chapter 5, the type of services, of the VTS Manual (IALA 2016), which draws on IMO Resolution A.857(20), as already specified above.

Since its foundation, and initial dedication to aids of navigation, IALA, has evolved, and now comprises 4 committees specialized in maritime issues, prepares reference documents and is internationally accredited by the IMO for governments to meet or follow its standards. An evolution that has been illustrated by recognition and acceptance worldwide and that will continue to grow with the change of status. The beginnings of encouraging a change of status from (NGO) to Intergovernmental Organization (IGO) were in 2010, and it became a reality in January 2021[57]. This is a change that will have an impact on the IGO being increasingly influential, through improving international harmonization, and affiliations with the main organizations such as IMO, IHO, the International Telecommunication Union (ITU) and the World Meteorological Organization (WMO).

As IALA remarks, "From the first beginnings to world-wide success", it is about a global harmonization solution, a growing challenge.

4.5. VTS equipment.

It has already been stated that the main equipment in performing VTS functions are radio and radar. The VHF has been the base tool for the first 50 years of the VTS system's existence. Over time, other equipment has been incorporated, including sensors such as AIS, but with new technologies, the tools of the VTS will increase. The regulations and standards that govern which systems a VTS Operator needs to use are becoming obsolete or lagging behind.

4.5.1.The VHF.

The level of automation on a VTS is quite low. The experience, skill and ability of the VTS Operator to assess and analyse traffic situations are the main sources for risk assessment and the decision of whether the VTS should intervene or not. If there is intervention, it is done by maritime VHF band (up to about 35 nautical miles). Terrestrial communication based on MF (to 150-400 nautical miles) and HF (mainly the Artic region) radios are not included in this thesis because they are not a device used by all VTS Operators and therefore, they are not part of the empirical analysis, but the VHF is a system used not only by SOLAS regulations, but a wide variety of ships engaged in inland navigation and pleasure crafts.

[57] Data collected from the webinar organized by the IALA on December 17, 2020. Session 2. "Transforming IALA from NGO to an Intergovernmental Organization (IGO)" by the Secretary-General Francis Zachariae.

The Very High Frequency, VHF, called radio, was the first long-range communications equipment that exceeded visual capacity. It was preceded by the international code of signals that includes messages through flags, with arms, light or acoustic signals based on the Morse alphabet invented by the American, Samuel Morse, who gave the code his surname in 1837. Thanks to the Italian inventor Guglielmo Marconi, who managed to transmit radio signals across the Atlantic in 1901, wireless communications, radio transmission, were born. The first marine radiotelegraphy station was installed on board ships, using Morse code.

The electromagnetic waves used in radio transmissions cover different spectra and are grouped by frequency bands. Those that use very high frequency bands are called VHF, and range from 30 to 300 MHz, with wavelengths from 10 to 1 meter. Although its use is better known in radiotelephony, it is also used for broadcasting in FM, TV, satellite navigation and radio beacons for aviation (Figueras 2003). It is not the object of this thesis to examine the world of radio, but it does highlight that the VHF is the main equipment of the VTS, and its use and prolongation in time is due to several factors, among which are the components of use, costs, and recycling.

It is a communications system that is fed by terrestrial antennas, with a high degree of reliability, suffering little atmospheric interference and operating at low or no cost. In addition, it is a relatively easy device to operate, although it is not without its necessary course of training and study, especially if the radio has Digital Selective Calling (DSC) included in the GMDSS system. The radio could be defined as a device by which we listen to and transmit messages, without knowing where they come from or where they are going. Only with voice identifiers, is it possible to know which interlocutors are speaking (leaving aside the external frequency detection aids (DF), goniometer or the DSC). It is, therefore, a transmission of voice by phone but it is also a very elementary data transmitter when certain information, previously registered or programmed in the same device needs to be sent "in writing" to be read. That is when DSC technology appeared, allowing the sending of not only emergency calls, but simple messages to individual station or a group of stations, using a specific channel (currently 70 for distress calls) and the identification number, Maritime Mobile Service Identity (MMSI). The ITU published the technical characteristics for use in the maritime mobile service in 1974[58], but, at that time, the Call Sign (CS) was used, it was not replaced by the MMSI until 1982.

The fact that, with the push of a button, a message can be projected to all ships (on channel 16) without being recognized, or without the broadcasting station being registered, has caused the radio to be misused. Its effectiveness as a means to receive emergencies is unquestionable. It is, without doubt, extremely practical for routine communications, such as reports, but the fact of not knowing who is sending a message at any time is a major disadvantage. The radio is equipment that is always connected, 24 hours a day, and, for the VTS Operator who is on duty, it means that channel 16 is always being

[58] ITU-R M.493.

monitored, in addition to other working channels. Experience as a VTS Operator provides empirical data on what it means to listen for hours to a station (ship) misusing VHF for amusement. There are multiple recordings to prove it. It is more than simply annoying when it prevents important communications. One day, as a new line of research, a system will be invented in which, when a message is transmitted by radio, all receiving equipment will be able to see where it originates from and who is, at that moment, pressing the PTT (Push-To-Talk) so that everyone (VHF range) knows who the transmitter is, (either by looking at the MMSI or IMO number or some other system not yet implemented). This would prevent non-compliant use of the radio. But until new technology is developed, VHF technology remains the primary equipment of professionals at sea and on shore. For ships it is the lifeline of sailors, a window not only to communication between other colleagues, but also to contact land. For a crew member, the VHF is an indispensable tool that is carried during the watch, unless the watch is on the bridge, in the same way that the mobile phone in the pocket is now carried but, on board, it is the portable VHF or walkie-talkie that allows communication across the different decks of ships, is the auxiliary of the rafts or rescue boats and is a link between other, nearby ships, or in manoeuvres with other agents such as terminals (among other utilities). For VTS Operators, the radio is their emblematic equipment, the oldest and the one that defines it, alongside radar, as the VTS system. The approximate range of 50 miles, when working at maximum power (25 watts), more than sufficiently covers the miles required by a VTS, including the territorial sea. But more importantly, it is the means that allows reception of automatic emergency calls from ships.

All the equipment is evolving in the era of digitization and therefore VTS is entering e-Navigation and the VHF radio equipment is of special interest. Over the years it has been observed that technology is advancing at an accelerated rate. So accelerated that, at times, a new technology immediately follows another that has only just emerged. Even scheduled obsolescence expires prematurely. However, while new equipment and technologies are emerging, mostly based on satellite systems, VHF radio equipment appears to be immune to time, in its role as an almost indisputably effective and operational tool. Mastering an entity as elementary as a standardized communications system is what determines part of its efficiency. Thus, its rudimentary nature confronts the new technologies that want to replace it with computerized data exchange. It is reasonable to ask if it will ever be made redundant or will it remain in parallel. The history of the mass-media tells us that in general, the old media do not perish before the new but are readjusted to coexist. In this sense, the radio, in its essential role of radiocommunications and current pillar of the domain of the VTS controller, has a “recyclable” or reinvention potential when digitization and VDES appear. The world is changing from analogue to digital, as seen with telephone, television, photography, radio and other media. The potential expansion of VHF digital communications is increasing, and the essence of digital communications enables more effective communication, avoiding misunderstandings. Offering a digital sound with less background noise improves the quality of data transmission, and speeds up reporting, and VDES will give way to a new generation of long-range communications.

The basis of the operation of the radio justifies its extended use. However, its use will be reduced as new technologies are implemented, such as the aforementioned VDES or the STM concept, as analysed in Part III. Maintaining and developing land communications could be considered as a “jury” communications system, as the “spare” is called in nautical terminology, which all sailors know because loneliness or isolation is always a risk on board. If communications is based on and dependent on satellites, no matter how reliable in theory, they are not infallible.

4.5.2. AIS vs Radar.

Maritime traffic surveillance systems did not gain international recognition by the IMO until 1985[59], with the publication of an IMO resolution, as stated previously, but VTS did not undergo any substantial change until the Automatic Identification System (AIS) equipment appeared. Its invention and implementation on board ships has allowed for a large-scale, ground-based view of merchant shipping in real time, and this enormously helpful tool has become essential for VTS centres.

Radar is the other equipment, together with radio, that defines the VTS system, as has also been specified previously. Not in vain has IALA devoted extensive publications[60] to it, but the fact that both forms of equipment are together in the same chapter is due, firstly, to the integration of AIS signal into radar and secondly, to the growing tendency to implicitly trust the AIS signal. There is question over whether AIS can replace radar and if it is the tool of the future. These are considerations derived from long experience as a VTS Operator, but at present, with current technology, AIS is not a substitute for radar but a complementary system.

An ITU Recommendation initiated in 1992 on characteristics already reported that several administrations used transponders for the purpose of obtaining information on ships entering and navigating within VTS areas. Some administrations made extensive use of transponders to track ships on high-traffic waterways, even where radar may not be available, and also for ship-to-ship identification. The data exchange between ships and land was between ships and VTS.

Subsequently, the IMO resolution MSC.74(69) was adopted on 12 May 1998: Annex 3: “Recommendation on performance standards for a universal shipborne automatic identification system (AIS)”, that the AIS should improve the safety of navigation, aiding the efficient navigation of ships, the protection of the environment and the operation of VTS. AIS was defined as a “VTS tool”, that is, from ship to shore for traffic management. In the IMO Resolution on the 1997 Guidelines for VTS, the AIS was not explicitly named.

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[59] Resolution A.578 (14) adopted on 20 November 1985. Guidelines for Vessel Traffic Services.

[60] IALA Recommendation V-128 on Operational and Technical Performance Requirements for VTS Equipment. Annex 2.Radar.p.9.

The Resolution A.917(22) of 2001 and subsequent Resolution A.1106(29), adopted on 2 December 2015, advised that the AIS is "an additional source of navigational information. It does not replace, but supports, navigational systems such as radar target-tracking and VTS;" but also, at the beginning, adds a caution to the OOW, officer of the watch, "not all ships carry AIS" and "some coastal shore stations including Vessel Traffic Service (VTS) centres, might not be fitted with AIS."

However, there are different References that include the AIS as a device for the VTS or shore-base.

1998	ITU	ITU-R M.825-3[61]	Characteristics of a transponder system using Digital Selective Calling techniques for use with Vessel Traffic Services and ship-to-ship identification.
1998	IMO	Resolution MSC.74(69) Annex 3	Recommendation on performance standards for a universal Shipborne Automatic Identification System (AIS).
1998	IMO	SOLAS V Regulation 19	Carriage requirements for shipborne navigational systems and equipment "AIS shall provide automatically to appropriately equipped shore stations" (…) "exchange data with shore-based facilities".
2001	IMO	Resolution A.917(22)	Guidelines for the onboard operational use of shipborne automatic identification systems (AIS).
2002	IALA	Recommendation	R0123 (A-123) The provision of shore based automatic identification system (AIS).
2002	IALA	Guidelines	On the Universal Automatic Identification System (AIS)
2002	EU	Directive 2002/59/EC Article 9	Infrastructure for ship reporting systems, ships' routing systems and Vessel Traffic Services.
2015	IMO	Resolution A.1106(29)	Revised Guidelines for the onboard operational use of Shipborne Automatic Identification Systems (AIS).

Table 20. References to the AIS for the VTS chronologically

It was in December 2000, with the maturity of the AIS system, that the revision of Chapter V of SOLAS via Resolution MSC.99(73), began to include new requirements related to the incorporation of the AIS equipment on board and, with the establishment of Regulation 19, set out the different periods of adoption according to specific tonnage. The equipment became incrementally mandatory, with deadlines ranging from the end of 2004 until 2008, according to the SOLAS Chapter V Regulation 19, "Carriage requirements for shipborne navigational systems and equipment", prescriptions applicable to on-board equipment. The SOLAS ship names are those that must be equipped according to the Convention and are: "all ships of 300 gross tonnage and upwards, engaged on international voyages and cargo ships of 500 gross tonnage and upwards, not engaged on international voyages and passenger ships irrespective

[61] Although the first version comes from 1992 in its reference nomenclature ITU-R M.825-0.

of size”. Those for which the convention does not apply are called Non-SOLAS vessels, these types of vessels are primarily pleasure craft or small fishing vessels and use another type of AIS called AIS-Class B, which provides limited functionality but they can still be tracked.

There are notable differences between both AIS and Radar, but also some similarity (Hirche 2010). Some of the main features are detailed below, since the AIS will be part of a higher level (see Part III) in terms of future technologies, and which are also the subject of this research.

RADAR	AIS
electromagnetic waves	VHF radio frequency signals
rotating antenna	fixed antenna
Gyro and log (ships)	GPS, VHF and ECDIS*
measuring system	information system
direct detection only	direct and indirect reception (by rebound)
no identification	identification (except silent mode)[62]
direct signals only	decode non-direct signals
locate targets (passive)	displays targets transmitting data (active)
coastline profile	cartography
detects moving or static objects	show moving or static objects with AIS on
limited coverage	limited but greater coverage
with ARPA: assesses the risk of collision	no assessment
false echoes Antenna side lobes and ghost targets (multiple reflections)	wrong information data recorded
no messages sending	messages sending

***** Electronic Chart Display and Information System.

Table 21. Radar vs AIS

It is a substantially differential factor that if a ship does not have the radar on, it does not influence the VTS evaluation, but if it turns off the AIS, it does.

Radar is in itself a very broad field of study and is not examined in any detail in this dissertation. However, it is interesting to note some references to its origin that date back to 1886, when Heinrich Rudolf Hertz demonstrated that electromagnetic waves were reflected off metal surfaces. Much research and development has been undertaken, which has managed to advance the science until the current radar system has been created. A reference to the most developed type of radar comes from 1935 with the physicist Robert Watson-Watt, who worked on calculating direction and distance by measuring the response time of a wave, later to know the speed of the object. The operator made marks with a wax pencil[63] on the green radar screen and measured the speed with a slide rule. Each echo was identified by

[62] Silent mode is a function where the equipment is on but does not transmit its own AIS signal. Some ships, or aircraft, such as warships, naval auxiliaries and other ships owned or operated by a Contracting Government and used only on Government non- commercial service, can use this option.

[63] They were also part of the navigation internship program to obtain a degree in Nautical Studies at the Faculty of Nautical Studies of Barcelona (FNB) with Professor Ricardo Rodríguez-Martos.

radio and recorded on a piece of paper. It is currently calculated by computer. The appearance of the ARPA (Automatic Radar Plotting Aid), towards the 60s, that was integrated in the radar, ARPA-Radar or automatic plotting radar, improved its performance, but it was not possible to identify the identity of the threat. An ARPA assesses the risk of collision and allows the operator to see the manoeuvres proposed by his own ship. In the case of VTS Centres, the dynamic component is lost, since the tower does not navigate, but the risks between ships are evaluated. The stationary radar of the VTS which records the movement of the echoes is stabilized (since the antenna is at a fixed point) and the vectors on the screen represent the true movement of the echoes.

Radars provide automatic target detection and tracking, unlike the AIS, which needs to request this, and also do not rely on an external positioning system, as required by AIS. Radar's passive method of labelling an echo on the radar screen can be possible using information derived from voice communication, either directly, with the support of DF, or indirectly from DSC and the MMSI. From the first radar screens to today, they have evolved considerably, from analogue to digital image. Today's VTS radar is a flat-screen computer.

The AIS is a much more recent technology. First, it is necessary to identify the Transponders, with the aim of obtaining information from ships. They are electronic devices that transmit a message as a response to a received and recognised coded interrogation, working on interrogation and replies that can be displayed on a radar screen or other displays (Heijden 2020,13). The transponders have a long history, but it was not until 1956 that the debates with the ITU (formerly CCIR, Comité Consultatif International des Radio-comunication) began. The exchange of information between shore and ships became possible and, later, ship-to-ship, over several generations of radio transponders from different countries, among which are included the Netherlands, Germany, Sweden, UK, USA and Canada.

The system was developed in the 1990s but, as with many other cases, where, after an accident, new international agreements are borne, the AIS is associated with two historical accidents that boosted its development, with the oil tanker Exxon Valdez running aground in Alaska's Prince William Sound on March 24, 1989 and the stranding of the Braer in January 1993 in the Shetland Islands (Harre 1999). Until then, navigators and shore stations had been dependent on visual navigation, analogue radar and voice communications to mitigate collisions but, internationally, it was recognized that a vessel tracking system was needed and a better way for ships to "watch" each other.

Firstly, it was developed as a short-range system, transmitting information through the VHF signal. The Canadian Coast Guard (CCG) started to implement Automated Dependent Surveillance System (ADSS), which meant that tankers navigating by Prince William Sound area were to be equipped with transponders to transmit information to the Vessel Traffic Centre (VTC) serving the port of Valdez Alaska. The ADSS is a fully operational radar which uses DSC on VHF Channel 70 to relay DGPS vessel positions. This system used several VHF remote sites, linked to the VTC via microwave, as a repeater (Heijden 2020:18). But the low transmission speed and the limitations of using a single channel 70 for all ships and for distress purposes (GMDSS), which means an overload for this channel, made them look for another technology for the transponders. That is how Self Organised Time Division Multiple Access (SOTDMA) and the Time Division Multiple Access (TDMA) technology were developed, which do not work, like transponders, on interrogation and replies. So, the AIS is not actually a transponder, but the first digital communications system for navigation and safety that works through broadcasting. Firstly, the name "4S"[64] transponders were introduced as a system but later, it became AIS. How this technology works is described in Part III, but note that it is based on the need for mobile phones.

The term "Automatic Identification System" was proposed by the United Kingdom in NAV41/6/33[65] because the term "transponders" could create confusion, since it is associated with radar devices, particularly those used with aircraft. Known as terrestrial AIS (T-AIS), the messages were received exclusively by ground stations, this technology continues to play a critical role today, with base stations spread across the globe. As it works on the VHF radio waves, the limitation is on the horizontal range, from 20nm to 100nm for ships and shore-base. To satisfy the needs of global identification of the ships, the use of satellites was necessary. To track ships in a wider horizon and long-range or global monitoring system, a low orbit satellite surveillance system, as a space-based AIS, was developed (Chen 2014). It was in the early 2000s that different countries developed projects to launch AIS satellites (S-AIS) from various commercial companies. GPS allows tracking, providing time and position data, but the shipborne AIS also enables transmission of static and dynamic information of the ship.

The basic architecture of the system consists of five components with bi-directional and uni-directional communication links between them (Figure 12). Ships' antennas act as repeaters with VHF communication link. Small low-orbit satellites with transponders receive the VHF signal, which can reach altitudes of more than 50 nm, and transfer it to the earth station (Chen 2014).

If the oceans cover about 72% of the earth's surface, a navigable surface area of 140 million square miles needs to be covered. The satellite-based AIS allow a global ship surveillance, but there arises a question of how many satellites are needed for effective coverage.

[64] The name "4S" stand for "Ship to Ship and Ship to Shore" and was introduced in Sweden.
[65] The meeting of IMO-NAV41 in September 1995.

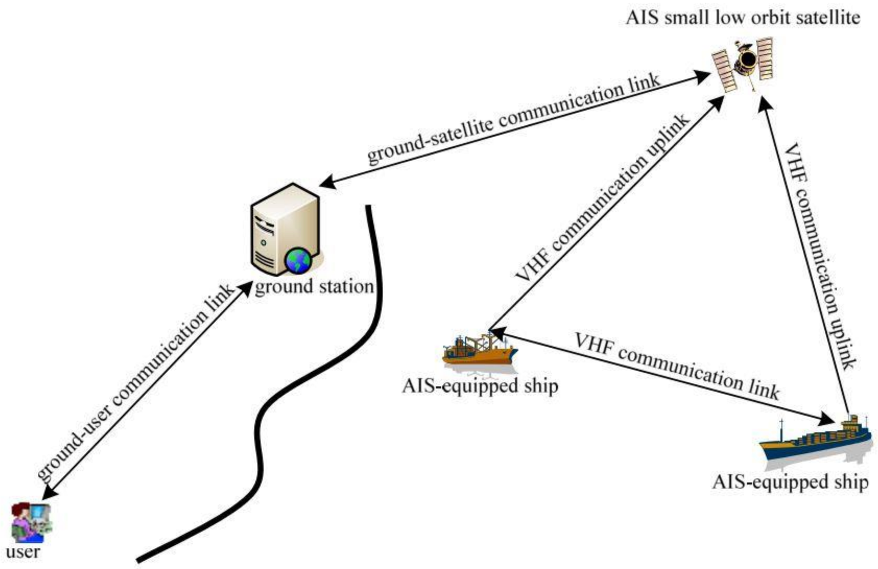

Figure 12. Satellite-based AIS architecture 5 components: satellite, shipborne AIS, shore station, user, and communication link

Despite progress, the SAT-AIS also has certain limitations. Receivers can still detect, but are limited in high density traffic areas.

AIS has been a great advance for seafarers, both at sea and on land. For officers of the watch, the AIS is a unidirectional monitoring system that transmits information via VHF broadband, visible by all nearby vessels, so it is considered an aid to navigation. The AIS, for ships, has enabled seafarers not only to interpret which category the other ship belongs to, through a complex system of lights and markings (COLREG), but now, through a screen, it is possible to know that and much more. It is also possible to access a file with complete data of the characteristics of the ship, destination, last port of call and type of cargo, among others. AIS reports rely on the shipborne AIS unit and can be turned on or off, can be configured correctly or incorrectly, as well as needing an external position fixing system, so AIS data is not always reliable. The accuracy of their positions has also been analysed (Greidanus et al. 2016). For this reason, the AIS should not always be relied upon as the only tool. The IMO warns seafarers, specifically the OOW, that they should always be aware that other ships, in particular leisure craft, fishing boats and warships, and some coastal shore stations, including VTS centres, might not be fitted with AIS, as advised by the IMO Resolution A.1106(29). But this caution must also be taken by the VTS with respect to ships.

The AIS itself is still a signal and, without background mapping, it is difficult to interpret where the targets are traveling near the coast, relative to the ship's position, unlike the radar, which can also detect the profile of the coast. So, the AIS needs either to be integrated into the radar, or to be displayed on a screen with a graphical georeferenced electronic layer, a type of nautical chart, so that where ships are navigating can be interpreted. That is why it is so important that it be a mapping according to reality, since the signals could be displayed on the ground, not due to signal error (which can also happen) but due to lack of agreement between the layer and the actual geography. Therefore, users are cautioned to always keep in mind that the information provided by AIS may not give a complete or correct "picture" of maritime traffic in their vicinity. This means that the position received on the AIS display might be referenced to a standard system. There are several formats, but due to their importance, the IMO has also intervened in their official and international recognition, in several phases.

The IMO started to recognize electronic charts in the 1990s. The Resolution A.817(19) "Performance Standards for Electronic Chart Display and Information Systems (ECDIS)" dates from 1995. At that time these were included in the SOLAS V/20, and there was no reference to AIS, which had not yet been conceived, so the radar image and ARPA could be displayed. The navigational information system (ECDIS) should be able to display selected information from a standardized database, that is, the information provided by the electronic navigation chart system (SENC), with positional information from the navigation sensors, to help the navigator in planning and following the route. The ECDIS was seen as a tool to reduce the navigational workload, as compared to use of a paper chart.

In 2000 the revised SOLAS V "Carriage requirements for shipborne navigational systems and equipment" in the Regulation 19 and the ECDIS, which was to be carried by all ships, regardless of size, was adopted. Even so, the use of paper charts as backup was contemplated.

The Resolution MSC.232(82) of 2006, "Adoption of the revised performance standards for electronic chart display and information systems (ECDIS)" recommends that Governments ensure the installation of ECDIS with the specifications detailed in the Annex to the resolution no later than 2009. It was already contemplated that Radar information and/or AIS information could be transferred to ECDIS as layers to assist in route monitoring.

The benefits of AIS extend beyond just informational data. It has certain functions that could resemble radar, such as alerts, which can be set to indicate, for example, when a ship is approaching within one mile or when the speed decreases, and the CPA function between two targets with AIS, but it does not match the radar, since some data is displayed with delay, apart from everything that has been considered above. With the LRIT, it is considered that there are 3 different sensors to monitor ships from the VTS position (IALA 2007) since the fourth sensor, which could be said to be the visual[66] one, in the case of the VTS, is more limited. Depending on the location of each Centre, it will have some view of a local traffic situation, but in any case, it will only be a partial view. So the trust of the traffic controller lies above all in the screens. The situation on board and sailing is very different, where a visual check can be vital and, furthermore, it must be done to comply with the regulations, "Every vessel shall at all times maintain a proper look-out by sight and hearing" (COLREG, Rule 5) but inside the book there are 20 other "look-outs".

[66] Resolution A.857(20). Figure 3. Employs VTS sensors. p 22.

In the case of a VTS, it would not be compliance with COLREG but with the "visual" from the Guidelines. But in the case of the seafarer, any overconfidence in the AIS could trigger unwanted situations. The graphic illustration (Figure 13) above demonstrates this situation (Britannia 2017).

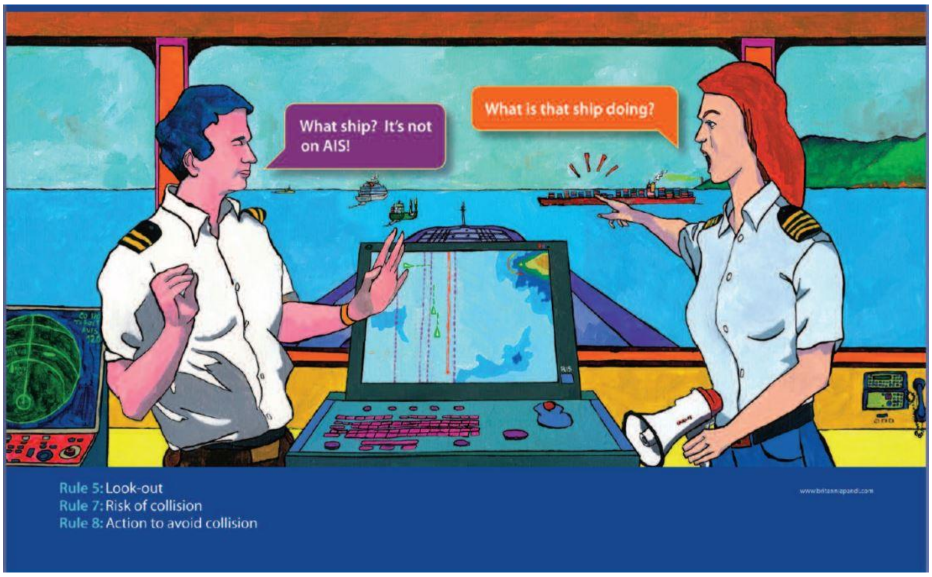

Figure 13. Loss prevention. Look-out and AIS

Radar is known for some typified interpretation errors, such as false echo or theft of an echo. But AIS is also susceptible to errors. The AIS, as a receiver, shows a series of information that comes from other equipment and this can fail, so the AIS would then also be affected (since it does not correct), but there is other data that the user must enter, meaning it is not exempt from human errors. In this sense, years of experience as a VTS Operator have identified that the most common errors are around the type of vessel and the status of the vessel.

The Navigational Status is the status in which the ship is at that moment. The Navigational Status of the vessel is one of the most common errors, especially when leaving the port. The AIS information appears as moored or anchored, when the ship is already navigating. It is understood that the ship sails with all the activity of the manoeuvre, the documentation on board and the preparations for the next port, and yet the device has not yet been updated with the new situation. Another example is the destination port shown by the AIS which, when the ship reports, is communicated as a different one.

Erroneous information, such as showing a tanker with navigational status as a sailing vessel (Figure 14), can be easily verified with the naked eye. A motor tanker is not likely to hoist a sail[67]. However, it is confusing information, and even more so in certain conditions, such as reduced visibility (Salinas 2006).

[67] Although it is known that some companies are known to have equipped merchant ships with a kite sail to reduce fuel consumption. E.g. The 'Beluga SkySails'. Retrieved from: https://www.nbcnews.com/id/wbna22788488

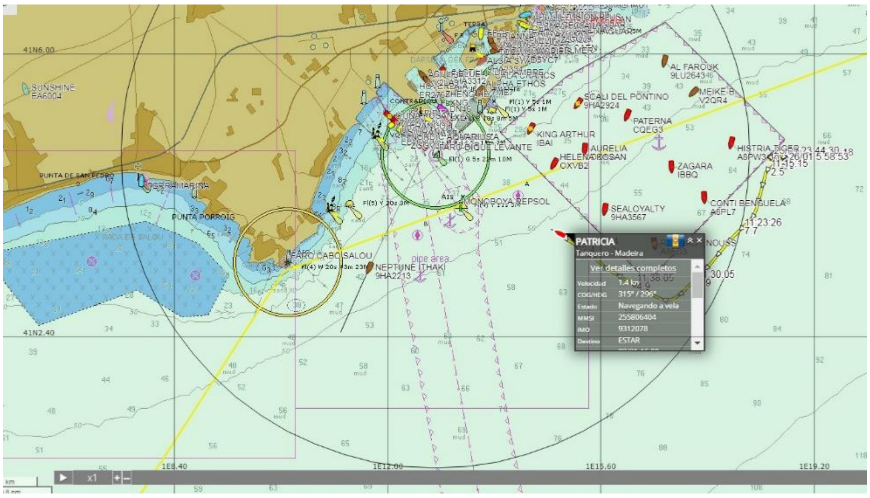

Figure 14. *T*he ship's navigational status as sailing AIS screen captured at 12:03UTC on January 26, 2021.Tanker PATRICIA

One of the functions of the VTS Operator is to verify that the AIS information is correct, a key factor for safety, and the result is that the vessels appreciate any correction offered to them. Ships that must drift, due to bad weather or waiting for an available berth, usually use the UNC status. However, unless they have an engine failure, they should use "underway using engine". This has been studied in detail, in regards to the implications with the COLREG, whether to propose the introduction of a new AIS status, the "underway but engine stopped" (Salinas et al. 2012). This new status, however, has not been implemented, and the VTS Operator must request the ship to change it unless she really has an engine failure.

Another type of erroneous AIS information, associated with a failure in the signals, is the position or data of the ship. Two echoes are observed on the radar screen, one with the AIS information and the other not (Figure 15). From the radar, the two echoes are observed and it can be discerned which is the real one. However, only one is visible on the AIS screen and is the false one.

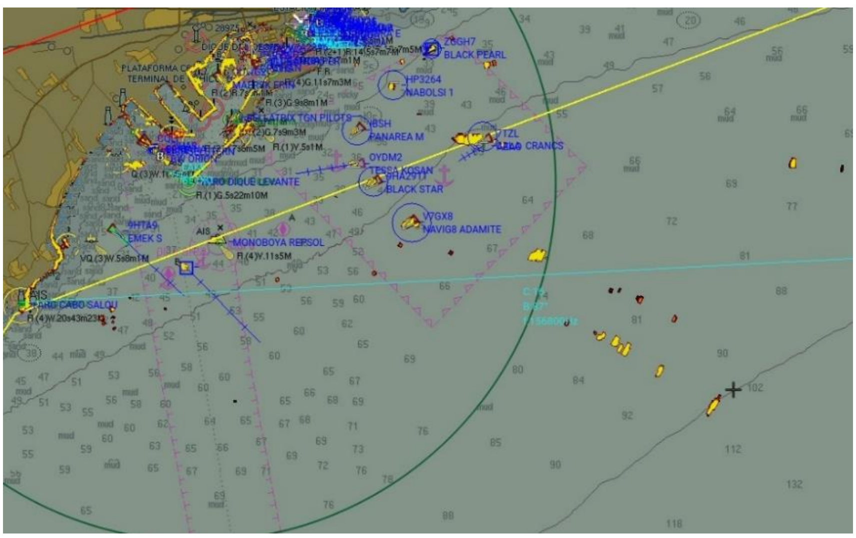

Figure 15. Radar screen AIS with two echoes of EMEK S ship. Captured at 18:21 UTC on July 12, 2019

From the verification of the AIS information, it was obtained that the ship measured 624 meters in length and the beam was 81 meters, something that is not yet possible (Figure 16). The real echo is the one that has no information, where the ship is sailing, while, on the AIS screen, only the one that is aft of the real echo is observed. In this case, two errors converged. The AIS data should have been entered correctly, the ship was, in fact, 119,6m x 16,9m, and the ship's GPS gave an incorrect position. VTS systems have complex algorithms that unify the radar and AIS tracks into a single one, as long as the established conditions are met. In this case, the algorithm estimated that they were two different targets[68].

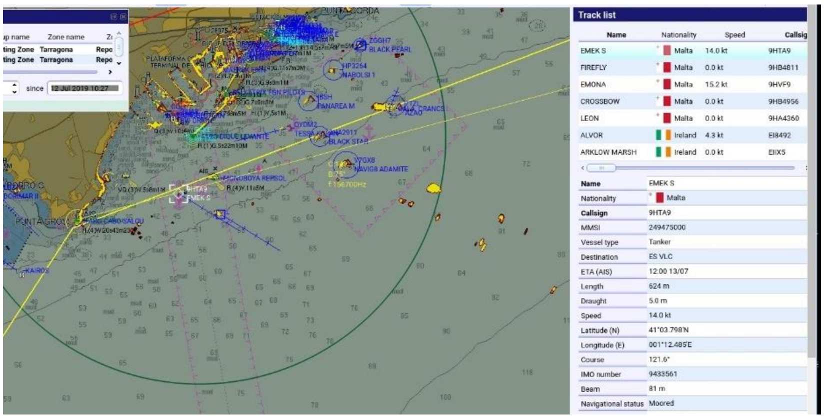

Figure 16. Radar Ship EMEK S wrong status (underway and appears as moored), error in length and beam and error in position. Captured at 18:21 UTC on July 12, 2019

An opposite case is the one that does not have the ship data entered and the length appears as zero. The AIS shows a very small target. The ships C. HORSE is 101.32 meters in length and, on the AIS screen, appeared as very small target, while the vessel DORYSIA, berthed at the same quay, is 184 meters, and the ship SAFFET AGA, berthed at the opposite dock, is 80.8 meters (Figure 17). It is clear that the targets do not have a ratio of proportion on the AIS screen, but the radar does. In this case the error can only be seen in the AIS[69]. The ship was warned by the MRCC Tarragona of this error and turned the equipment on and off several times in case this would resolve the issue, but to no avail.

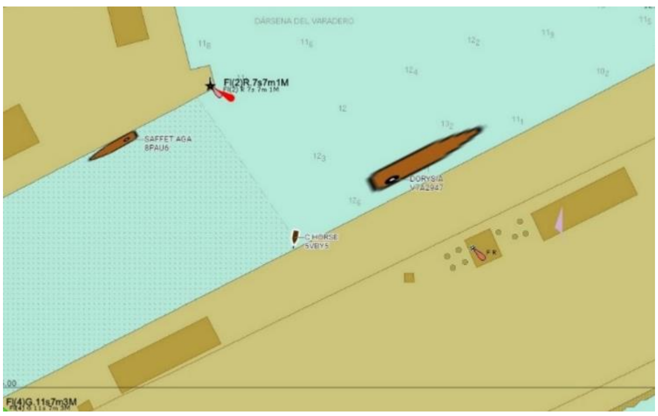

Figure 17. AIS screen with data and target of the vessel C. HORSE. Captured at 13:14 UTC on August 24, 2021

[68] Evaluation thanks to the Department of Information Systems of Sasemar, José Luis Martínez Ruiz, via email on January 15, 2021.

[69] AIS shall be maintained in operation at all times except where international agreements, rules or standards provide for the protection of navigational information. This means that even when berthed in port, it must remain on. Retrieved form: https://www.imo.org/en/OurWork/Safety/Pages/AIS.aspx

The symbol for the loss of a target is a cross above it, currently. But if the entire screen appears with target losses, it means that there has been a general system failure (Figure 18). Since the AIS system of a VTS works in a network from a central server, the failure affects other VTS centres.

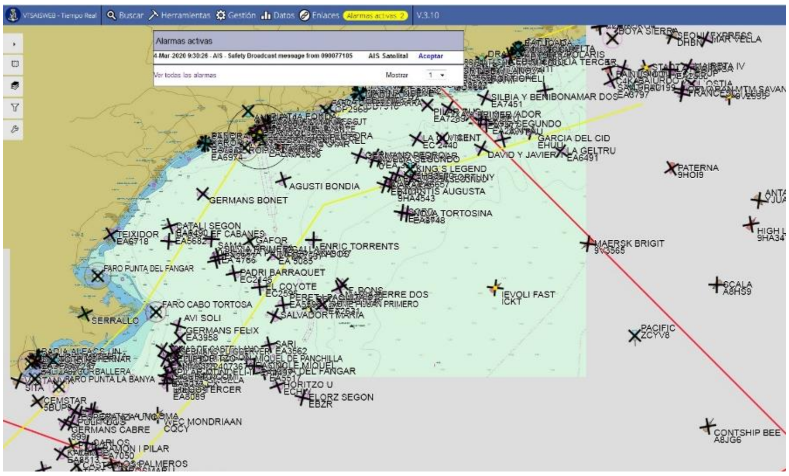

Figure 18. AIS screen with all targets lost. Captured at 11:17 UTC on March 4, 2020

Also, it may be the case that a ship's signal is lost during a track and when it is recovered, it joins the points in a straight line (Figure 19).

Figure 19. AIS screen with loss of track from a target. Captured at 21:51 UTC on May 2, 2021.

AIS screen with loss track signal from a target, in this example, from the vessel CHEM NEW ORLEANS arriving at Tarragona Port. The system joins the signal points with a straight line, that is, the moment it is lost and the moment it is recovered. All these examples shown, although there are more, are to introduce the idea that the AIS system with its errors, can be improved upon, as is introduced in Part III.

4.5.3. LRIT vs AIS.

The acronym LRIT stands for Long-Range Identification and Tracking. The terms "long range", gives the idea of going further but perhaps not as much as "global", and the terms "identification and tracking" offer a connection to the AIS.

In 1999, after the motor tanker ERIKA accident off the French coast, in which 30,000 tonnes of fuel were spilled, the European Union adopted some directives aimed at preventing accidents at sea and consequent marine pollution. One of them was Directive 2002/59, (EC 2002), amended by Directive 2009/17/EC, to establish a community system of information and monitoring of maritime traffic in order to improve the safety and effectiveness of such traffic. It included recommendations for a better response by governments to incidents, accidents, or potentially dangerous situations at sea, and specifically search and rescue operations, but also demanded an increase in the prevention and detection of pollution by ships.

At the same time, the EMSA was being established through Regulation (EC) No. 1406/2002 of June 27, 2002, and, as soon as it began operating in 2003, it was granted the responsibility for establishing and operating a new maritime monitoring and traffic system; This is how SafeSeaNet (SSN) was born.

The process for the creation of SafeSeaNet began in 2004, based on the short-range AIS transponders designed to provide information about a ship to other ships or ground stations automatically. However, its evolution was at the end of that year, when the AIS would be mandatory for vessels[70]. Over several stages, from 2004 to 2009, this system was installed, enabling Member States to exchange information through the AIS, including sharing incident reports and other data such as cargo or estimated times of arrivals (ETA) to port.

In 2006, the AIS entered a global dimension, thanks to the long-range identification and tracking (LRIT). The AIS combined the reception of data from VHF/HF radio antennas and satellite signals and, concurrently, the IMO made amendments to the SOLAS V 19.1 Convention (EMSA 2007), via MSC.202(81), urging authorized Centres to promptly put in place the Resolution MSC.211(81) adopted on 19 May 2006. Annex 14: "Arrangements for the timely establishment of the long-range identification and tracking system", within a timeframe of 2 years.

In 2010, an important advance was made with the development of the graphic interface. The AIS information could be displayed on a map, geographic information system (GIS) or as an electronic nautical chart, offering an instant description of a majority of maritime activity in real time. Its benefits included the ability to zoom from the EU level to specific quays within a port, to visualize the historical positions of vessels and obtain information at different levels among the Member States. A kind of secure network was outlined for registered and accepted users who could exchange and view specific

[70] As follows on SOLAS Chapter V: Safety of navigation, Regulation 19 Carriage requirements for shipborne navigational systems and equipment. 2.4 p. 370.

information related to security. Technically, the architectural core of SafeSeNet is the European Index Server (EIS), a secure hub-and-spoke network that reduces and optimizes data transmission time.

This terrestrial control network, which was conceptualized at sea level, based on the AIS, is complemented at a spatial level by the development of satellite systems. The creation of LRIT, became part of the global long-distance identification and tracking system for ships, under the coordination of the IMO. The system was initially created for maritime safety purposes but was soon expanded for use in areas such as search and rescue (SAR) and protection of the marine environment. This process being inverse, as previously outlined, to SRS, which were initially developed for SAR purposes and then applied to Safety. Ships send automatic position reports every 6 h, which are received by Inmarsat or Iridium type satellites, and are transferred securely to the data centres managing the LRIT information on behalf of the flag States. The Maritime Safety Committee (MSC) of the IMO makes political and technical decisions about the LRIT system at the international level, where it has given its coordination to the International Mobile Satellite Organization of (IMSO). However, at European level, EMSA would become the International Data Exchange (IDE) operator, the message routing distributor between Data Centre (CDs), which collect, store and supply information from users around the world, through an internet-based network.

The LRIT is a bi-directional monitoring and communications system solely for government agencies and their representatives, which locates ships and exchanges information as a closed loop. As this information is not visible among nearby vessels, it is not considered an aid to navigation, but it is considered a useful tool from the shore, hence the importance of VTS centres being recognized users and having access to information. A VTS of a Member State, through the SSN of the EMSA, can obtain various data from both AIS and LRIT in real time, and also historical data (EMSA 2007). To illustrate this, an image of the density of traffic in Europe in 1 year has been selected. Figure 20 shows that 31,783 ships were monitored during the year 2019, in the Mediterranean and the colour scale corresponds to the traffic density. The overlapping black marks are the real-time traffic, since being accessed. The general cargo ship Holandia arrived at Tarragona Port on October 14, 2020. This image was unthinkable 10 years ago.

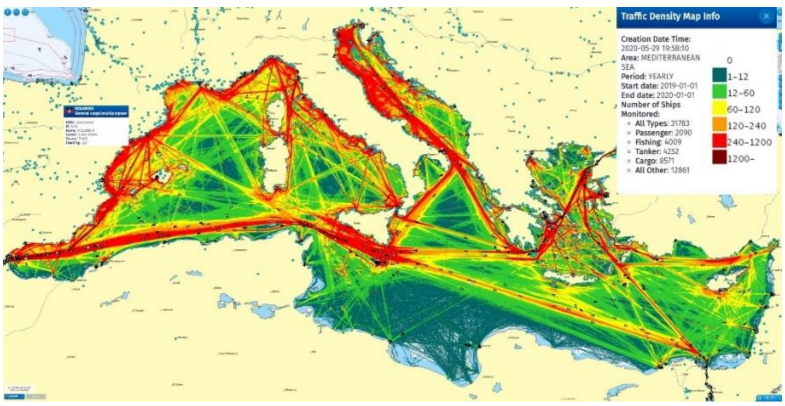

Figure 20. LRIT screen density map for one year and real-time traffic. SSN Ecosystem GUI by MRCC Tarragona

The purpose of the LRIT system is to provide the Flag State with the global identification and tracking of vessels but also to share information relevant to safety. Any incident registered by a VTS, or MRCC centre can share the information, through the SSN platform.

Both the AIS and the LRIT show the density of maritime traffic existing in a certain area but, as mentioned, they have clear differences between them. The following table provides a summary.

AIS: Automatic Identification System	**LRIT: Long Range Identification and Tracking**
All ships of 300 GT and above on international voyages, and all ships of 500 GT on coastal voyages are to be fitted with AIS	All ships of 300 GT and above on international voyages, and all ships of 500 GT on coastal voyages are to be fitted with LRIT
works on VHF communication	works on satellite Communication
AIS has 2 dedicated channels 87B and 88B	No Fixed Channel
Coverage for AIS is 35-40 nautical miles	Worldwide coverage is available for LRIT
Broadcast System	Closed Loop Communication - reporting system
Transmits automatically at fixed time intervals	Response to Flag State poll call / query
Transmits; Static, Voyage, Dynamic and Safety Data	Transmits; Identity, Position, Date & Time
Time Interval Depends upon Navigational Status and speed of vessel	Normal Time Interval Every 6 Hours, can be changed to Min Every 15 minutes or Max once in every 24 Hrs
AIS is connected to Radar, ECDIS and VDR and has inputs from GPS, Gyro, ROTI* or Log	LRIT is connected to VDR and has inputs from GPS
Track & Locate Ship in coastal water	Track and locate ship in Long Range
AIS is an Aid to Navigation	LRIT is not an Aid to Navigation
AIS information is available to ships in vicinity	LRIT information is not available to vessels in the vicinity

*ROTI: Rate-of-turn indicator. SOLAS V. Regulation 19.2.9.1.

Table 22. AIS vs LRIT

The LRIT system architecture is illustrated in the IMO Resolution MSC.263(84) adopted on 16 May 2008: "Performance Standards and Functional Requirements for the Long-Range Identification and Tracking of ships". What can be seen is that the LRIT system consists of the LRIT information transmission equipment on board, the communication and application service providers, the LRIT data centre, including any related vessel tracking systems, the distribution of LRIT Plan data, and the International LRIT Data Exchange, a regional, national and international cooperation to collect and exchange data, in essence, a path to information shared globally.

From the position of VTS Operator and as a member state, any information obtained from a vessel is received and can be shared. For example, reporting that a ship has had a machine failure when leaving port and, if the next port is a community port, it can be reviewed through the maritime authorities. But the EMSA platform goes beyond the control of ships within the EU, and extends, in practice, globally, making it possible to track ships. An example is the stranding of the Japanese bulk carrier Wakashio, which ran aground on the afternoon of August 25, 2020 off the coast of Mauritius Island, an area east of Madagascar, some distance from European waters. From the MRCC Tarragona, it was possible to follow, a posteriori, and obtain the track that the ship made. Thus, with the track-back function, it is possible to obtain the routes carried out by the ships "à la carte". There were no casualties, but there was a fuel spill on a reef bed, a fragile and highly valuable ecosystem. It is estimated that about 1,000 metric tons of fuel had spilled. Figure 21 shows to what extent it is possible to have a visualization of the traffic of a specific area from miles away.

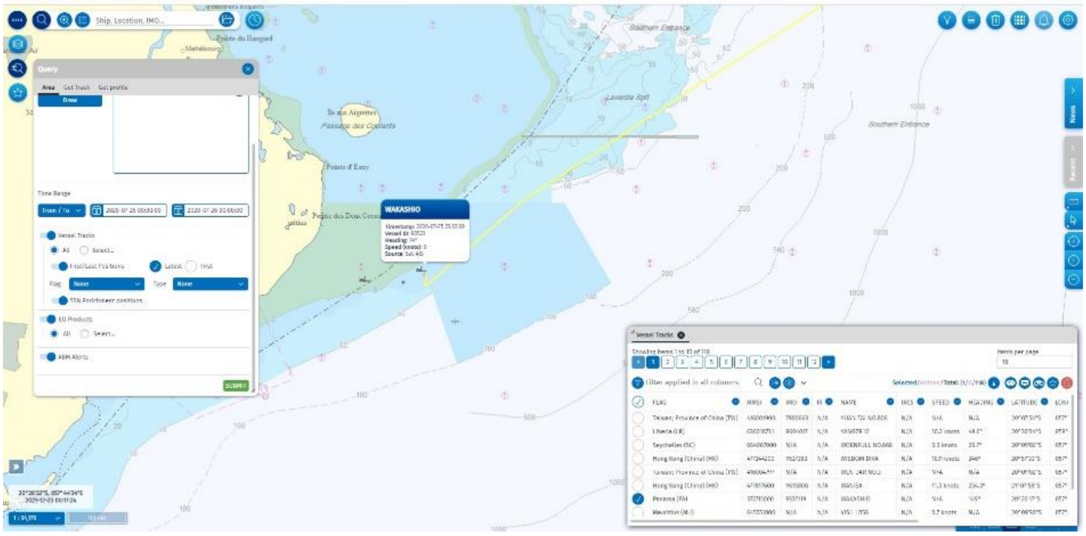

Figure 21. Track of the vessel Wakashio aground near Mauritius Island, 24h from 25/07/2020 to 26/07/2020

The potential of this tool is enormous, with a wide variety of functions that also increase over time, through technological and computer advances.

Chapter 5. The need for a VTS Centre.

Governments monitoring marine traffic in congested areas have implemented Vessel Traffic Services to avoid congestion or conflict. By keeping track of vessels movements, they ensure navigational safety in a limited geographical area. Within the EU, Member State authorities are required to ensure vessels use VTS in compliance with the regulations in force. The relevance of VTS has been examined in publications by different authors (Ustaoglu and Furusho 2002). It is a well-known fact that most VTS Centres have been established without carrying out any type of prior official analysis, but it is also true that there are several reasons why answers to the need for the service can be found. To argue the importance of VTS, the main Wh-questions have been followed (indicated below, from a) to f)). These have been linked to the IALA list for reference, documentation relating to VTS[71]. How to know whether or not to implement a VTS and why? Knowing why a VTS is necessary is one of the most difficult questions, not because of the question, but because of the number of answers that could be given.

a) Why

VTSs are necessary for various reasons, but there are three main reasons, constant in international references, that define their need based on their purpose. These are to contribute to safety of life at sea, safety and efficiency of navigation and the protection of the environment[72].

The three aims should be sufficient to implement a VTS, since "safety" is always paramount and it is necessary for life, navigation and environment. But these three main purposes are also linked to providing timely and relevant information to mariners, by assisting in decision making on board, managing, and organizing the movements of ships, overseeing the safety of navigation, and providing the appropriate advice to respond to developing unsafe situations. Therefore, they are connected with SAR operations, and Maritime Assistance Services (MAS) according to IMO Resolution A.950(23), and Places of Refuge according to IMO Resolution A.949(23), including not only Search and Rescue but firefighting, pollution response and salvage operations (IALA 2021). IALA also include a guideline with a broad perspective, the Guideline 1102[73], dedicated to considering interaction with other stakeholders[74], such as pilots, tugs, fishing vessels, terminals, agents and many other services[75]. Apart from those named, it includes other services such as security and, within what would be SAR operations, different types of accidents with ships, such as collision, capsizing, sinking, grounding, fire on vessel, Not Under Command (NUC), man overboard (MOB), in consideration with established medical assistance. It also takes into account other, broader aspects, such as legal aspects, protest actions against

[71] IALA Reference List. ANNEX 2 - Standards, Recommendations, Guidelines and Model Courses relating to VTS. 2019. Updated.
[72] SOLAS V. Regulation 12. p.362.
[73] IALA Guideline 1102. VTS interaction with allied or other services. Ed.1.0. December 2013.
[74] Ibid. Annex A. Examples of possible stakeholders. p.8.
[75] Ibid. Annex B. Possible interaction between VTS and allied or other services. p.9.

a vessel and natural disaster[76]. VTS contributes significantly to security of offshore installations, and in monitoring and reporting maritime security issues in the area (Akwasi 2015).

All this, includes consideration of its influence over and beyond the area assigned as VTS, and the establishment of regional, national, and even international agreements. It is, therefore necessary to consider VTS in a much broader role than simply traffic control, and as covering areas larger than those established as VTS Area.

But there are other persuasive arguments for its establishment, such as the contribution to the reduction of ship traffic accidents and increased cost savings. The best way to assess the effect of a VTS on maritime traffic safety is by determining the risk reduction that can be achieved. In this sense, IALA has developed different types of risk management tools to help determine the level of risk. These are considered as tools within the reach of VTS and, given the growing importance of the role played by ports and their dynamics, it will be increasingly necessary to use them. But since it is not yet carried out, the need for a VTS is more in line with the volume of traffic. It should be noted, however, that an important advantage of these tools is that they can help to assess the level of risk of existing ports and waterways, but also change factors, such as determining the likely level of risk of new ports and proposed waterways or substantial changes to those already underway that raise new issues. These are cited in the *When*.

On *Why implement a VTS?* IALA has no doubt that is a significant investment and gives two answers through two questions[77]:

- What are the safety, environment and economic consequences of having or not having a VTS?
- What is the level of investment that can be justified to improve the safety and efficiency of navigation, safety of live at sea and the protection of the marine environment for a particular waterway?

With these, forceful answers in the form of a question, there are also arguments in the background. Because VTSs are internationally recognized, this is a guarantee of consistency and solidity of service and wide acceptance internationally. As has already been shown previously, in the inverted regulatory pyramid, VTS are internationally regulated, as they are collected by the IMO in both conventions and regulations. Each contracting government undertakes to organize "its" traffic, but under the framework of the IMO guidelines, whose Resolution “invites” contracting governments to take into account the guidelines when implementing a VTS service.

Then, they are associated with the IALA structured documentation, within the seven Standards related to VTS that are not mandatory, but are the framework. The implementation of the Standards by all

[76] Ibid. Annex C and D. pp.10-3.

[77] IALA webinar “VTS implementation. What steps to take when implementing a VTS”. Chair: Monica Sundklev, held on May 6, 2021. There were 160 attendees online. Available at: https://www.youtube.com/watch?v=-81QZxgEctY

coastal states harmonizes Marine AtoN around the world (VTS included). These contain normative, (those with which it is necessary to comply, to claim compliance with the Standard), and informative (those that specify additional desirable practices but, with which, it is not necessary to comply to claim compliance with the Standard), provisions[78] and are related to the Recommendations. The seven Standards are:

1. S1010 Marine AtoN Planning and Service Requirement
2. S1020 AtoN design and delivery
3. S1030 Radionavigation services
4. **S1040** Vessel Traffic Services
5. **S1050** Training and Certification
6. S1060 Digital communication technologies
7. S1070 Information Services

All have a connection in one way or another with the VTS, but IALA gives four references to the points l 1, 4, 5 and 7, listed above. However the main standards are S1040 and S1050, so they are included in these Wh-questions, although S1060 and S1070 will become more important in the near future (IALA 2018d-g). The IALA Recommendations specify *what* practices shall be carried out and the Guidelines, *how* to implement practices normally specified in a Recommendation.

IALA has prepared a document[79] that includes a list in table format, visually very clear, with the aim of giving the references of the documentation necessary for the development, implementation, and operation of VTS, and that it will be updated according to changes or additions (IALA 2019b).

The VTS Standard has, in addition, seven scopes and each one refers to specific Recommendations and Guidelines with their reference:

– VTS Implementation
– VTS Operations
– VTS Data and information management
– VTS Communications
– VTS Technologies
– VTS Auditing and assessing
– VTS Additional services

And the Training and Certification Standards has three:

– Training and assessment

[78] Retrieved from IALA webinar: “Standards, Recommendations and Guidelines” by Minsu, Jeon. Technical Operations Manager. IALA Standards (Normative and Informative) slide on 21 January 2021.

[79] IALA Reference List IALA. Documentation relating to VTS. p.6-8.

– Accreditation, competency, certification, and revalidation
– Model Courses

The IALA VTS Manual has been updated every 4 years (until the online version appeared in 2021, which will be updated more often and in a more dynamic way,) as a complement to Recommendations and Guidelines, not as a substitute. It provides a clear and concise source of reference on the establishment and provision of VTS[80].

The recognition continues to the point that VTS are implemented with national laws[81] through maritime administrations that comply, in turn, with international ones. That is, VTS are considered throughout the legislative pyramid.

When a VTS is established, the VTS centre is the first agent that the vessel will share information with. In order for the VTS to perform its functions with competence and agility, it must have all the information related to the arrival of the ship, therefore, the VTS is the neurological centre of the system, in that it controls the traffic, it does not act as an administrative role[82], but the VTS Operator must have all the signature regarding the logistics of the arriving or departing vessel at hand.

b) When

When a VTS is needed is something that should be decided through following some procedure. Referring to the SOLAS V reference, the terms of having or not having a VTS system established, it falls to the decision of each State. It is not quantified, nor does it obey any mathematical formula, it is assigned to the rank of opinion: "Contracting Governments undertake to arrange for the establishment of VTS *where*, in their opinion (…)"[83], under the variables of "volume" or "degree of risk", the service is justified.

In "volume", this could indicate that, rather than relating to a certain number of ships operating in the area, it would be related to the size of the port that operates, with merchant ships of a certain tonnage.

Regarding the "degree of risk" evaluation, it could be said that it is very difficult to determine, since it has a cultural component. Not all cultures have the same concept of risk. There are various risk management methodologies, but IALA proposes a package of tools to quantify and analyse this level of risk, a Management resource, endorsed by IMO in SN.1/Circ.296 in 2010, in which tools are described by IALA Recommendations and Guidelines. In that circular there were two (point 1 and 2 listed below), but now IALA proposes four tools, with different approaches.

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[80] Retrieved from IALA webinar: "Standards, Recommendations and Guidelines" by Neil Trainor from Australian Maritime Safety Authority (AMSA) on January 21, 2021.

[81] In Spain: "Real Decreto 210/2004, de 6 de febrero, por el que se establece un sistema de seguimiento y de información sobre el tráfico marítimo".

[82] Carlos F. Salinas, Head of VTS Area at the Jovellanos Centre. Speech during the training sessions to VTS Instructors in MRCC Tarragona. On May 9, 2021.

[83] SOLAS V. Regulation 12. Section 2. p.362.

1. Qualitative risk assessment as a security assessment procedure in ports and inland waterways Port And Waterway Safety Assessment (PAWSA). This requires the participation of up to 30 competent people involved in the professional maritime sector as users of inland waterways, stakeholders and agencies responsible for implementing risk mitigation measures, described in the guideline: "The Use of Ports and Waterways Safety Assessment (PAWSA) Mk II Tool" (IALA 2017f).
2. Quantitative risk assessment, as analytical risk assessment in waterways. This variable is quantifiable, using some type of tool to analyse that level of risk, and there are computer programs for the calculation. One of them has been developed by the IALA, the IALA Waterway Risk Assessment Programme (IWRAP Mk II), which requires a comprehensive dataset of AIS information, described in the Guideline "The Use of IALA Waterway Risk Assessment Programme (IWRAP MKII)" (G1123). This method is purely probabilistic, which means it is based on statistics.
3. Simplified risk assessment, using a basic risk matrix approach, Simplified Risk Assessment (SIRA), described in the Guideline, "The use of the simplified IALA risk assessment method“ (IALA 2017h), which was developed to allow Competent Authorities to evaluate the volume of traffic and the degree of risk in their waters, so that they can comply with their obligations according to SOLAS V. Regulation 13 (IALA 2017e). This leads to a qualitative estimation of the level of risk and the production of possible risk control options, to reduce said risk to an acceptable level.
4. Simulation[84]. The Use of Simulation as a Tool for Waterway Design and AtoN Planning (G1058) proposes to use simulators as tools capable of providing realistic and accurate results when using channels and ports. The purpose of the simulation is to identify and mitigate risks (quantitatively) to the sailor navigating in a specific waterway, canal or port area. It may also include evaluation (qualitatively) of channel design, location, and technical specification of AtoN and manoeuvring aspects (IALA 2011a).

All approaches can be used individually or in combination, sequentially or in parallel. Authorities are guided by IALA to establish and conduct user consultation when planning new AtoN or future changes (IALA 2009b).

When the need is considered, before knowing how, the IALA establishes considerations when initiating and planning a VTS in their Guideline "Establishing, planning and implementing VTS"[85]. IALA groups together these considerations for initiating and planning a VTS, as a risk management toolbox that provides a detailed methodology for identifying and evaluating relevant issues and problems that it proposes to include[86]; traffic data, the geography of the area, protection of the marine environment,

[84] An extract of the use of simulation in maritime risk management: "IALA Risk Seminar Simulation" by Knud Benedict. Available at: https://www.youtube.com/watch?v=Crj-h4-8frs

[85] The Guideline G1150 that in its second version of 2020, will be modified due to the references included in the R.A.857(20) already updated as R.A.1158(32).

[86] Ibid. Annex A. pp.12-5.

accident and incident data, the VTS area, VTS Centre operations, design and technology, allied services, legal, VTS personnel, recruitment and training, future requirements and financial affairs.

Furthermore, VTS is particularly appropriate in an area when it includes any of the assumptions contemplated in the IMO Resolution[87]. Traffic management needs should be carefully researched and determined by casualty analysis, risk assessment and consultation with local user groups, as the IALA tools require, and these parameters also include; traffic carrying hazardous cargoes, conflicting and complex navigation patterns, difficult hydrographical, hydrological and meteorological elements, shifting shoals and other local hazards, environmental considerations, interference by vessel traffic with other marine-based activities, a record of maritime casualties, existing or planned vessel traffic services in adjacent waters, narrow channels, port configuration, bridges and similar areas where the progress of vessels may be restricted and existing or foreseeable changes in the traffic pattern resulting from port.

Risk Management			
What		*How*	
R1002	Risk Management for Marine Aids to Navigation	G1018	Risk Management (May 2013)
		G1123	The Use of IALA Waterway Risk Assessment Programme (IWRAP MkII) (June 2017)
		G1124	The Use of Ports and Waterways Safety Assessment (PAWSA MkII) Tool (June 2017)
		G1138	The Use of the Simplified IALA Risk Assessment Method (SIRA) (Dec 2017)
		G1104	The Application of Maritime Surface Picture for Analysis in Risk Assessment and the Provision of [Marine] Aids to Navigation Service Delivery (Dec 2013)
R1015	Marking of Hazardous Wrecks		
R1016	Mobile Marine AtoN (MAtoN)		
R1003	Maritime Data Sharing for Risk Assessment and Analysis		
O-138	The Use of GIS (Geographic information Systems) and Simulation by AtoN Authorities		
R1009	Disaster Recovery		
Quality management			
O-132	Quality Management for Aids to Navigation Authorities	G1052	Quality Management Systems for [Marine] Aids to Navigation Service Delivery (Dec 2013)

Table 23. IALA reference documentation on Risk Management

c) Who

Who has to establish a VTS is the Contracting Government of the coastal States, as has already been identified by the IMO[88]. States are responsible for promulgating laws and regulations and for taking all

[87] R.A.857(20). Section 3.2 Guidance for planning a Vessel Traffic Service. p.10.

[88] SOLAS Chapter V. Regulation 12.

other measures that are necessary to give full effect to the VTS, in order to guarantee the safety of human life at sea and the protection of the marine environment (IALA 2020a).

Contracting Government(s) or the Competent Authority[89] are legally and officially responsible for the VTS service. Whoever takes charge must take into account the training and accreditation of the VTS staff. From the considerations necessary to provide different types of training, with different levels published in the IMO matrix of 1997[90], to the IALA standards, it has changed considerably.

The certification of the VTS Operator can be either through the courses that the IALA offers in the World-Wide Academy (WWA) or through Centres accredited by it, which meet the standards. So, in this section, those responsible for the formation and accreditation of VTS personnel are identified.

VTS Operators must be trained and accredited under IALA Standards 1050. Therefore, the Competent Authority can enrol their staff in the IALA Model Courses or register at the training Organisations that should follow the Guideline, “Accreditation of VTS training organizations and approval to deliver IALA VTS model courses” (G1014), associated with Recommendation R0149.

Those in charge of providing the VTS service[91] under the managements activities included in the new IALA Guideline are known as “VTS Management” (IALA (2021f). But the personnel who will exercise the profession of VTS Operator are duly qualified people, who perform the tasks that contribute to the services of the VTS. As recognized in the Resolution A.857(20), there are a both wide variety of entry requirements and type and scope of training, due to the lack of unification of criteria worldwide. That is why the IALA, with the approval of the IMO[92], has developed the standards and courses that every VTS Operator needs.

The first challenge VTS Operators face is a recognition of prior knowledge, aptitudes, characteristics of personal suitability and auxiliary skills necessary for the functions to be performed. They also need to undergo the existing procedures to evaluate their ability to meet medical standards, according to the working conditions of the VTS position in question, skills to solve spatial problems and other skills such as the ability to work under pressure and the linguistic capacity required for the VTS in particular[93].

As considered by the IALA in the “Assessment for Recognition of Prior Learning in VTS Training” (G1017), personnel take specific training courses divided into four types, listed in the Chapter 4, and described in the IALA Guidelines and VTS Manual (IALA 2016c), a theoretical revalidation systems (IALA 2021c), but also, face exercises on simulators (IALA 2005b), need to obtain accreditations (IALA 2021b) and even audits thought the “Auditing and Assessing VTS” (G1101).

[89] According to IMO R.A. 857(20). 1. Definitions and Clarifications.
[90] Ibid. Section 5.4 Training.
[91] The VTS Provider is the VTS Authority understood according to the R.A.857(20).
[92] MSC/Cric.952 up to V-103/3 (2000), Cric.1065 up to V-103/4 (2002) and Cric.1065/Rev.1 up to V-103/5 (2018c).
[93] IMO R.A. 857(20). Section 5.2 Recruitment and selection. p.16.

All these accreditations refer to the profession of the VTS Operator, people who are supervising, monitoring and interpreting the maritime flow through a screen, and who should be more of a marine expert than a physicist or engineer. That is why a mariner is a potential VTS Operator.

Training and assessment			
What		*How*	
R0103 (V-103)	Training and Certification of VTS Personnel	G1017	Assessment for Recognition of Prior Learning in VTS Training (2021)
		G1027	Simulation in VTS Training (Dec 2005)
		G1103	Train the Trainer (Dec 2013)
		G1156	Recruitment, Training and Certification of VTS (Dec.2020)
Accreditation, competency, certification and revalidation			
R0149 (O-149)	Accreditation of Training Organisations	G1014	Accreditation of VTS training organizations and approval to deliver IALA VTS model courses (2021)
Model Courses			
			V-103/1-5

Table 24. IALA reference documentation on Training

d) What

Apart from needing adequate personnel, what is also needed is an adequate location, with equipment and facilities necessary to effectively accomplish the objectives of the VTS[94], the complete hardware and software as a coherent entity, which comprises the VTS System (IALA 2015,12). The tools used by the controller depend on how equipped the VTS Centre is, but must meet capability to monitor traffic, based on IALA Recommendation R0128 (V-128) “Operational and Technical Performance of VTS Systems”. Obviously, the essential equipment must be provided, which is VHF radio and radar, but also that which is already essential, such as AIS and the telephone (IALA 2007a). A VTS Centre uses equipment similar to most offices, such as fax, computers with internet connection, cameras, fixed and mobile telephony, but it also needs satellite telephony. Operator training and qualification enable the handling of other fundamental equipment that is also present in some Centres, such as radio in its different frequencies (HF and MF), Navtex, environmental sensors, electro-optical systems, the DF included in the radar, long-range sensors and data processors included in the Guideline 1111 “Preparation of Operational and Technical Performance Requirements” of 2015 (IALA 2015c).

[94] Ibid. Section 3. Guidance for planning and implementing Vessel Traffic Services.

VTS Communications			
	What	*How*	
R1012	VTS Communications	G1132	VTS VHF Voice Communication (Dec 2017) VTS Voice Communications and Phraseology (2022)
VTS Technologies			
R0128 V-128	Operational and Technical Performance of VTS Systems	G1111	Preparation of Operational and Technical Performance Requirements for VTS Systems (May 2015)
A-123	Provision of Shore Based AIS	1082	An Overview of AIS

Table 25. IALA reference documentation on VTS Communications and technologies

e) Where

Where a VTS Centre or service should be located is something that seems obvious insofar as, if the Coastal States need them, they should be located on the coast, in port areas, with real views as IMO recognizes, overlooking the port, even if it is only a part of the maritime stage, since the control is through screens. Limits depend on geographical location and port size.

Currently, the maximum range of a maritime traffic control system, in any case, can only be exercised while the vessels are in inland waters and not beyond the Territorial Sea (TS), that is, 12 miles. For controls within the EEZ, Exclusive Economic Zone, up to 200 miles, and international waters, the approval of the IMO is necessary and, in these cases, they are TSS, areas of passage with mandatory reporting.

The where can also be connected to the type of VTS, according to the area it covers. In this sense, the three different types are considered (IALA 2016:27), described in the previous Chapter. The two types contemplated by the IMO[95] are the Port or Harbour VTS, mainly dedicated to port entry and departure traffic, and the Coastal VTS, control of maritime traffic in a certain area, this includes TSS. It may be the case that the same VTS Centre performs Coastal and Port functions. And the third, VTS in Inland Waters, under IALA consideration (G1166).

The Coastal VTS does not present confusion in terms of its management and scope, but the Port or Harbour VTS is a subject worthy of study. There are ports where certain functions are mixed between different agents working in the same port, so they are duplicated. This redundancy creates situations where ships exist in a potentially confusing scenario. The competence limits of each entity that interacts with the traffic must be clearly delimited and defined, mainly in favour of safety and efficiency. It must be ensured that VTS operations are harmonized with maritime traffic organization and reporting measures, aids to navigation, pilotage, and port operations (IMO 1997b).

[95] Resolution A.857(20).

VTS Implementation G1166* VTS in Inland Waters (2021)

*No associated Recommendations, dated 2021.

f) How

In planning the VTS to be established, use should be made of available manuals prepared and published by appropriate international organizations or associations, which include IMO and IALA documentation.

To plan and implement a VTS, so that it can fulfil its three defined purposes, IALA describes 5 phases, which involve initiating, planning, implementing, controlling and closing, under the Guideline "Establishing, planning and implementing VTS" (G1150) and PDCA cycle.

Define Operating hours, responsibilities, framework procedures.

VTS Implementation			
What		*How*	
R0102 V-102	The application of the '**User Pays**' principle to VTS		
R0119 V-119	Establishment of VTS (2020)	G1150	Establishing, Planning and Implementing VTS (2020)
		G1160[96]	Competencies for planning and implementing a VTS (2021)
		G1071[97]	Establishment of a Vessel Traffic Service Beyond Territorial Seas (Dec 2009)
		G1083	Standard Nomenclature to Identify and Refer to VTS Centres (June 2011)
		G1142	The provision of Local Port Services other than VTS
		G1144	Promulgating The Requirements of a VTS To Mariners – A VTS Users Guide Template (2019)
		G1167	Guideline VTS Management (2021)
VTS Operations			
R0127 (V-127)	Operational Procedures for Vessel Traffic Services	G1089[98]	Provision of VTS Services (INS, TOS & NAS) (Dec 2012) (Dec.2020) pending Dec.2021
		G1110	Use of Decision Support Tools for VTS Personnel (Dec 2014)
		G1131	Setting and Measuring VTS Objectives (Dec 2017)
		G1045	Staffing Levels at VTS Centres (Dec 2018)
		G1118	Marine Casualty / Incident Reporting and Recording, Including Near-Miss Situations as it Relates to VTS (Dec 2016)

96 Retrieved from IALA webinar "VTS Implementation" held on May 6, 2021.

97 Ibid. Proposed to be withdrawn in Dec.2021. (IALA 2022a).

98 Approved Council 72 Dec.20. Issue pending adoption of new IMO Resolution. Retrieved from IALA webinar: IALA Guidance documents. Online Tuesday 23 February 2021 by Barry Goldman from International Harbour Masters Association (IHMA).

		G1141	Operational Procedures for Vessel Traffic Services (Dec 2018)
VTS data and information management			
R0125 V-125	The use and presentation of symbology at a VTS Centre		
R1014	Portrayal of VTS information and Data	G1105	Shore side Portrayal
VTS Auditing and assessing			
What		*How*	
R1013	Auditing and Assessing Vessel Traffic Services	G1101	Auditing and Assessing VTS (Dec 2013)
		G1115	Preparing for an IMO Member State Audit Scheme (IMSAS) on Vessel Traffic Services (Dec 2015)
		G1054	Preparing for a Voluntary IMO Audit on Aids to Navigation Service Delivery (2021)
VTS additional services			
		G1070	VTS Role in Managing Restricted or Limited Access Areas (Dec 2009)
		G1102	VTS Interaction with Allied or Other Services (Dec 2013)
		G1130	Technical Aspects of Information Exchange Between VTS and Allied or Other Services (Dec 2017)

Table 26. IALA reference documentation on VTS Implementation

5.1. VTS in Spain.

It has been shown that a VTS can carry out more functions than those limited to maritime traffic. They can also lead other related functions, such as SAR missions. In some countries, the VTS Centres are in charge of all these operations, as in Spain.

Mainland Spain has a coastline of 5,978 Km, plus the coastline of the Canary and Balearic Islands, which make a total of 8,000 km, making it the country with the largest coastal area in the European Union. In addition to this, being in a strategic geographical location that joins the Mediterranean Sea with the Atlantic Ocean, it is one of the densest maritime routes in the world. It is also a logistics platform for southern Europe, in terms of transported goods. The Spanish Port System closed the 2020 financial year with 515,682,392 tons moved[99].

The VTS Centres are located in State-owned ports, with the Maritime Districts and marinas being exempt from this service. In this sense, they are ports that have a certain commercial activity, with merchant ships.

The State-owned Spanish Port System has 46 ports of general interest managed by 28 Port Authorities (AAPP), coordinated by the government agency State Ports (Puertos del Estado, Organismo Público

[99] Retrieved from Puertos del Estado Webpage. https://www.puertos.es/en-us.

Puertos del Estado (OPPE)), a body answerable to the Ministry of Transport, Mobility and Urban Agenda (MITMA)[100].

Today, the control of traffic in the ports of general interest of the State is over waters of service areas. There are two zones, according to geographical location and nature of service.

• Zone I, for inner port waters, which include the waters between the breakwaters and the spaces necessary for docking and turning manoeuvres, and

• Zone II, for external port waters, which include the entry and manoeuvring zones, anchoring zones (if provided), and subsidiary zones subject to port tariff control. This area can reach up to 7 or 8 miles out to sea but does not, in any case, exceed 12 miles.

The Port Authorities hold powers over these service areas of the ports, over the planning of the areas, projects, construction, conservation and exploitation of the works carried out and over maritime signals, as well as authorizations.

From SOLAS to National law, Spanish national regulations establish who is in charge of traffic control. The Spanish Maritime Safety and Rescue Agency, also known by the acronym SASEMAR, is a public business entity (EPE), attached to the MITMA, under the General Directorate of the Merchant Marine (DGMM). It was founded in 1992, as a result of the enactment of Law 27/92 on State Ports and the Merchant Marine, coming into operation in 1993, and assuming "the provision of certain services that require greater freedom of management, such as maritime safety and rescue or the fight against pollution”[101].

It was immediately committed (BOE no. 198, 1997) to attend, through the MRCCs, not only emergency situations, but also incidents or circumstances that could constitute a threat and in which ships were involved, taking command of the control of maritime traffic, restricting navigation and even directing a specific route of a ship[102]. Thus, the Spanish Maritime Safety and Rescue Agency was officially in charge of maritime safety in Spanish waters in 2011, through Royal Legislative Decree 2/2011 (Ministerio de Fomento 2011a), which, as its article 268, establishes: “constitutes the provision of public services for the rescue of human life at sea, and the prevention and fight against pollution of the marine environment, the provision of monitoring services and assistance to maritime traffic, maritime safety and navigation , towing and ship assistance, as well as those complementary to the above”[103].

In this way, the control of maritime traffic is carried out through MRCCs, where the level and scope of provision to be exercised is agreed with each Port Authority. Hence the non-uniformity and variety of different cases that exist in the traffic management between the different State Ports.

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[100] Previously Ministry of Public Works.

[101] Ley 27/1992 de 24 de noviembre de Puertos del Estado y de la Marina Mercante. Preámbulo 3. e).

[102] Real Decreto 1253/1997 on 24th of July. Anexo III.

[103] Real Decreto Legislativo 2/2011, de 5 de septiembre, por el que se aprueba el Texto Refundido de la Ley de Puertos del Estado y de la Marina Mercante. Capítulo III. Artículo 268. Objeto de la Sociedad.

It is estimated that an average of 350,000 ships are controlled annually by the Spanish Maritime Safety and Rescue Agency. Sasemar achieves rescue and Search and Rescue (SAR) operations in the areas of responsibility assigned to Spain, which cover more than 1,500,000 km². This wide extension includes the VTS zones that do not have this dimension, insofar as their legally limited scope, but do have a link with the ships that navigate through this zone, in the event of any incident that could affect them. Maritime Rescue contributes to increasing the safety of maritime traffic through intense traffic supervision. It is, therefore, a mixed civil system that is in charge of SAR and VTS functions. SAR zones reach much more than VTS areas.

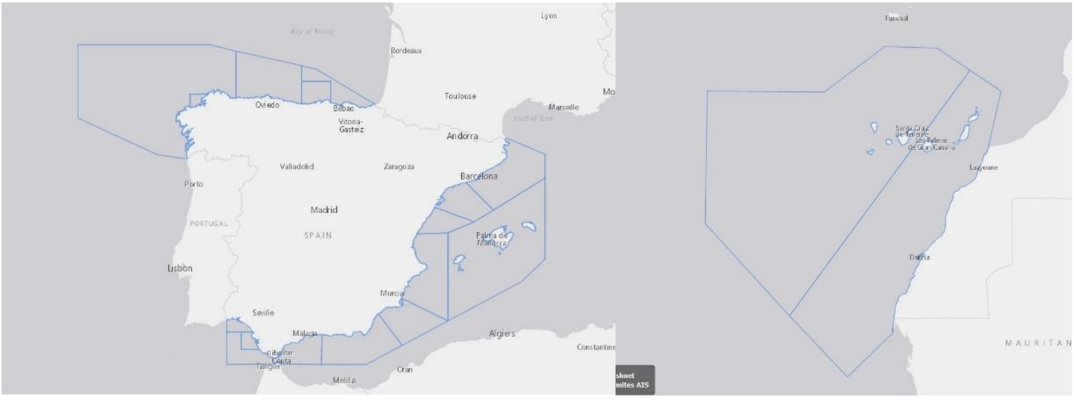

Figure 22. Spanish SAR area

There are 20 Rescue Centres in total, 19 MRCCs distributed around the coast, and the National Rescue Coordination Center in Madrid (CNCS). The level of provision of the VTS service is not the same for all the Centres for the reason mentioned above. It obeys, solely and exclusively, the internal contracts that each authority signs between the different stakeholders coexisting within the port. Therefore, several models of VTS provision coexist in the Entity. The list of ports in which Spanish Maritime Safety and Rescue Agency carries out port traffic control are as follows; Avilés, Bilbao, Cádiz, Cartagena, Castellón, A Coruña, Ferrol, Huelva, Pontevedra- Marín, Santander, Tarragona and Vigo. In Spain there are the TSS: Cabo de Palos and Cabo La Nao, for voluntary use, but also the TSS of obligatory report to the corresponding VTS Centre. These are: Cabo de Gata by MRCC Almería, Finisterre by MRCC Finisterre and Eastern and Western Canary Islands by MRCC Las Palmas.

Statistics show a considerable number of ships controlled through these VTS Centres of Spain. In 2019, the traffic of 316,016 ships was controlled, and the following year, somewhat less, due to the global pandemic situation, despite the fact that maritime activity did not stop, unlike other sectors. Therefore, in 2020, there were a total of 254,312 ships. Of this total, 123,619 ships were identified as they passed through the TSS, and 130,693 ships were controlled at the entrances and exits of the Spanish ports in which Spanish Maritime Safety and Rescue Agency provides this service[104].

[104] Statistical data from the 2019 Annual Report on Maritime Safety and Rescue Agency. Available at: http://www.salvamentomaritimo.es/sala-de-comunicacion/informe-anual

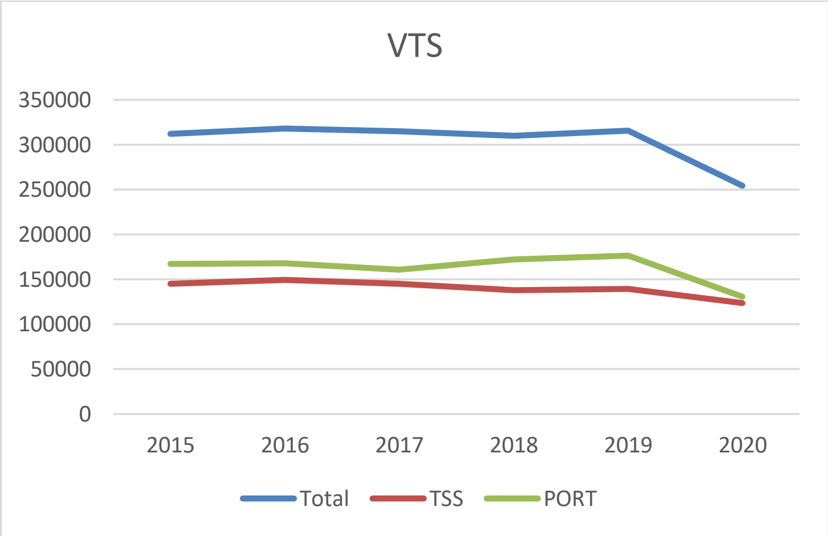

Figure 23. Number of ships controlled by VTSs from 2015 to 2020

The graph illustrates the data collected from the Spanish Maritime Safety and Rescue Agency annual reports, from 2015 to 2020. A certain consistency can be observed in terms of the numbers of vessels that have interacted with the VTS Centres, both in port approaches and in TSS.

5.1.1. An assessment of a VTS.

This thesis focuses on the important role played by VTS over time and analyses their ongoing evolution, which, as has already been shown, is becoming increasingly important. For this, it is not the intention to describe each of the VTS Centres, but rather, through one example, to describe the functions and relevance of the VTS. In this case, the VTS in Tarragona will be the example used to perform an analysis, following IMO and IALA parameters.

The Tarragona VTS Centre has been chosen to analyse and apply IALA tools in order, on the one hand, to demonstrate the applicability of said tools and what data can be obtained and, on the other hand, to assess their usefulness.

The port of Tarragona does not present particularly high-density traffic conflicts, but it is a dynamic port, in terms of structural changes, and is committed to increasing its port activity. All ports have specific characteristics and peculiarities, but the port of Tarragona, due to its location and types of traffic, is particularly interesting.

For the initial study, a series of considerations were drafted, according to the Guidelines, "Establishing, planning and implementing a VTS" (G1150), in its Annex A (IALA 2020:12).

Defining the proposed implementation of the VTS and its viability does not make sense, given that the Centre is already operational, and its importance and necessity is unquestionable, but addressing relevant issues and problems associated with the volume of traffic and the degree of risk in the waterway can be done using a methodology.

This process of establishing, planning and implementing a VTS requires the collection of data useful for the the IALA Risk management toolbox, with the "advantage" that the VTS Centre is already operational. The main information collected from it is detailed below.

General description of the Tarragona VTS system:

This paragraph needs to be considered before examining the IALA Guideline. There are different models for traffic management, depending on the participating entities. In many ports, everything involved in managing the traffic is carried out by one entity or two or even three. The port of Tarragona is an example of coexistence between three different entities that participate at different levels with traffic management, therefore, it serves to illustrate the diversification of functions in terms of maritime traffic management.

a. VTS Service: Taken over by the Maritime Safety and Rescue Agency, which performs the complete functions of VTS and its staff are accredited VTS Operators. They work on VHF channel 74 and identify themselves as: Tarragona Traffic. The area includes up to 4 miles from green at the end of the breakwater, plus the anchoring area.
b. Assistance to Pilots: Lookout Personnel, under the dependency of the Tarragona Pilots Corporation. They work on VHF channel 14 and identify themselves as: Tarragona Pilots. The zone of piloting has a radius of 4 miles. Compulsory pilotage for ships above 500 GT.
c. Assistance to Port: Port Authority has technical personnel who do not interact with merchant ship traffic, so they are a Local Port Services (LPS) as described in the IALA guidelines (IALA 2018b). They work on VHF channel 88 and identify themselves as: Tarragona Port Control. Inland water area of the port.

The system works as a chain of information between a. b. and c. It has its advantages but also its drawbacks. Some situations arise if, for example, a ship calls on channel 16 to the "Port Control" station, the question is, which of the three services would answer? This depends on where the ship is located, operational knowledge of the ground services, not the ships.

SRS:

Reports of ships arriving at the port from 2 hours or 20 miles if they carry dangerous goods, the rest at 1 hour or 10 miles from arrival to the mouth of the port. The involvement of different agents creates redundancy in data collection, makes ships have to repeat certain information. From the VTS perspective, ships repeat the same information more than once to different stations within the same port. This happens, for example, when the pilot station asks them the port of destination and later, they make Reports of ships arrive at the port from 2 hours or 20 miles, if they carry dangerous goods, the rest at 1 hour or 10 miles from arrival at the mouth of the port. The involvement of different agents creates redundancy in data collection and means ships have to repeat certain information. From the VTS perspective, ships repeat the same information more than once to different stations within the same port.

This happens, for example, when the pilot station asks them the port of destination and, later, make the departure report to Tarragona Traffic.

It also generates confusion on the part of the ships when it comes to reporting, since they do not know who they should call to get what information. Years of experience as VTS Operator have allowed identification of situations of this type:

- If the ships contact pilots first, then they no longer call Tarragona Traffic.
- If ships contact traffic first, they simply want to know if they have a pilot on arrival.
- If they are four miles away, they have already forgotten to call Tarragona Traffic, either on arrival and on departure.
- At the anchorage, they report to Tarragona Pilots but, when monitored by the VTS, the ship also reports to Tarragona Traffic, so ships duplicate the information given.
- The departure report is made when the vessels reach 4 miles from the green light. They stay on 14 and in the end, they need to be called on 16 or pilots need to be asked to notify them.
- The inbound report requests the maximum draft, however, the VTS Operator does not know which dock the ship will berth in, but it is necessary to know, in case of a conflictive traffic situation or that they should not approach shallow waters[105].

This complex reporting system, agreed under the procedures of the three entities, specifically between two of them, shows that one factor is the internal procedures of a traffic management system, which must be well planned, and another is the usability, in that the ships know what they need to do. In this case, they do not agree.

The methodology to identify and evaluate relevant issues and problems includes twelve points (from A.1 to A.12), in order of appearance, as set out below.

A.1. Traffic data.

The traffic volume of the port is estimated at around 2,500 merchant ships, entering and leaving each year. In addition, the entrance of the commercial port is also the one that gives access to the marina, "Marina Port Tarraco", with 33 moorings, from 45 to 160 meters in length[106]. It is also a base port for a fishing fleet of about 30 vessels that do not participate in the reporting system, but do interact with traffic. The port moved, in 2019, 33.18 million tons of goods, of which 9.7 tons was crude oil[107].

[105] The MT Seasprite reported a maximum draft of 15m. The berth should be at terminal 80S, whose maximum draft is 14.75m, so the manoeuvre was aborted. An example to illustrate from October 7, 2019.

[106] Retrieved from: https://www.porttarraco.com/en/berths/berth-map

[107] Data from Annual Report 2019 Port Tarragona. Available at: https://www.porttarragona.cat/es/port/memorias

However, it must be taken into account that the port is committed to an increase in passenger ships, after having completed the works on a new dock named “Baleares” (official inauguration on October 29, 2021)[108] and continues to promote other traffic.

Analysis of the complexity of traffic patterns can be done through the traffic densities, including traffic trends and, also, the breakdown of all vessel traffic in terms of type and size of ships and cargo, especially ships with dangerous goods (under IMDG code). Detection of crossover points and hot spots, where there have been some kind of incident, is also a component. All this requires historical data, as IALA recommends, for the past 10 years.

But the volume of traffic is defined as “the number of ships within a specified waterway, within a specific period”. It is essential, in the daily work of the VTS, to know the amount of traffic, to be able to quantify and, at the same time, identify the location of the areas with the greatest confluence of ships and those that may be considered conflictive in terms of navigation safety.[109].

A.2. Geography of the VTS Area.

Geography and characteristics of the VTS Tarragona area: The port is located in the south of Catalonia, being the second most important, after Barcelona. It is one of the main ports on the eastern fringe of the Iberian Peninsula, but it occupies the first ranking in terms of traffic movements of dangerous goods.

The port of Tarragona does not have a marked entry channel or channels. It circulates with the regulations of the world system A[110], where, to enter, it circulates on the starboard side, red to port. This creates two directions of circulation, one for inbound and one for outbound, oriented NNW/SSE.

In the direction of the entrance to the port, circulation to starboard, there is an oil installation Single Point Mooring (SPM) the petrol platform, which, in turn requires 3 cables of clearance (restricted area). It is a mooring buoy for tankers. The SPM separates the pilot boarding grounds, A and B, respectively, on both sides, East, and West. The distance between the SPM and the green light at the port entrance, at the end of the breakwater, is 0.75 miles, bearing at 156º (SE).

The 4 miles are a pilotage area and include practically the entire anchorage area, whose shape is similar to a regular 5-point pentagon (2.5 miles x 2.6 miles approx.). The word "practically" is used, since there is a corner that protrudes out of the 4 miles, so it is excluded from the pilot zone, thus, the total anchoring area is regulated by two different procedures, creating a certain ambiguity. If the reporting point is 4 miles away, a ship anchored in that corner would be in breach of the rule if she departs. Its extension allows more than a dozen ships to anchor, and passing ships can cross it without restrictions. The

[108] Retrieved from: https://www.porttarragona.cat/es/autoridad-portuaria-tarragona/comunicacion-y-prensa/notas-de-prensa/item/2830-port-tarragona-inaugura-el-nuevo-moll-de-balears

[109] Risk Management course. Lecture 1. “Calculation process overview” by José Cristóbal Maraver. Deputy Chief of the MRCC Tarifa. CESEMI.

[110] The “Agreement on the IALA Maritime Buoyage System (MBS)”, signed in Paris on the 15th of April 1982. Retrieved from: IALA webinar: “History of IALA in a few clicks” conducted by Omar Frits Erikkson, Deputy Secretary-General & Dean of World-Wide Academy. December 17, 2020.

anchoring area is from 25 to 67 meters deep, the shallowest being the closest to the coast, with a rocky bottom and mud. The positions are distributed according to lengths and type of ships, corresponding to the minors, those closest to the coast and those of dangerous goods, those closest to the inlet. Due to the prevailing winds in the area, notably the Mistral, a strong northwesterly wind blowing from the south of France into the Gulf of Lion in the northern Mediterranean, it is a safe anchorage for winds less than 30 knots. But, if the wind blows up from the quarters I, II, and III, with gusts of up to 25 knots (Force 6 on the Beaufort scale), the ships must have the main engine ready to maneuver and, if the wind is sustained, they must leave the anchorage and weather out the storm beyond 4 miles.

The maximum currents are 2 knots. Few cases of fog ice conditions are nil. The anchoring area is located at least a mile from the coast (between 3 and 7 cables) in part in front of “Playa del Miracle”, the beach of the city of Tarragona, next to the train station. For mooring manoeuvres, the height of the maximum wave must be less than 1.50 meters.

At 22.6 miles, bearing 163º from the green light, there is an oil platform, the Casablanca platform, and its facilities include an underground line to the port. At 9.7 miles, the nautical chart indicates the *Pipe area* of 1 mile wide. As it is marked with an axis line, some ships interpret it as the entrance and exit channel. The starboard side passes through the SPM and, on the port side, there is the pilot boarding ground B.

The entry dock is the reference dock to give positions by bearing and distance to ships, with a green light at the end of the breakwater, but also by latitude and longitude. The main entrance of the port is linear, without winding fairways, and is oriented NNE/SSW, with a width of 450m, a total length of 2400m and a maximum draft of 26m. At the end of the port entrance there is a bascule bridge, made up of two 51.5 m leaves, with a total length of 187 metres, which separates the commercial area from the recreation and fishing area, as well as connecting the commercial docks of the port. Its opening is required for air drafts greater than 6.5m.

A.3. Protection of the marine environment.

This port is especially sensitive to environmental issues due to the type of goods and facilities. These include hazardous products in petrochemicals, oil in the Repsol terminal with the SPM 7 cables from the entrance, and the coal terminal. A spill of any IMDG product would cause serious damage to the ecosystem. The port also contains the mouth of a river, the Francolí River, which is a particularly sensitive landform. There are materials in the port to fight pollution, specialized personnel and emergency plans agreed upon by all port workers depending on the degree of alertness, called *Port self-protection plan* (PAU), among other agreements.

A.4. Accident and incident data.

Records over the last 10 years indicate that the maritime accidents/incidents in the area are very low in the waters approaching the port. According to historical data regarding the circulation of merchant ships, prioritizing the protection of the SPM, the entrance to the port is diverted to the port side, exit side. However, the fishing fleet prioritizes entry in a straight line and invades the SPM area. In the BOPT (*Butlletí Oficial de la Província de Tarragona*) nº142 of 06/21/2001[111], the resolution restricting navigation in the waters surrounding the Repsol Oil SPM in Tarragona was published. With the exception of 6 specific cases, however, there were no refences to fishing vessels.

On April 28th, 2015, the fishing vessel CONSUELO TERESA collided with the SPM, fortunately, there was no considerable damage or economic loss, but there have been other minor incidents afterwards. In this particular case, the allision was an unwanted event and the consequences, damage to ship. The recommendation would be that the fishing boats respect the shelter. In terms of data collection, the frequency of accidents or incidents, the statistics show that they are concentrated mainly in the area of approach to the port, around 4 miles and among the vessels involved, fishing boats stand out.

There has been no serious accident in 10 years, neither has there been any case of a merchant ship grounding in the waters near the port.

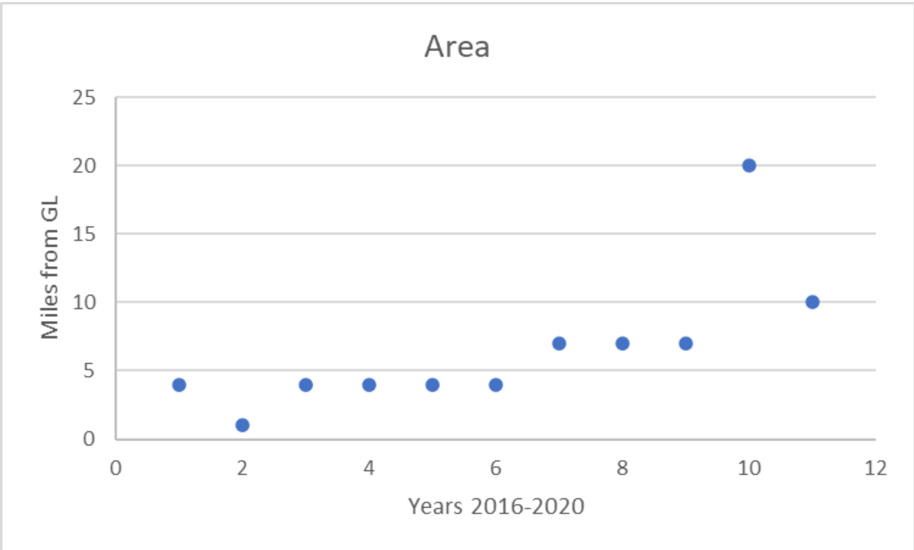

Figure 24. Incidents/accidents in Tarragona VTS area

The graph depicts the main incidents/accidents that occurred in the VTS area from 2016 to 2020. The conflict zone would be between 4 and 10 miles from the mouth of the port, the Green Light (GL) is the reference point at the end of the breakwater.

[111] BOPT available at: https://www.diputaciodetarragona.cat/ebop/arxiu/index.php?op=anunci&id=6303&ebop_any=2001

A.5. VTS Area.

This section, aims to delineate the VTS area and, if applicable, the sub-areas or VTS sectors. The first guidelines published by the IMO for VTS in 1985, through Resolution A.578(14), Guidelines for Vessel Traffic Services, (in Chapter 2 “Planning a VTS”, section 4), indicate that a VTS area can be divided into sectors, but as few as possible. In this vague wording, one might wonder if three, for example, would be considered too many or not. And it states, in point 5, that the areas and limits should not be located where ships normally alter their course or manoeuvre, or when they are approaching converging areas, route crossings or where there is cross traffic. In this other non-specific definition, the distances in miles or cables that would give rise to this confluence of maritime traffic are unknown. That is why it is important to maintain risk analysis on maritime traffic. Since the VTS area is already defined, the following figure shows the zone, areas, and sub-areas.

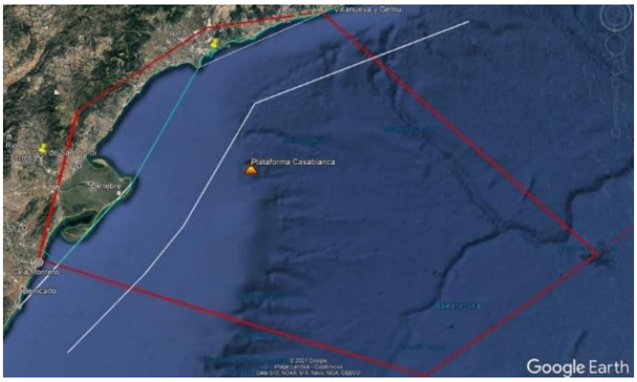

Figure 25. MRCC Tarragona SAR area, BL and TS limit

And within 4 miles, the subareas are configured as shown in Fig. 26 The diagram depicts the approach area to the port, including the 4-mile radius, the port limits area that is Zone II, the pilotage area, the pilot's embarkation points, the SPM named here as Single Buoy Mooring (SBM) with the return radius and the anchorage area indicated by the points with coordinates.

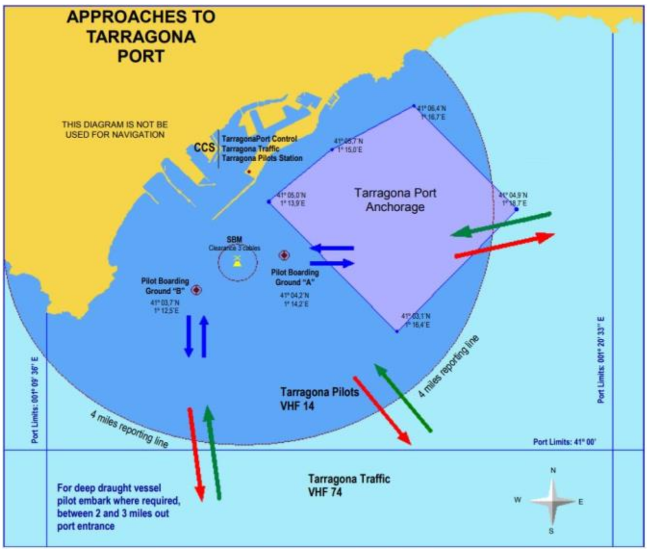

Figure 26. Area 4 miles TGN Approaches to Tarragona Port

There are no rules for ship traffic, such as one-way traffic zones and hazardous cargo, as indicated by the guideline.

The Port facilities allow the operation of different types of ships, such as tankers, including crude oil, chemical tankers, gas, bulk carriers, general cargo, containers, livestock, RoRo or Passenger, of different tonnage and lengths. The most common are between 100 and 250 m in length, although larger ships have moored at the SPM.

Tarragona borders from North to South, with the ports of Barcelona and Castellón, so the adjacent VTSs are MRCC Barcelona and MRCC Castellón, and all share coordination of operations and procedures. However, they have different reporting systems, so the same information about a ship that calls at one of the mentioned ports is not shared.

A.6. VTS Centre.

The VTS Centre operates 24 hours a day, 365 days a year. Being a mixed Centre, the staff performs routine room tasks, maintains control of maritime traffic in the assigned area and is attentive to any emergency that may be announced, either by VHF radio or by telephone. The guards are always covered by a minimum of 2 VTS Operators, who carry out shifts, there being three shifts in one day; morning, afternoon and night. The shift changes are made with enough time to exchange information, and the Room is never unattended. All professionals are accredited and follow health and safety guidelines provided by the company. Each Centre has its manual of procedures that are updated according to needs.

A.7. Technology.

The basic technology of the VTS Centre is composed of VHF radio equipment, radars, and AIS. There are 2 VHF radios stations dubbed in marine band, with DSC, a VHF air band radio, plus 2 portable VHFs. Since there are radio and radar antennas in different places, there is local and remote range for greater coverage. There are computers with internet connection, currently working with 5 screens, for named main elements, that is, DSC (digital radio through I.P.), AIS (called AISWeb, whose server is currently Cellnex Telecom), radar, radio VHF (digital), a screen for computer systems that includes a specific program of the company, with the acronym SIGO, and video cameras, Close Circuit TV (CCTV). Computer screens are also used to access other programs and platforms necessary for the development of VTS functions. More than 10 access points to pages with login and password are counted. Oceano (Radio warnings), IncaWeb (internal procedures), ViaPortus (ship authorizations), TarragonaPilots (forecasts of maneuvers), SafeSeaNet (vessel infractions and incidents), Oilmap and Sarmap (specific programs for drift calculations), Safetrx (an accessible tool that can be used by recreational boat users during their voyages), Equasis (which provides safety-related information on ships and companies), access to the meteorological station of the port of Tarragona, information and courses through the CESEMI website. Both the radar and the AIS have a recording and back track system and the radio and telephones have recorders. In addition, the room has an emergency electrical backup circuit to safeguard the equipment, in case of general electrical failure.

A.8. Allied services.

In terms of the services that operate within the port waters, there are cooperation agreements between the assets of port community. This includes pilot boats, availability of tug assistance, barges, supply boats and Port Police, in agreement with other police forces. Outside the waters of the port, cooperation extends to other entities such as local and national police forces, fire fighters, Red Cross, civil protection, beach lifeguard services and other collaborators.

A.9. Legal.

Being an MRCC, it is linked to the IMO documentation, according to the circular SAR.7/Circ.14 of 2019, as outlined in the annex. It comprises a list with the minimum documentation that an MRCC must have and is exclusively for SAR, but, at the same time, some of it is directly linked to the VTS, including the SOLAS, GMDSS, SMCP or other references, such as Res. MSC.131(75), or Resolution A.950(23) among others, (the list contains up to 100 reference documents, plus links). The legal framework is consistent with national law and, being a VTS Centre, the main national laws are the VTSs regulated by RD 2/2011 consolidated text of the LPMMRD 210/2004 of February 6 (Amendments RD 1593/2010 and RD 201/2012), the Royal Decree 1334/2012, of September 21, on the information formalities required of merchant ships arriving at or leaving Spanish ports and Law 14/2014, of July 24, on Maritime Navigation.

The APT is the public body with legal entity and its own assets, responsible for the management of the port of Tarragona, dependent on the MITMA ministry through OPPE.

A.10. VTS personnel, recruitment, and training.

The staff consists of 14 VTS Operators who cover all shifts throughout the year. All Operators have a maritime background and have passed examinations and tests to achieve the position of Operator.

All have degrees, training and certification under IALA, but also academic degrees at university and professional level through the DGMM. Operators can choose a destination, a VTS Centres in line with programs of transfer offers, with assignments according to specific requirements, such as seniority in the company. There is a VTS qualification revalidation system in accordance with IALA standards through the Training Centre in Jovellanos (CESEMI).

A.11. Future requirements.

Tarragona plans to expand the docks and increase traffic so that, in the near future, the evolution of maritime traffic could be affected, including the number of ships and types and sizes of ships, related to the cargo carried. Furthermore, and very important to note, technological advances could bring new tools for VTS and also developments in technology related to navigation. Implications of future packages are included in SOLAS and IMO regulations, such as MASS ships.

A.12. Financial.

The OPPE, a public body attached to the MITMA ministry, is responsible for executing the Government's port policy with functions of coordination and control over the entire state-owned port system. For this reason, it establishes that the Port Authorities have a service for the ordering and monitoring of maritime traffic in a uniform manner in all ports.

The collaboration framework agreement between Sasemar and OPPE, signed for the first time in 2014, established the amounts financed by Port States and the cost of the services that the Company would provide in each port, after agreeing and signing with each Port Authority. The service contract between APT and Sasemar, for the provision of the general service of organization, coordination and control of maritime traffic and the performance of coordination tasks and emergency action due to accidental marine pollution in the port, was signed a year later, the Royal Decree-Law 1/2014, of January 24, reforming infrastructure and transport, and other economic measures.

This is the last section Annex A of the guideline, so at this point, the VTS Centre implementation procedure would have started, so a name would need to be defined. The identifier of Tarragona Centre is Tarragona Traffic.

It has been explained that the IMO, through the resolutions regarding VTS guidelines, requires a “Name Identifier”. This has been the case since 1985, with the first resolution R.A. 578, to the second, in 1997, the R.A.857(20), “the VTS Centres in an area or sector should use a name identifier”. IALA also encourages the use of a common identifier between the Centres. The Guideline of 2011, titled “Standard Nomenclature to identify and refer to VTS Centres” (IALA 2011c), specifies that the name identifier should include two key elements, namely the geographical location of the VTS and its capability. It argued that there was a lack of consistency in the use of name identifiers by VTS centres (IALA 2021e). These included such terms as: ‘VTS’, ‘VTIS’, ‘traffic’, ‘control’, ‘coastguard’, ‘harbour control’, ‘harbour’, ‘port control’. The purpose was to find a standard nomenclature to identify and refer to VTSs around the world. “Where a VTS has been implemented by a Competent Authority it is recommended that the name identifier includes the prefix or suffix ‘VTS’.” IALA specifies that the name should be ‘Location VTS’ or ‘VTS Location’, therefore, in the case of the Centre of Tarragona, if it is “Tarragona Traffic”, it should actually be “Tarragona VTS” as the name. Melbourne VTS was formerly Melbourne Harbour Control[112].

[112] IALA webinar: “VTS Authorisation” by Stephen Dsouza. Session 2. August 26, 2021.

During the last 10 years it has been noticed that ships make the first call with different callsigns. The most named registries are Tarragona Port Control and Tarragona VTS. In order to establish a statistical report, the type of calls made by ships has been noted to obtain what % uses the callsign Port Control, Tarragona VTS, or Tarragona Traffic. In this way, the data shows the global ranking between the three types of identifiers, Tarragona Traffic being the least used. The results are an extrapolation from the days in which the registration was obtained, transferred to an annual statistic.

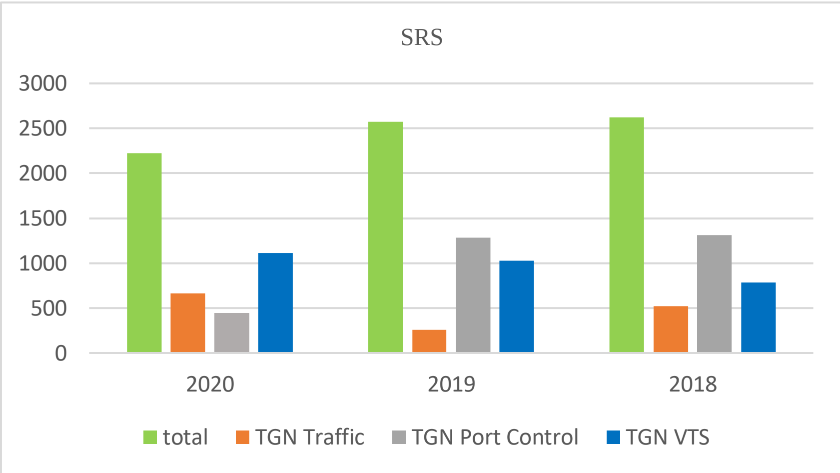

Figure 27. SRS system by VHF from ships to Tarragona Centre

It illustrates that the most familiar terminology among crews is "control" and "VTS" before "Traffic". In an average of nearly 2,500 vessels reporting annually to the VTS Centre, an increase in the identifier "Tarragona VTS" is observed, attributable to the encouragement of the IALA in this terminology. On the other hand, the increase in "Tarragona Traffic" is associated with ships with scales contracted with the port, whose identity name is already known.

The importance of conducting a risk assessment has more than one facet. The aim of Risk Assessment is to ascertain and minimise potential hazard and accidents. Risk Assessment can prevent undesirable scenarios and assist in development of stages to identify and manage hazards. In this way, reducing the number of groundings, collisions and allisions. Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process can be used (IMO 2018). All the detailed information obtained could be utilized in the IALA risk management toolbox.

The authorities responsible for managing the safety of navigation within a waterway have final decision on whether or not to carry out a risk management analysis, but there are several reasons for carrying out this process[113], such as:

– To comply with international obligations, such as the SOLAS Convention.
– When new maritime safety and environmental protection regulations are evaluated.

[113] Concepts of Risk Management. Lecture 2. "Reasons for carry out the risk management process" by Dawn Seepersad. IALA World-Wide Academy training course on the Introduction to the IALA Risk Management Toolbox. June 2021.

- In a comparison between existing and possibly improved regulations, with a view to striking a balance between technical and operational issues, including the human element and maritime safety/protection of the marine environment and costs.
- If there is a need for larger vessels to navigate the waterway occur.
- Changes in the budget available to manage the waterway.
- Whether there have been Accidents in the waterway
- At the request of interested stakeholders.

As a part of the IALA risk management toolbox, PAWSA, and the simplified formula, SIRA, need a significant group of diverse participants and are dependent on their opinions, including those of local pilots, stakeholders, industry sectors, environmental groups, the crucial role of a competent facilitator and a dedicated administration team, amongst others. In the case under study, located in Spain, the competences of the maritime sector are highly diversified, and this increases the number of necessary participants even more. The process of organizing both evaluations can be longer and more difficult. In this sense, the IWRAP Mk II tool has been selected to carry out a risk analysis because it is an objective and empirical tool, which uses a computer program.

IWRAP is a program that IALA makes available to all Member States, to accomplish an analysis using a quantified method. It is therefore a useful tool that can be used to comply with the provisions of the IMO, as stated above, which, through SOLAS in its chapter V, urges Contracting Governments to implement a VTS (Rule 12) or establish aids to navigation (Rule 13), as justified by the volume of traffic and required by the degree of risk. Furthermore, the IMO also invite member Governments to address IALA to assess the risk of collisions and grounding through the circular SN.1/Circ.296. This, includes IALA Recommendations, Guidelines, and tools to assess the risk.

IALA, has developed the Recommendation "Risk Management for Marine Aids to Navigation" (IALA 2017i) and the Guideline "The Use of IALA Waterway Risk Assessment Programme (IWRAP MKII)" (G1123). There are five main steps of the risk management process: a) **I**dentify hazards, b) **a**ssess risks (ALARP), c) **s**pecify risk control operations d) make **d**ecisions and e) take **a**ction. A formula to remember is using the acronym IASDA[114].

IWRAP MkII is a particularly interesting tool because it allows calculation of the probability of collisions and groundings, which are likely to take place in an area each year. Therefore, the probability of a maritime traffic accident occurring in the waters approaching the port of Tarragona can be calculated.

To begin risk assessment using the IWRAP, a) and b) are related to the sections of the 1150 Guidelines, 1. and 2., this needs information on traffic data and the geography of the VTS Area.

[114] Ibid. Section 1.

The essential inputs of this tool are: AIS data to obtain the traffic data and cartography of the area to understand the geography. With the AIS, terrestrial and satellite data (satellite AIS data alone is insufficient), the program performs the probabilistic calculations for a year, but this does not mean that AIS data for a whole year is required, rather, a sufficient representation to calculate the probabilities in that period. The more days of AIS data entered, the more reliable the calculated results. IWRAP makes it possible to quantify this degree of risk, based on mathematical calculations, and to present results based on the chances of collision and groundings. IALA states that around one month of data would be an acceptable approximation. The program requires the input of AIS data, but with specific formats. The IALA recommends different formats of AIS data exchange for using this toolbox, but the data set should contain all types of AIS sentences, both static and dynamic. The AIS data should be raw NMEA sentences, with a time stamp attached to the beginning of each sentence.

The intention of using this tool is to be able to complete a risk management exercise in the waters near the port of Tarragona. However, there are two conditions that make it difficult to obtain the necessary AIS data. Firstly, the large amount of data needed and, secondly, the degree of difficulty in accessing it, since it is not freely available to all users. With the commercial version of IWRAP MkII v6.5.8., which was available for a limited time, it has been possible to carry out an exercise that, although the results cannot be considered representative due to the paucity of data, does illustrate the potential of the tool, and can be related to c), d) and e) and therefore identifies what kind of data can be obtained and as a result, how important it is to assess a VTS area. This will be the basis for a future, detailed study, not as a new line of research, but as a continuity. The aim is to obtain the probability of collisions and, in this case, the probability of allisions which are likely to take place in the approaching waters of Tarragona port, each year. IWRAP does not calculate consequences of the accident, but the results can be used to calculate consequences.

Before entering the AIS data, a georeferenced nautical chart can be included to facilitate the study. In this case, the 1193 Tarragona WGS84 chart was used, each (AIS station broadcast its position referenced to the WGS-84 datum). Once loaded, it is still a flat layer type of information, without bathymetry data or structures. In this case, given that no groundings have been recorded, the polygons marking the shallow waters were not introduced, but the SPM was introduced, as a structure. The scenario covers two full and consecutive days, October 2 and 3, 2020, in NMEA format. Within these 48 hours an approximation to the analysis has been made. According to section 1., where an intersection between two conditions to be met in terms of maritime traffic circulation occurs is in the direction of entry: specifically, to navigate the starboard bound and keep safe distance in regards to the SPM. After analysing the traffic for more than 10 years, it has been noted that the merchant ships prioritize respecting the reservation, so they invade the exit bound, whereas the fishing vessels do the opposite, that is, navigating passing over the restricted area of the SPM.

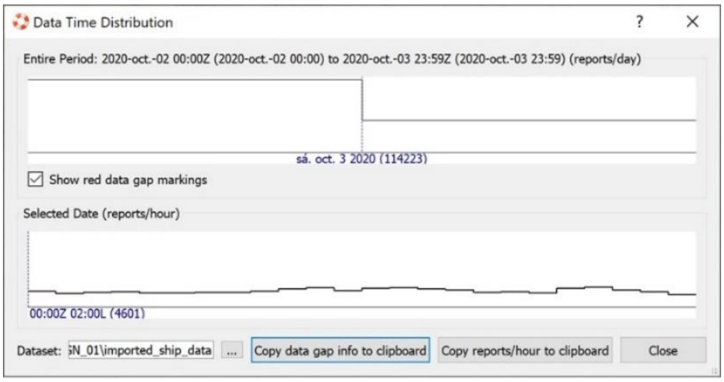

Figure 28. Data Time Distribution

After introducing the AIS data to the program, a traffic density is showed in the chosen area graphically, where it is possible to observe the main areas of traffic concentration (density) and the crossing areas. It is at the meeting and crossing points where the risk is concentrated.

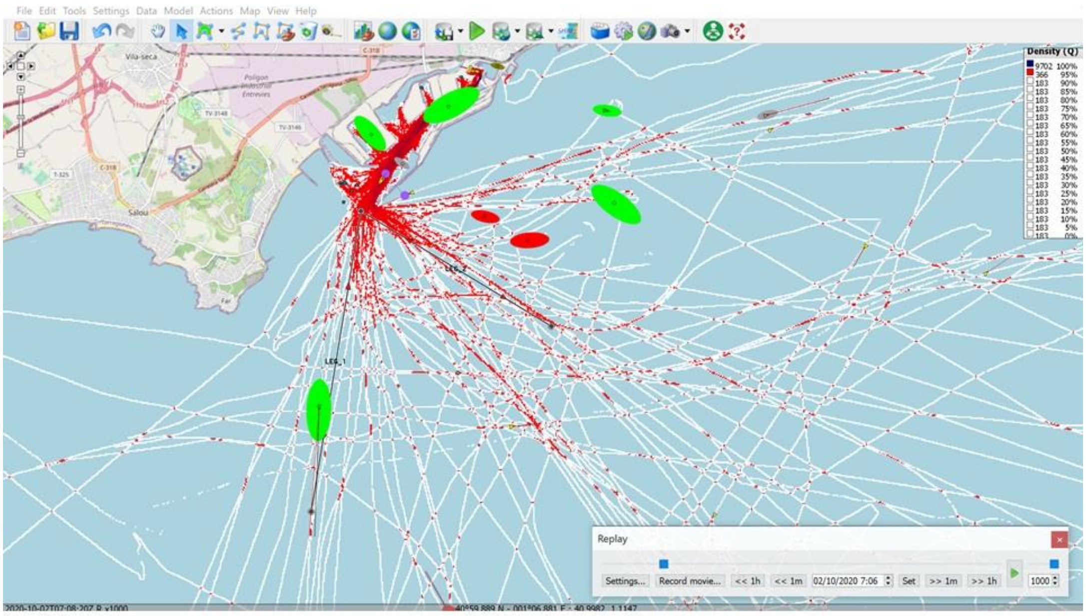

Figure 29. Replay mode scenario

With this first step, it is possible to determine the main navigation patterns followed by vessels, with traffic evaluation through replay function, the movements are observed of ships passing through those “lines”. The shipping lines are referred to as “legs” and, in this way, four legs are established, depending on the model to be studied.

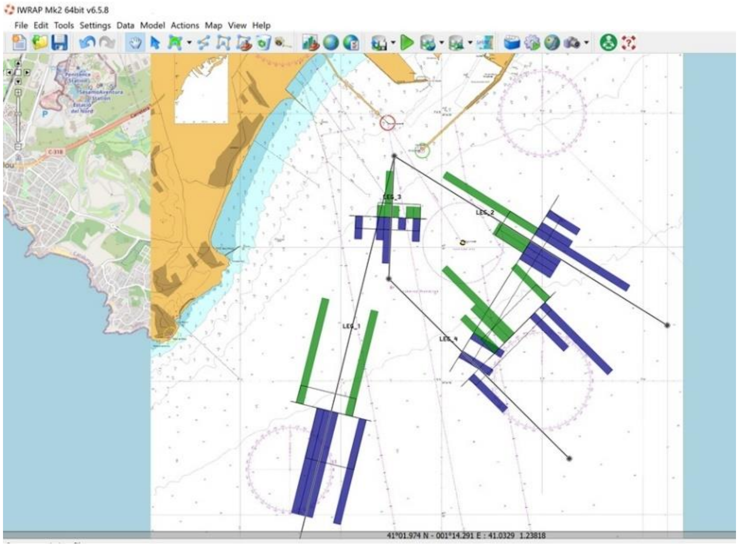

Figure 30. Four legs created

All four legs can be seen on the screenshot made. Building the lateral distribution of where ships move along the leg, it is possible to know how many ships move in each bin, along the leg. After extracting Model Data, deviations appear. It is possible to analyse the type of traffic and the amount. Without the drawn structure (the SPM) the results show that there are no allisions. Regardless of bathymetry or obstacles, only collision possibilities are obtained.

	SMP-mov-SPM no	Unit
Powered Grounding	---	Years between incidents
Drifting Grounding	---	Years between incidents
Total Groundings	---	Years between incidents
Powered Allision	---	Years between incidents
Drifting Allision	---	Years between incidents
Total Allisions	---	Years between incidents
Overtaking	4.908,17058	Years between incidents
HeadOn	3.612,00676	Years between incidents
Crossing	6.375,13521	Years between incidents
Merging	---	Years between incidents
Bend	---	Years between incidents
Area	---	Years between incidents
Total Collisions	1.568,73639	Years between incidents

	SMP-mov-SPM no	Unit
Powered Grounding	---	Incidents/Year
Drifting Grounding	---	Incidents/Year
Total Groundings	---	Incidents/Year
Powered Allision	---	Incidents/Year
Drifting Allision	---	Incidents/Year
Total Allisions	---	Incidents/Year
Overtaking	0,00020	Incidents/Year
HeadOn	0,00028	Incidents/Year
Crossing	0,00016	Incidents/Year
Merging	---	Incidents/Year
Bend	---	Incidents/Year
Area	---	Incidents/Year
Total Collisions	0,00064	Incidents/Year

Figure 31. Results No SPM no Allisions

But if we draw the structure following the contour of the letter symbol and indicating in the program that it is a solid structure with height, the results show that allisions exists, the results change and the allisions appear although with a very low probability.

	TGN_01-SPM Structure	Unit		TGN_01-SPM Structure	Unit
Powered Grounding	---	Years between incidents	Powered Grounding	---	Incidents/Year
Drifting Grounding	---	Years between incidents	Drifting Grounding	---	Incidents/Year
Total Groundings	---	Years between incidents	Total Groundings	---	Incidents/Year
Powered Allision	50,25409	Years between incidents	Powered Allision	0,01990	Incidents/Year
Drifting Allision	2.655,15931	Years between incidents	Drifting Allision	0,00038	Incidents/Year
Total Allisions	49,32060	Years between incidents	Total Allisions	0,02028	Incidents/Year
Overtaking	5.585,41167	Years between incidents	Overtaking	0,00018	Incidents/Year
HeadOn	3.683,00423	Years between incidents	HeadOn	0,00027	Incidents/Year
Crossing	6.375,13521	Years between incidents	Crossing	0,00016	Incidents/Year
Merging	---	Years between incidents	Merging	---	Incidents/Year
Bend	---	Years between incidents	Bend	---	Incidents/Year
Area	---	Years between incidents	Area	---	Incidents/Year
Total Collisions	1.646,32163	Years between incidents	Total Collisions	0,00061	Incidents/Year

Figure 32. Results allisions with SPM structure

To see which vessels are in these results, the table separated by type of ships depicts the fishing vessels within the probability.

Allision Results - Model: 'TGN_01' Job: 'TGN_01-SPM Structure'

Item Total Allisions

	e oil ta	Oil products tanker	nical ta	is tank	tainer	General cargo ship	lk carr	cargo	enger	ist fern	Support ship	Fishing ship	isure b	her sh	Sum
-1															
0											0,000725675	0,0087297			0,00945537
25											1,74736e-05	0,0063535			0,00637097
50															
75															
100		0,00238967													0,00238967
125		0,000732917				0,00121474									0,00194765
150															
175		1,71096e-05				7,10368e-06									2,42133e-05
200						7,98584e-06									7,98584e-06
225						1,66594e-05									1,66594e-05
250															
275		6,29745e-05													6,29745e-05
300															
325															
350															
375															
400															
Sum		0,00320267				0,00124649					0,000743148	0,0150832			0,0202755

Figure 33.Allision results fishing

And the Replay mode, shows where the fishing boats pass.

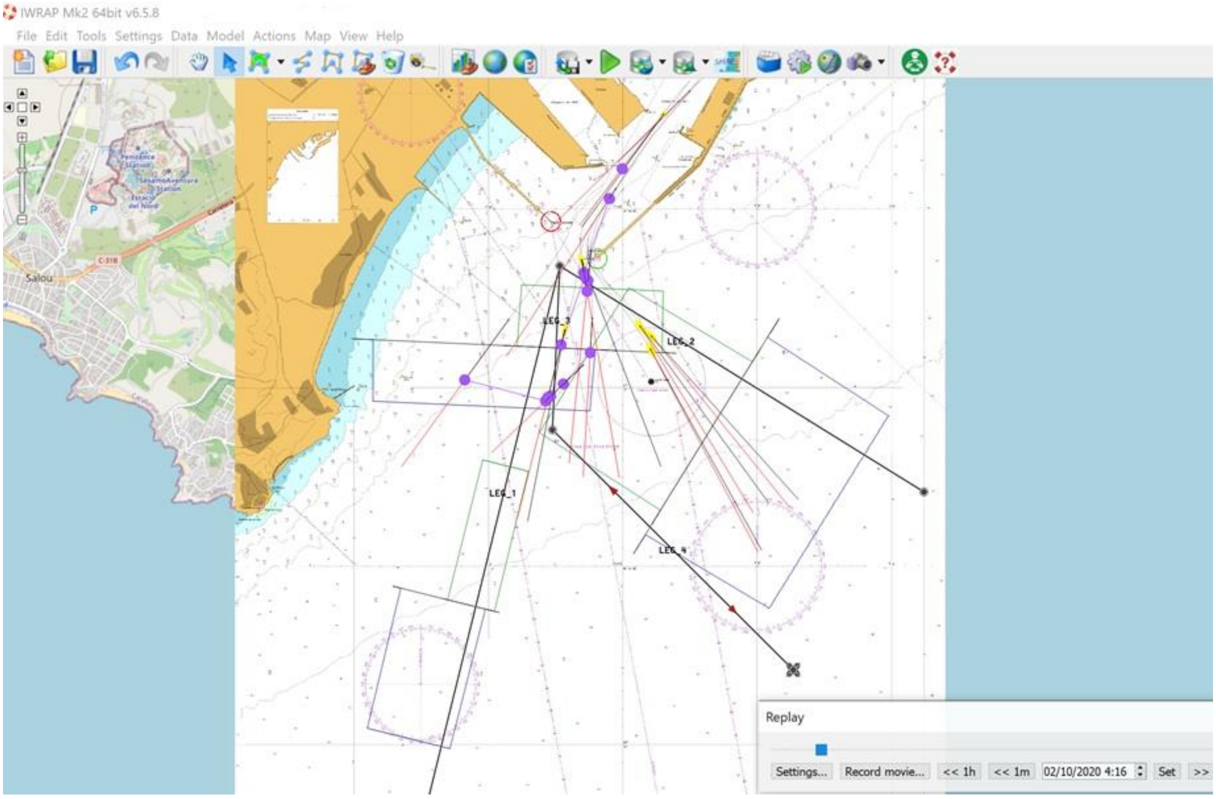

Figure 34. Replay fishing vessels

But since the SPM requires a 3-wire guard, if the structure is drawn with that diameter, the scenario changes. A structure with these dimensions has been created and the results depict that the allisions have increased.

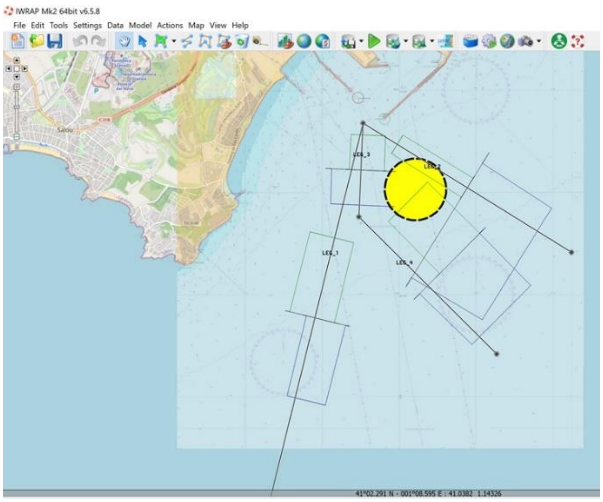

Figure 35. SPM structure of 3 cables

	SMP-mov-Fishing	Unit
Powered Grounding	---	Years between incident
Drifting Grounding	---	Years between incident
Total Groundings	---	Years between incident
Powered Allision	2,43803	Years between incident
Drifting Allision	124,00151	Years between incident
Total Allisions	2,39102	Years between incident
Overtaking	4.908,17258	Years between incident
HeadOn	3.612,01022	Years between incident
Crossing	6.375,13521	Years between incident
Merging	---	Years between incident
Bend	---	Years between incident
Area	---	Years between incident
Total Collisions	1.568,73725	Years between incident

Figure 36. Results allisions

As results, the following analyses can be obtained:

- It is possible to identify the amount of traffic in an area.
- Identify possible hazards in the waterway.

– Know the probability of which ships may be affected.
– Check if the risk disappears, lowering the probability of accidents.
– The traffic can be reorganized in a waterway after a IWRAP study.
– Changes in the waterway modify the results so is possible to do forecasts.
– The amount of risk that can be reduced and how.

It is possible to establish traffic routing measures, such as traffic separation schemes (TSS) or recommended routes. In this specific case, establishing TSS does not make sense, but it would be possible to establish specific entry channels, similar to the neighbouring port to the north, Barcelona. The word "port" does not appear in Rule 9 of the COLREG but it is recognised that, when it speaks of a narrow passage (which should be defined in Rule 3), it refers to the narrowing between breakwaters at the entrance of a port facility (Salinas 2004:60). The need to regulate an entrance to the port is logical, insofar as it is a highly conflictive sector, with a pilotage area and, in this specific case in Tarragona, with a SPM that can be an obstacle and make manoeuvres difficult, since the behaviour of ships is to keep to the outer limit "which lies on her starboard side" (Rule 9).

This tool has great potential, not only to calculate annual probability of different types of collisions and groundings[115] within a waterway and simulate scenarios due to changes on the waterway, but also to visualize attributes of vessels, for example, navigation areas for vessels with a specific speed or draft, or even estimate the CO_2, NOx, and SOx emissions within an area.

Historical data shows that it is not a particularly conflictive area in terms of density and accidents. However, there have been some cases and future trends indicate that it could get more complicated. Once the results are obtained, reporting is crucial for all authorities, stakeholders and all vessels involved. Any report on the process needs to clarify parameters, scenarios and actual methodology, in order to present a comprehensive projection of risk and, therefore, a clear guide to avoid potential, undesirable events.

Furthermore, it must be taken into account that most of the traffic is IMO cargo, dangerous goods, so this increases the probability of an accident with much more catastrophic consequences. The more traffic, the more likely complex traffic situations will occur, and, as has been pointed out, the port is committed to growth.

5.2. Present tools for VTS.

The types of sensors that a VTS can use to locate a ship have been shown. Thanks to the incorporation of satellite and digital technology, new possibilities have opened up that VTS, as part of the maritime sector, will also benefit from. The analysis of these has been reserved for Part III, but it is during this period, covered in Part II, up until 2017, that substantial changes have begun to be seen within the

[115] Types of collisions assessed in IWRAP MK II: Head-on, Overtaking, Bend, Crossing and Merging. Types of groundings: Powered grounding and drifting grounding. Lecture 3: Basic concepts of IWRAP MkII. IALA course July 2021.

maritime sector. AIS is increasingly used, not only for SOLAS vessels, but also for other types of vessels. The development of the AIS-T and AIS-S allows to search and locate ships around the world. Since the company's corporate AIS has a limited scope, it is common to consult open access platforms to locate a ship bound for Tarragona, in this case. This is the case with MarineTraffic or VesselFinder, for example, which allow the visualization of maritime traffic on a large scale.

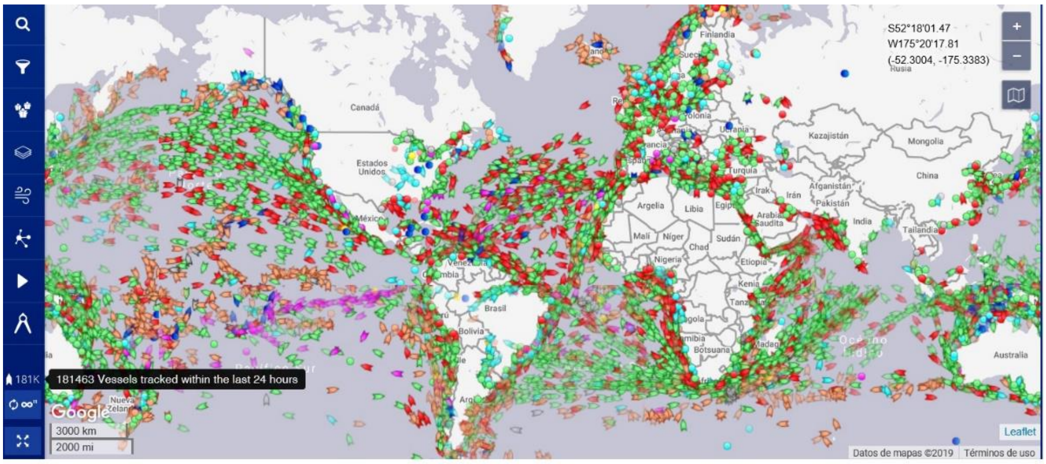

Figure 37. MarineTraffic web accessed March 2019

Currently, it is possible to search for any day, observe the global traffic of ships showing AIS signal and obtain an image of maritime density. As an example, on one day in March 2019 181,463 vessels were tracked within 24 hours. It is not an officially accepted tool but, for now, it serves as a resource to search for a vessel beyond the limits that the AISweb platform allows to see.

Through EMSA, the Spanish Maritime Safety and Rescue Agency, as a member state of the EU, has the credentials to access the SafeSeaNet portal with login and password. As described above, this computer tool is relatively recent and, in the last 10 years, it has undergone major changes and improvements in terms of performance. From its conception, where only the track of a ship could be consulted, now it is practical work tool that allows information on ships to be shared between States and, therefore, the centres that manage traffic and/or emergencies. Ships transmit the LRIT information to the LRIT Data Centre selected by their Administration, then this information is uploaded to the platform. This maritime application integrates other applications, such as the CleanSeaNet. Currently, Member State authorities can exchange additional passenger information for Search and Rescue purposes, waste information (MARPOL), in line with the new Port Reception Facilities Directive and share the information from the Incident Report created by VTS Centres. It also gives access to external Sites, such as the database of the Equasis.

VHF radio has begun to be digital in different VTS Centres. In the VTS Tarragona, the change was made at the end of 2021. The introduction of digital radio improves the quality of communications.

Some tests, carried out with the collaboration of the VTS Operators of Rotterdam[116], concluded that the digital sound was clearer than the analogue one, with better voice quality and noise reduction, thus, easier to listen to and less tiring.

Without considering them as new tools, there are new services that began their use in the Tarragona Center at the end of 2017. These are the WhatsApp and Telegram mobile phone applications. Their function is more for emergencies and the need arose because many users could provide their location more easily by their automatic mobile geolocation than by reading their GPS or giving geographical references. In short, their use is based on having a further means of sharing the ship's position.

[116] The results were shown during the presentations within the program of the work sessions of the IALA ENAV26 Committee, 29 September 2020.

Conclusions and recapitulation of PART II

In Part II, which covers 20 years, an exponential evolution has been observed in the consolidation of the VTS and its work tools. International recognition has been strengthened and increased among the port community thanks to the IMO, with its resolutions and inclusion in the framework agreement, SOLAS V, but above all, thanks to IALA which has developed numerous Standards, Recommendations and Guidelines for VTS. The VTS owes a lot to the IALA in these years, but the VTS Operators even more.

The arrival of the second guidelines for VTS after 12 years, did not bring significant changes in terms of functions, capability, or equipment for VTS, but they are associated with SOLAS V Regulation V/8-2 (at that time) and include the IALA Vessel Traffic Services Manual as a "further guidance on Vessel Traffic Services".

International Conventions		Years	About VTS
The United Nations		1945	
IMCO	37 years	**1948**	**RADAR+VHF**
3rd SOLAS		1948	
		1950	VTS Centres
		1957	IALA Established
4th SOLAS		1960	COLREG
		1965	FAL
Load Lines (LL)		1966	
		1967	TSS Dover-voluntary
		1968	R. A.158 (ES.IV)
		1972	COLREG
MARPOL		1973	
SOLAS, as amended		1974	
		1976	Convention (IMSO C)
SMNV		1977	TSS Obligatory
STCW		1978	MARPOL 73/78
		1979	SAR
IMO		1982	UNCLOS
		1983	R.A. 531 (13) SRS
		1985	**R.A.578(14) Guidelines for VTS (1st)**
GMDSS	12 years	1988	
GMDSS began		1992	
		1993	IALA 1st Ed. Manual VTS
		1994	R.MSC.43(64) SRS
STCW (amended)		1995	R. MSC.46(65) RS
		1996	
		1997	**R. A.857(20) Guidelines for VTS (2nd)**

Table 27. The strengths achieved in the context of the VTS chronologically 1945-1997

The chronological table continues back to Part I and takes, as reference, the moment in which the guidelines for VTS are updated. From 1997 to 2017, there have been some additions, but the Resolution of reference for the VTS since the IMO continued to be that of 1997, so that, in 2017, it was still a 20-year-old resolution. Vessels Traffic Services are consolidated internationally and linked to SRS and RS, an essential role in the control, surveillance and reporting of TSS and approaches to ports.

New technologies advance much faster than the regulations that govern them, and AIS became an essential tool for VTS. The widespread use of AIS has significantly increased the quality of the VTS mission but the limitations of the AIS must be always kept in mind and the radar will continue to be relied on. The AIS is, above all, a window to be able to see maritime traffic on a global scale, from open platforms, such as MarineTraffic or VesselFinder, for example, to contracted services with authorizations, such as LRIT or private data registration services.

The VTS Operator profession is standardized and certified by IALA, the organization that became intergovernmental, with membership from a large majority of countries in the world. All the recognition and qualifications, training and certificates make the position of Operator a profession with prestige and international accreditation.

The establishment of ships as a major means of transporting goods around the world ensures high port activity and, therefore, the VTS services are essential AtoN that contribute to safety of life at sea, safety and efficiency of navigation and protection of the marine environment.

The IMO has been urging governments since 1997 to have VTS Centres. However, States can establish VTS Centres for disparate reasons, because of the size of a port, because of its category or simply because of an operational need, but not because of having carried out a previous study based on qualitative or quantitative criteria.

Given the importance of ports and their dynamics, the use of risk analysis tools, in accordance with the IALA toolbox package, should be promoted, since the analysis can be done a posteriori. Carrying out the risk assessment process helps to maintain safe and efficient maritime navigation within a waterway. The use of computer programs, such as IWRAP, can be of great assistance in improving traffic management and preventing accidents. The AIS data should be accessible to the VTS Centres in an easy and flexible format, to be able to carry out risk analysis when necessary.

Coordination between VTS Centres would speed up the information in the reports and would ensure the ships do not have to answer the same questions, especially between ports in the same country. The vessel report should be done only once, from port to port, with the VTS sharing the information. If this is not possible, the system should guarantee that the workload does not rest on the ship but on those who operate the system.

The objective of traffic management is to ensure that no ship is in a situation that compromises the efficiency and safety of general traffic in the area. No ship should be faced with a problem that it cannot solve, or can only solve at great cost.

Thanks to the large-scale traffic surveillance tool, the LRIT, it is not only possible to have a vision of global traffic from land, but also to access relevant information on ships, a tool that was made possible by including it as mandatory for SOLAS ships.

Digital radios, mobile and satellite telephony are part of the tools of the Rescue Centres and VTS. the evolution, over this period of time, tended to increase the teams and the screens. This will be different in Part III. From a radar screen and a radio, VTS consoles that manage several screens and different radios have been implemented.

The mobile is a more widely used technology and, especially in the case of recreational boats, some users have shown more skill with the phone than with the nautical equipment on board. Currently, it is crucial that mobile telephony, with its applications capable of sharing a position, does not replace the radio or a radio beacon, due to the lack of coverage when moving away from land. Another analysis will have to be carried out, when the scope of global mobile telephony is available to everyone.

Remarks Part II:
New Guidelines for VTS (2nd) 22p.
1st IALA VTS Manual
The VTS service is recognized as a value for safety, efficiency, and the environment
Type of VTS: Port or Harbour and Coastal
Mandatory in territorial waters, voluntary beyond
Lack of standardization is recognized
Specific equipment for the VTS: Radar and VHF and AIS
Services INS, TOS, NAS
Functions: information, organization, and assistance
VTS area can be divided into sectors

Table 28. Remarks Resolution A.857(20) Guidelines for VTS

PART III

PRESENT – FUTURE: The VTS system towards e-Navigation.

2018 – and beyond

Introduction: Think Global, Act Local". This phrase was used at the "Earth Summit" in Rio de Janeiro, Brazil, 13 June 1992, and denotes how individual acts can influence major environmental problems. The value of this maxim can easily be lost in the frantic pace of life many experience, and this leads to the fact that, if one day something is not recycled, there seems to be no consequence. But the reality is that each attitude is important and is noticeable globally. Technology, in alliance with sociology, has created the concept of "globalization" that includes wide spectrums in its definition, but, in the subject of this thesis, it has allowed global transmitting and receiving information in various formats. The feasible communications flow from practically anywhere in the world is in 3D.

This third part highlights the third guidelines for the VTS and analyses the future trend that the VTS Operator faces, with the newest latent technologies. IMO's drive towards e-Navigation has encouraged the birth of new projects, the main ones of which are explained in this section. Global surveillance is the scale that will allow local operation, from the point of view of the VTS Operator, working locally, controlling the world, the oceans, and all of this will be thanks to both digital and satellite technology.

Chapter 6. "Take off" of the VTS.

Once the VTS system has been consolidated, now the "take off" is a metaphor that takes the VTS into the sky, through the use of satellite technologies.

"In the beginning, God created the heaven and the earth" is the first sentence of Genesis and, therefore, of the Bible, perhaps the most influential book in the history of mankind. "Sky" is the first literary noun and, from then on, it was covered with metaphysical connotations that various scientists tried to dismantle throughout history, until science to make it its own. Today is the technological habitat of satellite technologies.

"Taking off" can also be used to articulate the arrival of the third guidelines for the VTS. The third guide for VTS, about to be published, is analysed below, in its latest draft, with the changes and additions introduced.

6.1. The third Guidelines for VTS (2021).

This first paragraph has been changed at the last minute since, in January 2022, IALA published the name of the new guidelines for VTS, that is the Resolution A.1158(32)[117]. As anticipated by the IMO, the final adoption was at Assembly 32, in December 2021, and published circa 2022. The 32nd Regular Session of the IMO Assembly (Remote Session) was held from 6 to 15 December 2021, and the Opening Address was delivered by IMO Secretary General Kitack Lim[118].

Since the publication of Resolution A.857(20) of 1997, there have been no further revisions or modifications published. However, the maritime sector has been demanding an urgent update.

From 1997 to now, more than 20 years have passed and, during this time, important matters have occurred. Some of the most important, in relation to the maritime sector and influence on the VTS system, include; the implementation of the Automatic Identification System (AIS) on board ships, the creation of the Safe Sea Net (SSN), Directive 2010/65/EU, and later the European Maritime Safety Agency (EMSA), Regulation (EC) No 1406/2002, and the concept of e-Navigation, MSC.94/18/8, that is increasingly necessary, to incorporate the rapid developments of new technologies and their potential use. Governments, organisations, and different stakeholders, within the international maritime domain; have demonstrated the need to update the resolution.

IALA, through the expertise of the VTS Committee and a correspondence group (over 30 committee members from 20 organizations, representing competent authorities, VTS authorities, sister

[117] Published on the IALA web. https://www.iala-aism.org/news-events/iala-webinars/introduction-to-the-imo-resolution-a-115832/ (Accessed: February 5, 2022)

[118] Previously published in the IMO brochure on Assembly 32nd Session, London 6th-15th December 2021. pp 1-11. https://adobeindd.com/view/publications/c097ec03-449b-416e-b7be-6324432c89f9/7tfo/publication-web-resources/pdf/IMO_32_Assembly_2021_English.pdf

organizations and industrial members), has taken a coordinating role in the preparation of a new revised Resolution for submission to the IMO.

The first intention to carry out a review was in 2003 included in the agenda of the VTS Committee, however the process was stopped [119]. Thus, the first process review was initiated under the work program of 2014 to 2018[120]. . In 2016, the VTS Committee commenced the development of an unplanned output proposal for the IMO. In February 2018, a proposal for a new output for a revision of the resolution was submitted to the Maritime Safety Committee, in its 99th session, (MSC 99/20/3). On April 2, 2019, after the 46th Session of the VTS Committee had worked on the draft of the Revised Resolution, in its version 2.3.1 (IALA 2019c), the MSC published the progress on the review, via MSC 101/23/11 submitted by the IALA. In June 2019, the 47th meeting was held and IALA hosted a seminar at its headquarters on updating the resolution. IMO Member States, IALA members, international organizations and other stakeholders were informed and invited to participate in the draft version.

The work program was divided mainly into two sessions. A high level of announcement accredited a total of 77 participants from 25 countries around the world and 7 Sister organizations, who worked in a double format of presentations and technical debriefings (Uyà 2019:85). In all cases, the program was assisted by delegates and members of the IALA itself, the IMO, Competent Authorities, VTS Authorities, Pilot Associations such as IMPA (International Maritime Pilot's Association). International organizations included IHMA (International Harbor Masters' Association), IFSMA (International Federation of Shipmasters' Associations), BIMCO (Baltic and International Maritime Council) and IAIN (International Association of Institutes of Navigation). On behalf of Spain, the Spanish Maritime Safety and Rescue Agency, which is under the umbrella of the General Directorate of the Merchant Marine, of MITMA, was the one assigned to provide monitoring services and assistance to maritime traffic, maritime and navigation safety. Given the nature of the Resolution under study --of a specific nature in terms of maritime traffic--, the Spanish delegation was made up of the Head of the VTS Area, Carlos Fernández Salinas, whose headquarters resides in the Jovellanos Integral Maritime Security Centre (CESEMI). This seminar provided the opportunity to contribute, by expanding or modifying the draft, for IMO Member States, international organizations and companies in the sector that had not been able to participate in the preparation of the new initial proposal. It was a unique and conclusive opportunity to finalize details of the new Resolution.

The opening of the Seminar was given by the Secretary General of the IALA, Francis Zachariae, with a brief but very far-sighted introduction, emphasizing the importance of the event under three key points: the direct involvement of 31 participating committees from 20 organizations that have been working for two years in its final stage; highlighting the role of the Australian Maritime Safety Authority (AMSA),

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[119] Monica Sundklev during the IALA webinar: Introduction of IMO Resolution A.1158(32) Guidelines for Vessel Traffic Services. February 17, 2022, at 10:00UTC. Up to 220 attendees.

[120] Trond Ski, of the IMO VTS WG1 Committee, during the Seminar on the Revision of IMO Resolution A.857(20), 26-27 June 2019. IALA Headquarters.

the role of the VTS authorities and the direct correlation that exists between the increase in maritime traffic and the growing demand of the coastal States, for more maritime traffic services throughout the world. The Chair of the VTS Committee, Monica Sundklev, moderated the sessions, displaying her extensive knowledge of the maritime sector, not only in her own presentation, but also when fielding the comments and questions of the attendees. Thomas Southall fronted a presentation made by the Australian Maritime Safety Authority (AMSA) and began with a "Giving effect to the current Resolution", where he highlighted the main points of the review, which he explained as having been susceptible to confusion in different countries. Finland, with Sari Talja as representative of VTS Finland Ltd., explained the history of the VTS, which the Maritime Administration did not launch until 1997, the same year the Resolution was born. For them, it has meant a reform of transport and communications at the national level, which they have divided between three actors: the Authority, the Provider and the VTS Organiser. It was emphasized that the exchange of data and information between participants is essential for efficiency and security.

Carlos Fernández Salinas, also as an IALA VTS Expert, presented his paper "7 reflections on the new IMO Resolution regulations", highlighting how the new document can affect the different VTS authorities. He pointed out four key words that influence an imminent change; the neophobia before the novelty, the cultural perspective, the harmonization and the strength of it.

From Kiel, Germany, Dr. Christina Schneider, acting as legal advisor, offered a more futuristic vision, addressing the issue of VTS beyond the 12 miles of non-mandatory use, according to SOLAS V Regulation 12(3) and UNCLOS, but which may be increasing; IMO and governments will have to challenge this trend. The new resolution will contemplate the voluntary use associated with more than 24 SRS, Ship's Routing and Ship's Reporting System, that exist throughout the world and in accordance with SOLAS V/10 and V/11. He focused on the purpose of the VTS, its tasks and purpose, in the VTS area in territorial waters, which can be enforced with the right to give instructions influencing the decisions made on board, but without nullifying the ultimate responsibility of the Master.

After the presentations, the technical meetings consisted of opening debate among the attendees for contributions and considerations, and an application was also created to facilitate the collection of questions or online analysis. The panel discussion was joined by Pieter Paap, the delegate from the Netherlands and Steffan Priem, the Belgian delegate. The number of VTS operators, their training and qualifications and teaching venues, what standards a Centre must meet, and other issues that are not included in the Resolution, but that are delegated to the authorities of each country and in the IALA as a recognized body, were discussed.

Osamu Marumoto, representative of the IMO, explained the operation of the IMO to understand the long processes that are required in regulatory matters.

The issue of how to break traditional barriers in the face of rapid changes caused by new technologies, industrial globalization, and the increase in optimizing the logistics chain of the maritime sector was also raised.

The new Resolution will be more concise, it will have fewer pages, from 22 to 7, and it will have a single annex, instead of two, considering that it is easier to modify one of them than to amend an entire resolution. The main points that are subject to modifications of Resolution A.857(20), within the definitions[121] are, in order of appearance: The Vessel Traffic Service, VTS will be implemented by a Government, instead of "a Competent Authority". This is directly allied to point 1.1.2: *Competent Authority*. The term "Authority" raises semantic bewilderment over what is formally understood as an "Authority" and the one that is "Authorized" to exercise a function, in this case that of VTS. To avoid translation differences, the body that exercises the VTS service will be called "the VTS provider", a more accurate phrase denotation in a domain of shared sociolinguistics, (the English language). So, the *Competent Authority* will be the authority made legally responsible by the Government for Vessel Traffic Services and the VTS authority (point 1.1.3) will be the *VTS provider* which will mean the organisation or entity legally empowered by the Government or Competent authority, for the provision of a vessel traffic service. The *VTS area* means the delineated, formally-declared area in which the vessel traffic service provider is legally empowered to deliver the service. The compound expression of "service area" will be separated, with the understanding that the service is already provided in the area and, therefore, is redundant. The subdivision of area into sub-areas or sectors will also be eliminated in this definition. The *VTS personnel* instead of *VTS operator* (point 1.1.6) is understood as persons trained and qualified, who perform the tasks of VTS, so that the functions do not fall according to the tasks to be performed, but on the qualifications held. In this way, more importance is given to training, (all V-103 are included). But, in addition, a paradigm is opened in which the VTS by itself will already be a profession, while the generic personnel is dispensable in the verbal/oral articulation, since it does not provide information, determinant, unlike when accompaniement with a specific noun, such as "Operator" or "Instructor", with axiological semantic functions. If now, in the semantic field of transport and communications "controller" is associated with air traffic, without it being necessary to articulate "air", from now on "VTS" can be associated with maritime traffic without articulating "operator", in line with the evolution of a language that contains the acronym and the simplification and syntactic saving, an inclusive language that emphasizes the acronym VTS.

The definition 1.1.10, *Allied services*, denotes the word "allied" to mean services, other than a vessel traffic service, supporting vessel traffic, since safety and efficiency are already part of the functions of a VTS.

[121] Section 1. Definitions and clarifications. p.3.

One of the most substantial changes refers to the three types of services that are rendered by a VTS. The INS, TOS and NAS were used to differentiate the degree of interaction of the VTS with vessels and, furthermore, with the type of VTS, since the TOS and NAS services are normally associated with the Port or Harbour VTS, whilst the INS is with the Coastal VTS. However, these are not being recognised by mariners, who are the primary recipients of VTS, nor is there common understanding among VTS experts on the interpretation and the practical use of the three types of services. The word "Service" after each type of service was found to be the cause of current confusion. One of the authorities' main concerns is that these services are not declared or delivered consistently worldwide, while ships navigate in different VTS areas. VTS are delivering navigational assistance and traffic organisation without declaring the services. The aim is to exclude the types of VTS service in the revised resolution., to harmonise the interpretation and provision of vessel traffic service worldwide and understand that there is, in fact, only one "service" provided by a VTS. The service (not plural) consists of maritime information, monitoring, management and organisation of vessel traffic and navigation assistance by responding to unsafe situations (Southall 2019).

Although Resolution A.857(20) included, for the first-time, guidelines on recruitment, qualifications and training of VTS Operators in Annex 2, in point 1.1.3: "The various levels of knowledge and skill required of the operator, and the standard of training necessary to achieve these levels, have never been fully defined on a world-wide basis. At present there are no internationally recognized qualifications for VTS operators, and the approach to recruitment and training varies widely from country to country". So, to mitigate these variances, the existing resolution makes reference to the IALA VTS Manual. However, this Manual is only updated every 4 years. In order to avoid the pitfalls caused by a lack of updating, the new resolution will refer to the suite of IALA guidance relating to VTS Standards, Recommendations, Guidelines and model courses that are under continuous review. In this sense, "the Resolution is the bridge between SOLAS and IALA Standards"[122]. In addition, as already mentioned in Part II, IALA is committed to the online VTS Manual (IALA 2021) that will make updating even easier.

Since the review work began in June 2018, more than 15 meetings have been held. Final approval was from the IMO MSC 102nd session in May 2020, and then adoption, at the IMO Assembly 32 in Autumn 2021. IALA has developed a complete set of training recommendations, guidelines and model courses that will be ready and effective when the new resolution is published.

In September, IALA held the VTS47th session with the aim of finalizing the review (Gregory and Southall 2019). The VTS Committee would have finalised the draft revision for submission to the IMO-Sub-Committee on Navigation, Communications and Search and Rescue (NCSR), 7th session by January 2020, this was the forecast.

[122] Tom Southall during the presentation of the IALA webinar: Introduction of IMO Resolution A.1158(32) Guidelines for Vessel Traffic Services. February 17, 2022, at 10:00UTC. Up to 220 attendees.

As a final comparative analysis, the following table depicts the selected points of the Resolution on the second Guidelines for VTS and that are counteracted with the previous ones.

3rd 2021 **Resolution A.1158(32)** **Guidelines for Vessel Traffic Services**
7 p. 1 Annex*
Lack of standardisation**
Revokes R.A.857(20) Guidelines for Vessel Traffic Services
SOLAS V. Regulations 10-11-12
IALA Standards
VTS provider
Types of VTS: VTS
VTS service
VTS Personnel appropriately trained and qualified
VTS area
Equipment

* Includes 9 chapters.
**RECOGNIZING FURTHER that the use of differing procedures may cause confusion to ship masters, VTS should be established and operated in a harmonized manner and in accordance with internationally approved guidelines.

Table 29. Highlights Resolution A.1158(32)

6.1.1.All in comparison.

The evolution of the three IMO Resolutions referring to the VTS guidelines confirms, on the one hand, the long process that requires updating new resolutions and, on the other, the great effort and responsibility that updating a regulation represents. From the first versions to the current ones, more than 35 years have passed, something that could seem normal in the legislative field if it were not for the fact that new technologies have accelerated the whole world in many ways. The Table 29 illustrates the extract of the three resolutions with their main changes and references.

The process of the updates referring to the IMO Resolution for the VTS, proves that the reference documentation is currently ready. In the digital era, the regulations could be compared to all software being up to date, but the hardware of the VTS, if they are considered to be the means, remains almost the same.

1st 1985 Resolution A.578 (14) Guidelines for Vessel Traffic Services	2nd 1997 Resolution A.857 (20) Guidelines for Vessel Traffic Services	3rd 2021 Resolution A.1158(32) Guidelines for Vessel Traffic Services
17 p. Annex, 2 Chapters	22 p. 2 Annexes	7 p. 1 Annex
Requested by Governments and international organizations	Requested by Governments and international organizations	
Lack of standardisation	Lack of standardisation	Lack of standardisation
R.A. 158(IV) PAS	R.A. 158(IV) PAS	
R.A.531(13) SRS	R.A.854(20) SRS	
	Revokes R.A.578(14) Guidelines for Vessel Traffic Services	Revokes R.A.857(20) Guidelines for Vessel Traffic Services
SOLAS IV & V	SOLAS IV & V. Rg.8-2	SOLAS V. Regulations 10-11-12
	IALA VTS Manual 1st Edition	IALA Standards
VTS Authority	VTS Authority	VTS provider
Types of VTS: not specified	Type of VTS: Port or Harbour and Coastal	Types of VTS: VTS
Types of VTS functions: information, organization, assistance.	Types of VTS services: INS, TOS, NAS.	VTS service
VTS procedures: information, advice or instruction	VTS procedures: information, advice or instruction	
VTS Operator: appropriate qualifications and training	VTS Operator: appropriate qualifications	VTS Personnel appropriately trained and qualified
SMNV	SMCP	
VTS area can be divided into sectors	VTS area can be divided into sectors	VTS area
Equipment: VHF + Radar (+DF) and other equipment	Equipment: Radio + Radar, Computers, telephone, phone, telex, circuit TV, visual, other	Equipment

Table 30. The three in comparison

The resolution updates for the VTS have a temporary reading, the moment in which it is updated and the time of its validity. The initial reference point is when the VTS is born (Table 38). The last years are the most affected by changes and the introduction of new technologies.

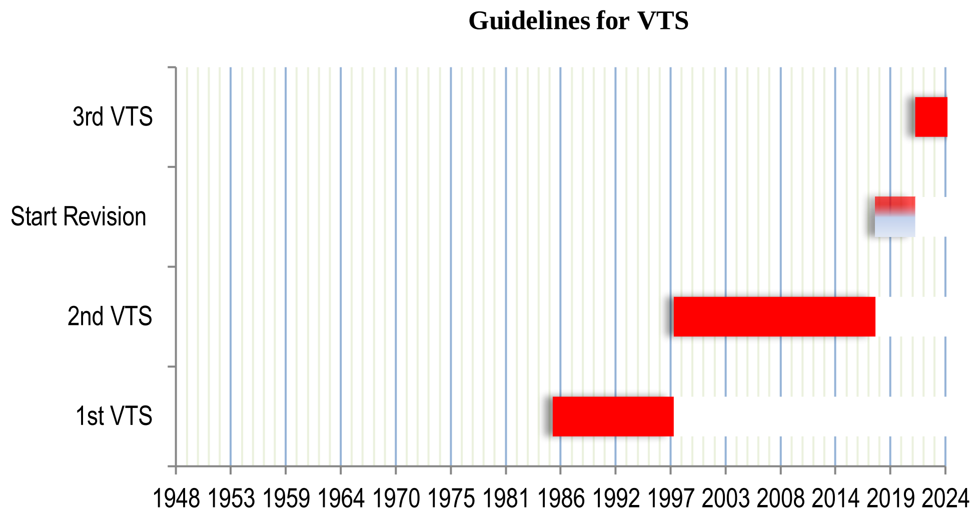


Figure 38. Resolution duration periods

Until the appearance of the second guidelines, the basic equipment of the VTS was the radio and the Radar, for almost 50 years. As explained previously (Part II), the obligatory use of the AIS on board vessels, according to SOLAS Convention, Chapter V Regulation 19 Carriage requirements for shipborne navigational, certain ships would have been fitted with an automatic identification system (AIS) not later than 2008. Consequently, this was also observed as an essential tool for the control of the traffic from shore. It is recognised by Resolution MSC.74(69) of 1998 that the AIS should improve the safety of navigation, aiding the efficient navigation of ships, the protection of the environment and the operation of Vessel Traffic Services (VTS). AIS was defined as a VTS tool, that is, from ship-to-shore for traffic management. The IALA also established Recommendations and Guidelines considering AIS as a tool for VTS from the first moment that the IMO did so, such as the Guideline 1026, whose first edition is from 2001 (IALA 2005a).

The third and current resolution fails to specify what tools a VTS must have in order to carry out its functions but refers to the IALA in that list and this is an advantage, since, the IALA appeal formula will facilitate future updates. Now it only refers to "equipment, systems and facilities", so any instrument used to exercise VTS can fit this definition.

IALA has developed a set of Standards and associated Recommendations, Guidelines and model courses specifically related to the establishment and operation of VTS, the objective is to locate the worldwide harmonization of VTS (IALA 2021). All these efforts have sought to ensure that the resolution serves as an effective instrument, providing a framework to implement VTS globally in a harmonized manner, and that it responds to significant global changes, since its adoption in 1997. It has been the work, so far, of 24 years. Although the result is an effective instrument, it is worth noting what this long process has meant. New resolutions, updates and revocations that have required so many years to be published, could risk being almost immediately ineffective (Martínez de Osés and Uyà 2020). The simplified and at the same time open nature of Resolution A.1158(32), together with the link to IALA, make this last resolution a more adaptable instrument in the face of future challenges. The reference to SOLAS V cannot be missing and is not missing from the three binding Regulations to the VTS, 10, 11 and 12. So, it is recognised by IMO instruments that include its leadership role in facilitating the uniform and harmonized provision of vessel traffic services worldwide, the word "worldwide" appears for the first time in the Resolution.

The most significant changes, such as the concept of "VTS service" in general, which includes the three contemplated in previous versions (INS, TOS and NAS), enlarge the dimension of the VTS. Its purpose is not limited to one function, but is committed to everything that involves the management of traffic in the VTS area, which also, by ceasing to be divided, opens the spectrum to a greater extent. The VTS operates beyond territorial seas, that is, towards out at sea.

6.2. Air Traffic Control as convergence (again).

Although there were many divergent elements in Part II, the trend was beginning to change with the standardization of the VTS and the introduction of new technologies in the maritime sector.

The road to e-Navigation bring ATC and VTS closer together, from some points of view. The projects that work on the e-Navigation concept are inspired by Air Traffic Control. Some promoters of the new projects affirm it, as do other professionals of the maritime sector, including captains (Martínez de Osés et al. 2014).

From the comparative table in Part II, it is obvious that the air and the sea are not the same. ATC can effect vertical separation between aircraft to facilitate collision avoidance; this is not possible for ships that all float on the same surface. There are clear differences, such as dimensionality, the environment which in space, is empty, whereas, in the sea, there are obstacles such as islands, structures or even the speed of transport (Praetorius et al. 2012). An airplane must maintain its speed, it can only be stationary when idle. Controlled and uncontrolled airspace exists in most countries but the Right of access to and from the sea and freedom of navigation and transit exists too, as discussed previously. But these are more conditioned to transport and means, than to the management of the land professional. In this sense, removing the mentioned variables from the first table, the future one would look like this:

	ATC	VTS	**VTS**[123]
network	airport to airport	arrivals and departures	port to port
space	controlled/uncontrolled	free	free / controlled
system	centralised	distributed	distributed / centralised
reliance	totally	part of	part of / totally
voyage plan	shared	not shared	shared
scene	full	Partial (area)	Full
performance	procedures	experience	Experience + procedures
training	standardized / continuous	Semi-standardized / at intervals	standardized / continuous

Table 31. ATC vs future VTS

[123] Considered the VTS within this Part III that goes from 2018 and beyond.

Network port-to-port - The near future of VTS will connect VTS Centres around the world, something that is part of the e-nav project, where information must be shared. At the time that a ship sets sail from one port to another, the VTS that has to receive the ship will be able to carry out a complete follow-up. This is not only thanks to the technologies that allow large-scale monitoring, but also to an interconnection between the maritime chain. Now the management acts as independent units, without sharing information, even in the same country there is no harmonization, as previously specified in chapter 5. This failing has also been exposed in international conferences, “Currently there is no, or very little, harmonisation between the various maritime Windows on a global scale sometimes not even between ports and terminals”, Jeppe Skovbakke Juhl from BIMCO[124]. But the projection is that the information will be shared on a large scale, also among the entire maritime community “Connectivity and Data sharing will be key elements of any e-Navigation solution moving forward”, Ed Wendlandt, Radio Technical Commission from Maritime Services (RTCM)[125]. The origin and destination relate to the scene, whose image will not be only "approaches" but a wider visual field, as much as the entire ocean.

Space free-controlled - Maritime space, covered by UNCLOS 82, is 40 years old, and there is no evidence that it is modifiable in terms of freedom of passage. However, it must be taken into account that the surveillance limits will no longer be confined, to 12 miles and the right to ensure safety and the environment must be addressed legally with the possibility of controlling areas, including on the high seas.

System distributed/centralised - It will be necessary to centralize coordination, not in the sense of a single neuralgic centre, through which all the information passes, but from the concept of digitized e-navigation, whose connection is decentralized within the Maritime Connectivity Platform (MCP)[126]. Thus, the need for platform decentralization for greater connectivity within the MCP concept[127].

Reliance part of/totally - Confidence in the VTS will be greater where it will also be involved in unmanned vessels, whose degrees of dependence on the VTS may increase and must be defined. Voyage plan/shared. Within the objectives of e-Navigation, which includes sharing information, is the exchange of routes between the VTS and the ship. Projects, such as the STM, were inspired by the ATC to apply it to the maritime sector.

The idea that the STM was inspired by aviation could lead to more serious consideration of the project, in a world that believes a life jacket will save lives more on a plane than on a ship. So, the STM was born similarly to air navigation, in which the pilot sends his flight plan to be validated in the Control tower. This project is described in greater depth in Chapter 6.3.1., but it should be noted here that, during the exercises related to STM Validation, several statistics were published, in different documents of the STM, after many

[124] The International conference “Developments in maritime digitalisation”. Session 2. Later published in the report Digital@Sea Asia Pacific. September 8-9, 2021. pp.50-4.

[125] The international conference “Digital@Sea North America”. Session 5. Later published in the report Digital@Sea Asia Pacific. September 8-9, 2021. pp.168-74.

[126] Described also in its webpage: https://maritimeconnectivity.net/ (Accessed: September 2021).

[127] IALA webinar “IALA G1161: Evaluation of platforms for the provision of maritime services”. September 30, 2021, at 10:00UTC by Thomas Christensen, Secretary General of the Maritime Connectivity Platform Consortium.

surveys were conducted on each of the participants, the author of this thesis included. In the Ship Navigation Survey Results, one of the interesting results related to ATC was from asking seafarers: “to what extent do you consider that some principles of ATC could be implemented in VTS?”[128].

As seen in Figure 39, most of the interviewees (37.5%) expressed the opinion that ATC could be implemented in VTS, but only to a certain extent.

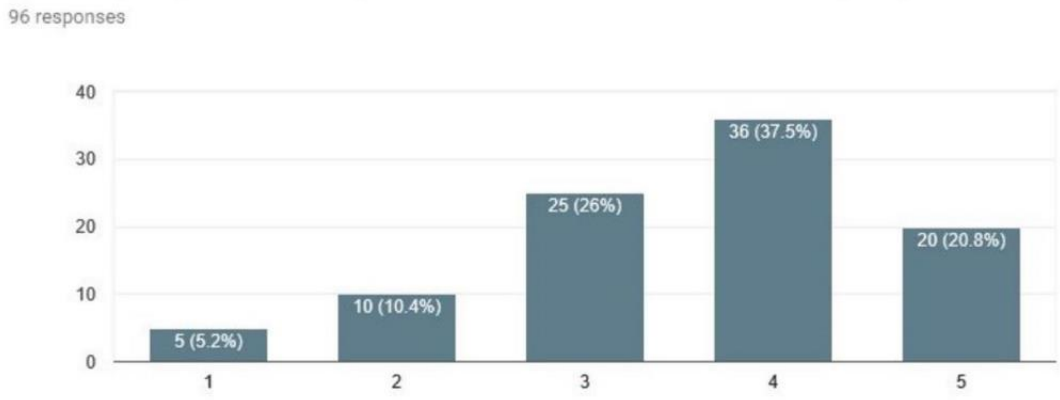


Figure 39. What extent it is considered that some principles of Air Traffic Control (ATC) could be implemented in vessel traffic services (VTS)

Performance-Experience + procedures - Sailors can be VTS, unlike ATC, who are not pilots, but the trend is that VTS operators can undergo training and qualifications without being sailors, although it will always be an advantage.

Training-standardized /continuous - The training and accreditation process of an air traffic controller is fully homogenized at an international level and continuous (Hughes 1998), and it is what the VTS Operator is tending towards, thanks to the IALA certification. The model courses are for continuous learning and training, not as often as TCAs, but with an established regularity. According to the IALA Model Course V-103/5 “Revalidation process for VTS Qualification and Certification”, it is recommended that Recurrent Training is carried out at intervals of not exceeding five years (IALA 2016:8).

The ATC and the Captain of the Aircraft are all part of the system, all are subject and must abide by strict, internationally adopted, operating controls and procedures from ICAO, Eurocontrol and National AIP, amongst others. Whereas a VTS Operator may not have the same information as the vessel, including very small ships, pleasure crafts, semi-submerged objects, ice-bergs, real sea state, the status of the equipment and main engine onboard, in order to make sensible navigational decisions. All these examples are difficult to integrate within the VTS System. Looking to the future, when all vessels at sea have an AIS-type automatic identification device that can be tracked from land, the management of traffic at sea will be closer to offering a more realistic scenario. Aviation is moving forward and has started to implement SESAR[129] (Single European Sky ATM Research). The concept began, in 2005 and has been developed over successive

[128] Pawel, Z. et al. (2018) Document No: STM Val_D5.26 STM-Catalogue of New Competences related to the Stakeholders involved in STM in Shore, on board and for Operational Safety. p.105.

[129] Webpage available: https://www.sesarju.eu/

phases, but addresses the digitization of the Digital European Sky, where not only conventional aircraft will be managed, but also what new technologies create, such as drones or unmanned vehicles. Now, SESAR in the air and Sea Traffic Management in the maritime sector are examples of holistic concepts.

Furthermore, new technologies also bring VTS closer to ATC. Digital VHF radios have functionalities like that of air traffic control consoles, that is, group channels or isolate channels, among other features. The final decision always falls to the captain on board (either ship captain or plane captain) so this is also a similarity between the responsibility of both professions, that of the VTS and the ATC and this is currently unquestioned. That is, until unmanned vehicle concepts are required to be implemented.

6.3. Towards the e-Navigation.

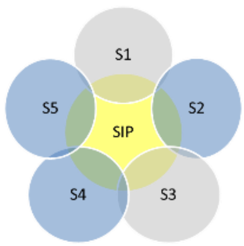
In 2005 the e-Navigation strategy was already credited with being a necessity: "E-Navigation would help reduce navigational accidents, errors and failures by developing standards for an accurate and cost-effective system that would make a major contribution to the IMO's agenda of "safe, secure and efficient shipping on clean oceans" via MSC.81/23/10 Work Program development of an e-Navigation strategy (IMO 2005: Executive Summary).

In 2006 the IMO approved the proposal of seven Member States (IALA 2018c) to develop an e-Navigation strategy, understood not as an electronic navigation, but as the harmonization of information, in electronic format, for bridge equipment, nautical charts, electronic aids, communications, and onshore infrastructure. The idea of placing an "e" in front of Navigation was formulated by the IMO to establish its own brand or protocol, which recognized this unifying concept. Understanding the letter associated with the "electronic" or "enhance" would limit its broad spectrum since, in addition, the generic term electronic marine navigation, was already in use. This need was analysed in a broader e-maritime spectrum, paving the way for new forms of ship monitoring and a completely new outlook for global maritime surveillance (Graff 2009:175), albeit more than ten years ago.

It can be recapitulated that there are clear examples of willingness to monitor and visualize maritime traffic worldwide (Chapter 4.5.3). With the development of computer science, IMO was sensible enough to perceive that those advances taking place on land should also occur at sea. The Strategic Plan of the Organization for the period 2008 – 2013, Resolution A.989(25), adopted on 20 November 2007, recognized that technological developments had created new opportunities. E-Navigation was defined as: "harmonised collection, integration, exchange, presentation and analysis of maritime information on-board and onshore by electronic means to enhance berth-to-berth navigation and related services, for safety and security at sea and protection of the marine environment", according to the first formal definition registered by the IMO in 2008, MSC85/26/Add.1 Annex 20; Strategy for development and implementation of e-Navigation. But it also considers being able to reduce collisions and groundings caused by human error, which are 60% of the cause of accidents, according to data published in the same MSC 85/26/Add.1 Annex 20, based on a closer cooperation in the decision process between ships and the VTS.

Since 2008, e-Navigation has been considered the future. However, its implementation is far from simple, as the Secretary General of the IMO recognized in 2016[130]: “E-navigation is the future; but it has been "the future" for a long time now” and added, “ the challenge now is to turn "the future" into "the present" so that all the much-heralded benefits and advantages of e-Navigation can be fully realized” (Lim 2016). Even now, more than 10 years later in 2022, e-Navigation remains on the horizon. The Secretary General’s words were so important that they were also recorded in other publications as a starting point to analyse the concept and trend of e-Navigation, “Implementing e-Navigation” (Hagen 2017).

The first International Conference on e-Navigation was organized under the auspices of the IALA[131] and the Danish Maritime Authority in 2011 (IALA 2017a), in close cooperation with the concerned maritime administrations of the IMO Member States and international organizations. Since then, other conferences and workshops have been held annually, in different locations, to continue the advances in electronic navigation and increase the participation of more countries, but e-Navigation has not yet brought any specific device or apparatus, simply a general idea of the need to standardize procedures and exchange information using satellite and digital internet technology. The Implementation Plan of the Electronic Navigation Strategy (SIP) was approved in November 2014, through the MSC 94th Session[132], 17–21 and contained a list of tasks necessary to address five electronic navigation solutions. These five goals were named as S1, S2, S3, S4 and S9, as prioritized e-navigation solutions. The issue is that a total of nine solutions were considered for the first SIP but NAV59 endorsed only these five. Consequently, the updated 2018 SIP, renumbered the solutions removing the term "prioritized" because it was redundant and, therefore, the solutions were the same but now listed as S1 to S5[133]. The so-called e-Navigation, namely: improved bridge design, standardized and automated reporting, integrity of bridge equipment and navigation information, presentation of available information in graphical displays and improved communication of VTS Service Portfolio, see the Figure 40. Solutions 2, 4 and 5 focus (in blue) on efficient transfer of marine data and information between all appropriate users (ship-to-ship, ship-to-shore, shore-to-ship, and shore-to-shore). And Solutions 1 and 3 (in grey), promote the viable and practical use of information and data on board.



S1: improved, harmonized and user-friendly bridge design;

S2: means for standardized and automated reporting;

S3: improved reliability, resilience and integrity of bridge equipment and navigation

S4: integration and presentation of available information in graphical displays received

S5: improved communication of VTS Service Portfolio (not limited to VTS stations);

Solutions on efficient transfer of marine data and information between all appropriate users

Solutions to promote the viable and practical use of information and data on board

Figure 40. SIP for the five e-navigation. Own elaboration

[130] Keynote address by Kitack Lim, Secretary-General of IMO at e-Navigation Underway conference on February 2, 2016.

[131] Available at: https://www.iala-aism.org/news-events/e-nav-underway/ (Accessed: May 2020).

[132] Maritime Safety Committee (MSC), 94th session. November 17-21, 2014. NCSR1/28 Annex 7. pp.2-10.

[133] MSC.1/Circ.1595. Annex, p.2

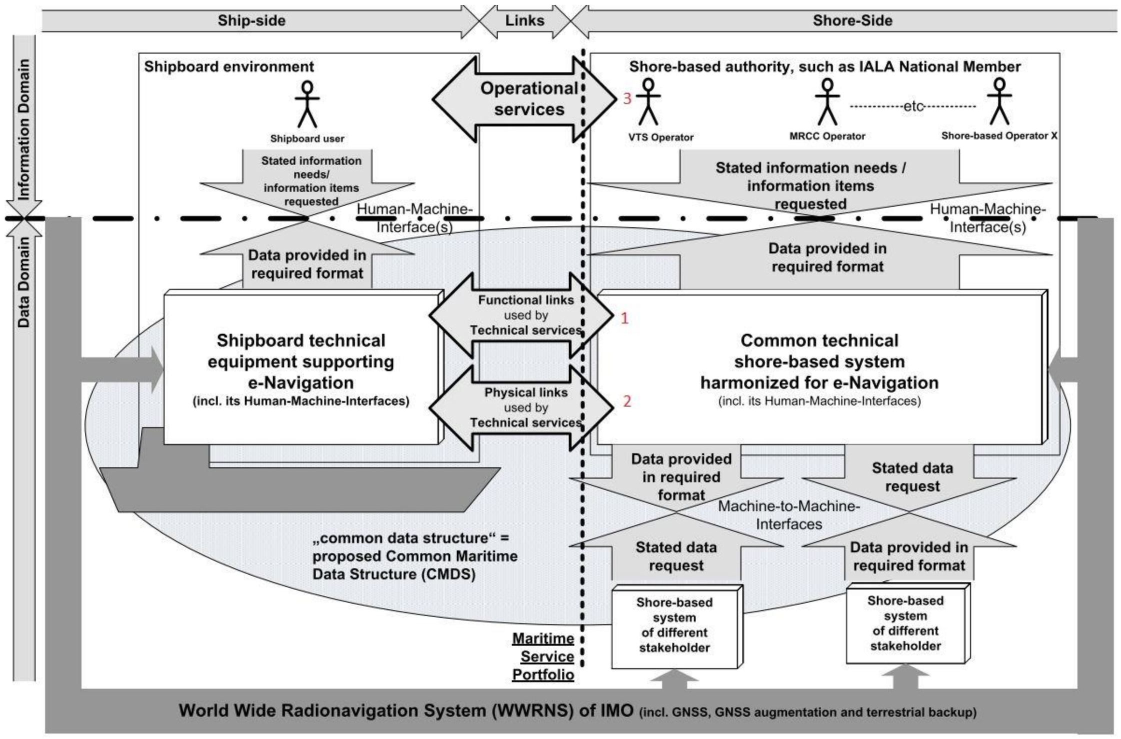
And considering that the needs may evolve and, therefore, new solutions must be incorporated, the IMO also establishes that risk control options be used, Risk Control Options (RCO), in order to aid the assessment of the new e-navigation sub-solutions.

These tasks for reforms were scheduled to be completed by 2019, contributing to harmonized information of the maritime industry. Well-designed on-board systems and close cooperation with land-based management tools and mechanisms would help make maritime navigation and communications safer and more reliable, while increasing transparency of and accessibility to information.

The IMO is the only international organization identified to define the technical, operational and legalities necessary to outline and enforce the general framework for the implementation of electronic navigation. The development of e-Navigation is a collective task among stakeholders in the maritime sector, but the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) and the International Hydrographic Organization (IHO) are essential. There are interested parties in each country that must submit their proposals, not only government representatives but also commercial agents, ports, members of the marine business chain, universities, equipment manufacturers and marine software technology.

To guide the community on land and sea to harmonize the solutions described, the IMO developed a graphic scheme to define the overarching e-navigation architecture. This graphic scheme indicates the architecture flow of data exchange between ship and land, in which every participant must engage in their part of the scheme. It is understood as an international agreement within the maritime community and the Common Maritime Data Structure (CMDS), where communications are the key for e-Navigation, and thus the importance of, and dependency on, the World Wide Radio Navigation System (WWRNS).[134]

[134] Numbers are added from Session1: "Implementation of the SMART-Navigation System". ENUW 2020 Asia-Pacific. September 8, 2020.



1: Standardization of data communication protocols, so that anyone can access services regardless of vessel type or nationality. (MCP)

2: Securing communication means to access information services at sea.

3: Design of a service architecture that provides the necessary information at the right time to help prevent accidents. (TS)

Figure 41. Overarching e-Navigation architecture

In essence, it is the definition of e-Navigation, 'harmonised collection, integration, exchange, presentation and analysis of maritime information" applied both on board and ashore. To enable both sides to communicate and ex-change information, e-Navigation refers to a Maritime Service Portfolio (MSP), a concept to achieve harmonization. The information and data flow are presented as a selectable and scalable service, according to the type of user and the phase of the trip, compatible with the on-board systems carried by the ships, in the area covered by the service. Each participant of this maritime chain has a path that allows them to interact, according to the immediate situation and needs, and the interactions are contemplated at all levels, M2M, H2M and H2H[135]. IALA used this architectural scheme in reference guidelines for provision of AtoN, and VTS guidance on the applications of electronic navigation from berth to berth, via Guideline 1096, where berth to berth includes port-to-port navigation (IALA 2013a). Furthermore, the scheme is also used in specific guidelines to provide guidance to the shore sector, starboard sector of the figure (IALA 2015b), the G1114, A technical Specification for the Common Shore-based System Architecture (CSSA) and G1113, Design and implementation principles for harmonised system architectures of shore-based infrastructure (IALA 2015a).

At European level, with the projects subsidized or co-financed by the EU, different protocols based on proposals related to e-Navigation have been developed to address these five goals considered in the

[135] Interfaces: Machine to Machine, Human to Machine and Human to Human.

MSC.94/18/8. Among these, there is the possibility of creating "a wide area navigation team"[136], where vessels and VTS can share tactical and planning information. In this sense, the Sea Traffic Management, STM, was undoubtedly the most important for its size and permanence over time (see next chapter).

E-Navigation requires serious investment in technology, so it is generally accepted internationally. The world is subject to many changes, many will not be adopted, unless mandated by organizations such as the IMO. There are systems that have been the same for 20 years, or have been extended in a mandatory manner or some sectors, such as port terminals, have developed these systems, as, recognized by the head of the Port Authority of Barcelona[137], relying on IMO. The IALA, via the Guideline 1107 on "planning and Reporting of e-Navigations Testbeds", had already recognized in 2016, the need for investing more time and effort into this issue, noting that much work is required to move from concept to reality, and that many test beds will be required to discover the best solutions (IALA 2016a).

Despite these forecasts, international organizations, together with various entities from the maritime sector, continue to work on this issue, and the results are presented regularly at international conferences, available to all.

E-navigation contributes to sharing information in digital formats with compatible platforms, that is, where the maritime community can be interconnected, through compatibility of programs, to share information. This exchange results in the improvement of safety, efficiency and protection of the environment and encouraging the development of different projects to achieve these objectives, as shown below. The key is in digitization, where solutions indicated by the IMO that are found for each sector, are interconnected and are not isolated solutions. Addressing this concept of e-Navigation has generated the creation of multiple acronyms.

The MCP aim is to find a global communication in order for e-Navigation to be efficiently implemented worldwide, in a secure and consistent manner. That is why all projects have based their services on the MCP, the framework developed to collaborate between different projects such as EfficienSea2 (EU), STM validation project (EU) and the SMART Navigation project (Korea). Stakeholders outside of these projects such as China Maritime Safety Administration (MSA) and Australian Maritime Safety Authority (AMSA) were also given access to carry out experimental developments of e-navigation services on the platform.

There is a need to achieve and agreement between all, public and private sector, so the introduction of a consortium, the Maritime Connectivity Platform Consortium (MCPC), is a stepping stone toward providing neutrality and independence for participants. The initial consortium includes a range of non-commercial organizations from academic sectors, such as Korean Research Institute of Ships and Ocean Engineering (KIRSO), Korean Maritime and Ocean University (KMOU), Research Institutes of Sweden (RISE) and from other authorities, including the Danish Maritime Authority (DMA), Swedish Maritime Administration

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136 IALA (2018). NAVGUIDE 2018 Marine Aids to Navigation Manual. p.67.

137 Albert González at the "STM Day. La gestión del tráfico marítimo y su impacto en la industria del transporte internacional" conferences held at the Facultat de Nàutica de Barcelona, UPC on December 11, 2017.

(SMA) and Ministry of Oceans and Fisheries of Korea (MOF). In the consolidation of this important consortium, the Secretary General of the IMO and the Secretary General of the IALA were present at the e-Navigation conferences, held on board the ferry Pearl Seaways, while sailing back and forth from Copenhagen to Oslo in February 2019 (IMO 2019)[138]. That means that the support of members of international organizations, such as IMO and IALA and including ITU, IHO, BIMCO, and CIRM, are the key for the MCP to become the de-facto platform for service provision and information exchange within the maritime domain.

IALA was partner in the project EfficienSea2, and is an advisory of a MCP project on maturing the MCP through the ENAV Committee. The workshop on “How to Run the MCP”, organized at its headquarters on November 21 and 22, 2017, was attended by 52 delegates, representing 19 countries. MCP implementation has already been addressed, with a focus on identifying preferred business and governance models and preparing a related exploitation plan for global information sharing. Work was done on 4 topics divided into groups to consider the governance model, the business model, the implementation plan and the legal and responsibility issues of the MCP (Doyle 2017).

Different schemes of the MCP architecture have been published, with various drawings and flow diagrams. However, igure 42[139] has been chosen because the VTS is among the elements included, but also, because it has been used mainly in e-Navigation projects (EfficienSea, Smart-Navigation and STM). The main secure cloud, or MCP, include three “Maritime” identities: Maritime Messaging Service (MSS), Maritime Identity Registry (MIR) and the Maritime Service Register (MSR). MIR enables the verification of information and MSR acts as a central reference point to provide and find services, both should rest with the Governance Entity whereas MSS should fall under ITU. MMS has three main functions: navigation messenger, data roaming between maritime communication links, and digital service call brokerage[140].

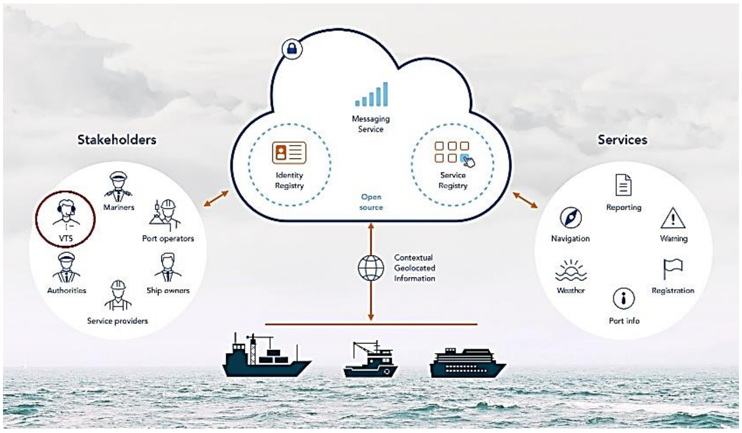

Figure 42. MCP Components for setting up a platform for the provision of maritime services in the context of e-Navigation

[138] The Secretary-General Mr. Kitack Lim of the IMO and the Secretary-General M. Francis Zachariae of the IALA on the ENUW International Conference under the title of “Paving the Way for a Digital Maritime World”, February 6-8, (2019a).

[139] IALA (2021d) ‘G1161 evaluation of platforms for the provision of maritime services in the context of e-navigation’, IALA Guideline, 1.0 (June), p.12.

[140] Technical presentation “Messaging service” by Dr. Jin Park, SMART-Navigation Project. November 21, 2017. IALA Headquarters.

Subsequently, the results for specification of Protocols for ship-to-shore communication were studied and the domain of the logical architecture from the Cloud was deepened, where protocol and interface to the IR and SR are HTTPS and SOAP (Simple Object Access Protocol) uses XML Information Set for its message format or SMTP basically (Andersen et al. 2018).

In essence, the MCP is the e-Navigation root. Since its inception, this platform has been widely studied and analysed in the various work sessions undertaken to identify and recognize its strengths and barriers [141].

Success does not happen automatically, simply by having a technical platform in place, but a legal framework, acceptance, finance, investment and vision of the future are also needed. Among the positive inputs is the reduction of the gaps between ship and shore. While need legal information is transferred digitally, other media such as radio are no longer used, reducing misunderstandings caused by language. The end user will be able to access digital information flows easily. The function of the MCP is to connect services to users. Since it does not provide or store the service provided, this means lower costs for day to day support of systems. The introduction of standards will make them easier to implement. MCP's s graphic indicative form is that of a cloud, which would connect between all the stakeholders and between different countries, since it is a program for global harmonization, with access through Identity Registry.

On the other hand, there are challenges to moving forward, in the sense that the system must not be slow, must be secure and must guarantee continuous development to ensure effective service. The future funding, either via annual fee, or with funds from EU or governments, competition from other proprietary systems seeking new opportunities in the market, immaturity of the organization, legal and liability issues, training, and the support of the maritime community, all need to be considered in order to advance successfully in e-Navigation.

IALA includes e-Navigation in the ENAV Committee, Information Services and Communications and in the same way as the VTS, the ENAV is divided into three WGs to deal with the issues, in WG1: Digital information system, WG2: Emerging digital technology, and WG3: Digital communication system. Under Standard 1010 it addresses the requirements (as seen, G1096, G1107). But, the VDES is included under the umbrella of Standard 1060, the Digital Communication Technologies, with its Guidelines, G1117 and G1139 (VDES are analysed in the next chapter since they interact directly with the satellites). Furthermore, the Standard 1070 Information Services specifically collects the Data models and data encoding, the basis for e-Navigation, in their efforts to find digital codes of common "understanding", such as ASM (Application Specific Messages) or S-100 (IALA 2021 1:29).

IALA, through committees and work sessions, organizes technical presentations, whereby experts in the sector disclose advances made in the matter. The G1161 "Evaluation of platforms for the provision of maritime services in the context of e-navigation" addresses specifically the need to find a secure and reliable platform to exchange information and services, guided by the IMO Resolution MSC.467(101). In this way,

[141] Workshop Report: How to run the MCP, hosted by IALA on behalf of the EfficienSea2 Project from 21st to 22nd November 2017. IALA Headquarters.

Members States and Organizations can submit their Maritime Service (MS), to the IMO, with IALA as intermediary. MS includes not only the VTS, but also pilotage, tugs, vessel shore reporting, telemedical assistance, local port information, nautical charts and publications, ice navigation, meteorological, hydrographic and environmental information, search and rescue and other Maritime Services that may be developed and implemented in the future. The MS already have their platforms and ways of operating but, in many cases, they are not connected. In addition, all these legacy platforms have been found to have significant drawbacks in today's digital environment. This has given rise to different proposals as seen, for example, with the STM, mainly to exchange routes. The Navtex device has been somewhat controversial. The STM itself proposed that it be information integrated into the ECDIS. Transmissions with infrastructures using radio equipment and antennas and not based on digital satellite-based technologies are questioned, due to lack of security, with the possibility to transmit malicious information and the impossibility of checking the authenticity of the source [142]. A MS can be implemented by one or more e-Navigation Technical Services (TS), therefore, TSs are the model of data and means of communication to provide a MS. The TS should be specified and documented, as described in IALA Guideline 1128, a purely technical guide that provides meta-information, aimed at service architects and system engineers (IALA 2018a). It is out of range of this thesis to describe, in depth, these protocols, but technologies already exist, it is not required to develop new ones, nor to harmonize them [143].

The MS of the IMO scheme, between the part of the sector ship-side and the shore-side, there are the MSPs. The fifth e-Navigation address improved communication of VTS service solution.

[142] IALA webinar: G1161 "Evaluation of platforms for the provision of maritime services in the context of e-Navigation" by Dennis Jankowski. September 30, 2021.

[143] E-Navigation Underway Asia Pacific. Session "Harmonization of Maritime Services" by PhD. Axel Hahn. September 8, 2020.

Maritime Services[144]		Technical Services	Data Models		
MSx		TSx	S-nx		Standardization Body
Give framework from user perspective. Defined by IMO, no technical (under verification and validation)		Harmonize technical access. Guidelines for Technical Service from Domine Coordinating Bodies	Universal Hydrographic Data Model Harmonize understanding of data		
MSP1	VTS (IS)*	IP	S-101	ENC	IHO
MSP2	VTS (NAS)*	Webservices	S-102	Bathymetric Surface	
MSP3	VTS (TOS)*	RTZ	S-103	Sub-surface Navigation	
MSP4	LPS	Coastal LTE stations	S-104	Tidal	
MSP5	Maritime Safety Information (MSI)	LEO Satellites	S-111	Surface Currents	
			S-112	Dynamic Water Level Data	
MSP6	Pilotage		S-121	Maritime Limits and Boundaries	
MSP7	Tugs		S-122	Marine Protected Areas	
MSP8	Vessel shore reporting		S-123	Marine Radio Services	
MSP9	Telemedical Maritime Assistance Service (TMAS)		S-124	Navigational Warnings	
			S-125	Marine Navigational Services	
MSP10	Maritime Assistance Service (MAS)		S-126	Marine Physical Environment	
			S-127	Marine Traffic Management	
MSP11	Nautical Chart service		S-128	Catalogue of Nautical Products	
MSP12	Nautical publications service		S-129	Under Keel Clearance Management UKCM	
MSP13	Ice navigation service				
MSP14	Meteorological information service		S-130	Polygonal Demarcations of Global Sea Areas	
MSP15	Real-time hydrographic and environmental info.		S-131	Marine Harbor Infrastructure	
			S-164	IHO Test Data Sets for S-100 ECDIS	
MSP16	SAR				
			S-201	AtoN Information	IALA
			S-210	Inter-VTS Exchange Format	
			S-211	Port Call Messages Format	
			S-212	VTS Digital Service	
			S-230	ASM	
			S-240	DGNSS Station Almanac	
			S-245	eLoran ASF Data	
			S-246	eLoran Station Almanac	
			S-247	Differential eLoran Reference St.Al.	
			S-300	None proposed yet	
			S-401	Inland ENC	IEHG
			S-402	Bathymetric Inland ENC	
			S-411	JCOMM Ice Information	WMO
			S-412	JCOMM Weather Overlay	
			S-413	Weather and Wave Conditions	
			S-414	Weather and Wave Observations	
			S-421	Route Exchange	IEC

*Should be revised or deleted depending on the update of Resolution A.857(20) already about to be published as R.A.1158(32).

Table 32. Interaction between different service levels

TS are needed to coordinate a seamless combination of different Snx. Information provided using Sxn based product specifications is brought together by TS to deliver a MS. The IALA, IHO, WMO and the IEC, in the main, share the strategic role of "product specification". This role consists of the elaboration of standard

[144] Based on the table that relates the MS described in the MSC.1/Circ.1610. Initial descriptions of maritime services in the context of e-Navigation, p.4. (2019d).

messages to be exchanged between stations digitally. The MSx can be matched with levels of need, for example, the need of a VTS service, will affect the Snx which that service will offer[145].

The IHO has developed some standards, "S". In 2010 it adopted S-100, a geospatial framework standard for hydrographic and related data, aligned with the ISO 19100 series of geographic standards (G1106). The S-100 standard -generic starting point-- is a framework document that is intended for the development of digital products and services for hydrographic, maritime communities. It consists of several parts that are based on the geospatial standards developed by the International Organization for Standardization (IALA 2017c). These pattern messages are, and will continue to be, part of the VDES (chapter 6.4.1). The role of S-200 domain (G1087) covers AtoN, VTS, Positioning Systems, Communications Systems and AIS, ASM and VDES, but the specific S-212 covers VTS digital information services (IALA 2017b).

The Strategic Benefits of developing Product Specifications are several. On the one hand, it does not require Governments to establish and maintain dedicated communication link(s) which have ever continuously shrinking services and are rapidly superseded by advancements in technology. On the other, it provides flexibility to the Maritime Industry to pursue communication technologies and services suitable for their fleet needs and trade routes[146].

ENUW, organized by IALA, DMA and Ministry of Oceans and Fisheries, has had three versions, International, North America and Asia-Pacific. From 2011 to 2020, conferences have been established to pool advances in the above topics. In 2020, another formula was exhibited, the Digital@Sea, to address the same concept of e-Navigation, and was supported by IHO, AMSA, CIRM, BIMCO and the Nautical Institute, along with other entities. The last conference of 2021 as Digiatl@Sea Asia-Pacific was organized in Sejong, Republic of Korea, during September, hosted online, due to pandemic status. To follow the conference online, a new Platform was enabled, *biz.gooroomee.com* , which did not support the load of connected people and crashed from the beginning, preventing attendees from following the conference, so it had to be changed, ad hoc, to another more stable one, YouTube. An example that digital technology is still maturing.

6.3.1. The Sea Traffic Management.

The STM has become a concept applicable to different strategies, following the structure of an inverted pyramid. STM has been developed as an integration project. This means that its beginnings as a project in itself were solid and with guarantees to fit within the challenges that might arise. The fact that it has “survived” throughout its different phases, especially the Validation phase, which was the most economically supported, reinforces the thesis that it represents an important tool to improve the maritime sector and to move towards a digital future.

[145] Extracted from the presentation “Harmonization is key” by Omar Frits Eriksson. IALA Deputy Secretary General and Dean of the World-Wide Academy. June 15, 2019.

[146] International Conference “The Future of Maritime Connectivity” by R. David Lewald from U.S. Coast Guards. Published later in the report: e-Navigation Underway 2020 Asia Pacific. p.48

It is a project that was born as a result of the programs that the EC co-finances for short periods of two or three years. The STM has been able to develop over the years, thanks to the "renewals" of the co-financing that has been present in its various formulas and different names, until 2018 (with an extension until June 2019). However, the following figure depicts how it was built with a solid and ambitious foundation, that has projected it beyond 2030 [147] as a master plan going through the foreseeable phases of Development and Deployment.

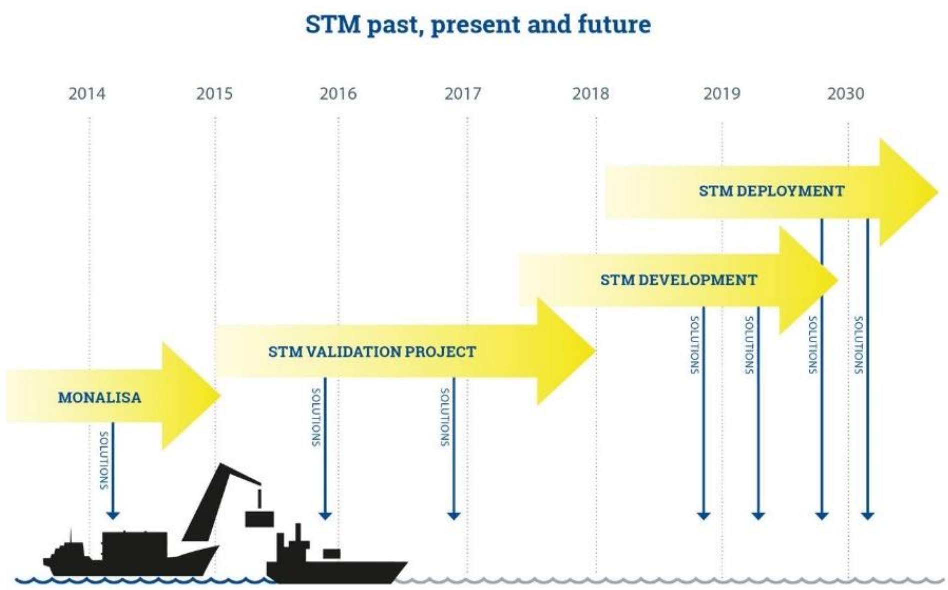

Figure 43. STM roll out timeline

From the beginning, the STM studied, worked, tested, and analysed each of the aspects involved in a plan of this magnitude. This means that the program considered, not only all the stakeholders involved but, in addition, covered aspects from pollution to legal issues, going through computer architecture and language, economic costs, business, feasibility, operationality, standardization, security and cyber security and training.

It was born in 2010**,** under the name, "Motorways and electronic navigation by intelligence at sea" (MONALISA), developed by the Swedish Maritime Administration, and supported by the European Commission for 2 years. It sought to define a set of systems and procedures to guide and monitor maritime traffic in a manner akin to the management of air traffic. In the past, air traffic services have been compared with vessel traffic services in numerous interesting articles, including Proctor (1973) and Bootsma and Polderman (1987). But while it was inspired by aviation for its management, for its operation it was inspired by the Trans-European Transport Network (TEN-T), a concept of a Europe-wide network. This conceives the forging of an interconnected, but not centralized, digital network of communications. The first concept to be developed from this idea was born as the Maritime Connectivity Platform (MCP), formerly known as the Maritime Cloud, and the birth of the MCP dates back to the EU project, EfficienSea (2009-2012), which

[147] Image published on September 10, 2018. Available at: https://www.seatrafficmanagement.info/image-gallery/

continues to develop nowadays [148] as examined in the next Chapter. The Figure below depicts how the network would be triggered

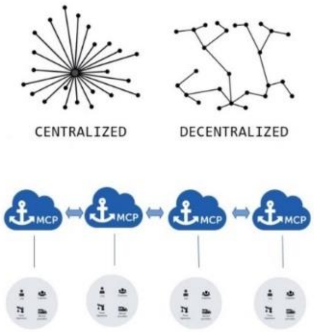

Figure 44. MCP platforms

A decentralized system but, at the same time, connected, in which it is understood that each "cloud" is a developed platform with an interface capable of connecting with another.

This first Monalisa already worked on the possibility of exchange of voyage plans, thanks to the main innovative services in electronic navigation of the maritime industry, (such as SAAB, and DMA's e-Navigation Prototype Display), that developed specific software compatible with the AIS signal and presented, in an electronic chart, the option to "play" with alternative routes of the ships. The first tests were carried out in the Baltic Sea, through the prototype platform, with 3 VTS Operators and 12 ships involved. All of them were in accordance with the exchange of routes, although the idea that final decision-making power should always kept on board [149] was highlighted.

It is important to mention that, between 2013-2014 Monalisa carried out research in the Artic, testing the route exchange over satellites. This project was named MICE (Monalisa on ICE) and the partners were Swedish Maritime Administration (Project Coordinator) and Chalmers University of Technology. In this scenario, the vessel Oden, an icebreaker, served as an AIS base station and was monitored by VTS Operators in Sweden. The communication was performed via an Iridium satellite link that was very stable, with a system latency of only 2-5 seconds (Hägg, Setterberg, Porathe et al. 2015). The recommended route took mainly into account the latest weather conditions, among others, and this improved situational awareness in that ice region.

MONALISA evolved into MONALISA 2.0 until 2015, when it was joined by other EU countries, not only in the Baltic Sea, but also in the Mediterranean. The scope covered 10 countries and was implemented by 39 entities from different areas of the maritime sector. All working together have achieved new standards and protocols that will enable communicative devices at several levels, ship to ship, ship to shore and VTS to VTS, creating a comprehensive and interoperable network within Europe. Inspired again by aviation management, the SeaSWIN (System Wide Information Services) concept was created to transfer digital

[148] International Conference "Digital@Sea Asia Pacific. "Common Platform for Maritime Informatics and the role of the MCC" by Thomas Christensen, Secretary General of the Maritime Connectivity Platform Consortium. Session 2. September 8, 2021.

[149] Retrieved from: https://www.iala-aism.org/technical/e-nav-testbeds/monalisa-1/

information, through the "Maritime Cloud" connecting services, with identifying registers, Maritime Identity Register (MIR). The Maritime Cloud concept has been derived as "A communication framework enabling efficient, secure, reliable and seamless electronic information exchange among all authorized maritime stakeholders across available communication systems"[150], based on the IMO e-navigation strategy.

Through the deployment of the different technologies applied, the possibility of real time service monitoring and coordinating maritime traffic, exchanging of information about routes exists. The concept is to plan and optimize new routes from shore and share them to ships, not because the captain is not a good sailor, but because of parameters possibly unknown or unavailable at sea. In short, STM is information sharing across the whole maritime transport chain. That was the main idea and intention. This stage included some test beds with the European Maritime Simulator Network (EMSN), with more marine technology companies involved (such Transas).

It was important that the link used to implement the new functionalities (route exchange format (REX)) in ECDIS was approved by IEC[151] with the cooperation of the CIRM (Comité International Radio-Maritime). Steps necessary for standardization, but also difficult to achieve when various approval phases are required by different committees. However, it was necessary to establish new protocols.

In 2016, the MONALISA project continued until the end of 2018, but was renamed Sea Traffic Management (STM). The STM started with a phase called "Definition", and then it was assigned the "Validation Project" phase, within the conclusive time space in 2018. Its future projection envisages two different stages, the Development, and the final Deployment, with a view to completion beyond 2030, as previously mentioned. The project harbours expectations that, in the next 12 years, the STM will be in service in the maritime sector. However, EU co-financing plans have neglected the project; in 2019, no budget item went directly to the STM project, as a part of a 6-month extension, (STM 2018b). But the Baltic sector continues to collaborate to administer this plan, seeking the complicity of companies, ship-owners, agents of the maritime sector and other authorities.

STM Validation continued aspirations to create an organized traffic management entity, tracking all ships at sea, using the AIS signal and, therefore, on the digital cartography, the Electronic Chart Display and Information System (ECDIS), where the targets are presented, and radar to monitor the distribution of ship routes from port to port, on the basis that, knowing the route plans of the ships onshore, alternative routes could be suggested (STM Midterm 2017). In addition, the optimization of the flow of traffic, port call synchronization, could contribute economically and ecologically to lower fuel consumption and reduce greenhouse gas emissions, due to the reduction of the waiting times of the ships (FNB-UPC 2017).

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[150] Vision of the Maritime Cloud. EfficienSea. Document E2-D3.2. Conceptual Model. p. 5

[151] On the 19th of August 2015, IEC adopted edition 4 of the 61174 standard, where Annex S contains the route exchange format. Monalisa 2.0. Activity 1.3. STM Voyage exchange format and architecture. (p.4)

The Project that ran from 2015 to 2018, under the name of Validation Project, was endowed with a budget of 43 million euros, of which 50% was co-financed by the European Union. Finally, 38 partners from 13 countries participated, at different levels of involvement, and 6 shore centres with simulators from the public, private and academic sectors and up to 50 partners were added (STM 2019:12).

To plan the development of the project, the strengths and weaknesses (SWOT analysis) of the maritime sector, operations and interactions were evaluated to define key objectives and indicators that were reflected in four strategic vectors:

1. Voyage Management: Voyage Management services will support individual vessels both in the planning process and during a voyage, including the optimized alternate route.
2. Flow Management: Flow Management: Uses the European Maritime Simulator Network (EMSN) and the test beds of Voyage Management. This flow management service will support both organizations on land and on ships, in optimizing the total flow of traffic through heavy traffic areas and areas with particular navigation challenges.
3. Port Collaborative Decision Making, PortCDM: Port Collaborative Decision Making: Will increase port claim efficiency for all stakeholders, through improved information sharing, situational awareness, streamlined processes and collaborative decision-making during port arrivals.
4. System Wide Information Management SeaSWIM: System information management: The exchange of standardized information is the heart of STM. The validation of the common infrastructure of maritime services, is by using platforms of interface and, the Maritime Cloud. It includes what software packages will be developed to work on this mega network.

Once established, 5 work areas were proposed, the 4 vectors above, plus one, which would be that of analysis and evaluation. The work areas were now called "Activity" and the members that made them up would be named according to the maritime or strategic sector from which they came. Therefore, the 5 activities were named as follows:

- Activity 1: Validation of Port Collaborative port Decisions, Making, (PortCDM). This activity works on the connection between ports and intends to expand it to where the previous project, MONALISA 2.0, reached, that is, it aspires to the network becoming larger. As the ports work with different approaches, logistical and commercial, this activity will pick up the varieties that it comes across. The test benches will seek to involve the sectors of the maritime industry, both public and private, to define what the construction of “Services PortCDM”.
- Activity 2: Validation of route management. This activity includes 2 test benches, one in the Mediterranean and one in the Nordic region. Areas of traffic congestion and adverse weather, especially in winter., are monitored. It also provides for crisis management, such as possible search and rescue emergencies.

- Activity 3: Flow management validation, EMSN. The European network of simulators was already developed in the previous MONALISA 2.0 project, and its evolution advances to simulate variable traffic conditions and establish how certain maritime areas are managed.
- Activity 4: Validation of common maritime services infrastructure, System Wide Information Management SeaSWIM. Basically, it works on the cybernetic infrastructure that will allow the exchange of standardized information, it is the Maritime Cloud, the cloud where the maritime data will upload, the heart of the STM.
- Activity 5: Analysis and evaluation. It is the most commercial part of research, in business, socio-economic study, risks, technologies, legal and institutional matters. It takes into account the guidelines and regulations of the IMO and IALA so that the reports can be considered valid.

These five operational activities were to forge the basic objective of the STM, to improve safety, increase the efficiency of maritime transport and be respectful of the environment. Safety in that it is directly related to the control from land of the movements of ships. Efficiency, insofar as by reducing the administrative burden, (which is estimated to be reduced by 80%, especially when using the context of the Single Maritime Window) [152], more information will be available to adjust the timing of port operations and agile traffic flow. It is the exchange of information between ports, and between ships and ports, which includes port authorities, terminals, pilots, shipowners and consignees, and VTS so that they are all synchronized. A concept similar to a Metromap, so that everyone works under one or several consensus and compatible computer applications, exchanging information for greater operability among all. The fundamental pillar of this synchronization is to adjust the arrival times of merchant ships to port, their ETAs, and reduce their operational stays as much as possible. But also adjusting the departure times to the maximum, the ETD, Estimated Time of Departure. And the part that respects the environment is basically defined by the fuel savings that will be made by reducing waiting times and stays, and therefore, CO_2 emissions.

In order to be able to work in common and in groups for each of the activities, a portal was opened, called *ProjectPlace*, only accessible for member with prior authorization, login and password. There, the drafts of each activity were shared, collecting all the suggestions, corrections, amendments, clarifications and other data, until the final documents of each topic were created.

Parallel to this work via the internet, face-to-face workshops sessions were scheduled in Tallinn, Venice, Valencia and London.

The technology that will connect all the actors (ships, ports, vessel traffic services, service providers, shipping companies) that participate in the economic activity of the ports and the merchant maritime business will not be unique in terms of a single manager, basically because of the planetary dimension that the STM wants to acquire, but all devices and instruments must be compatible with each other. This is one of the most difficult goals to achieve.

[152] Data collected from BIMCO. "Harmonization of maritime data models. Leading to port optimization" by Jeppe Skovbakke Juhl,. ENUW, September 9, 2020.

The STM promotes its services by offering a limited list of validated tools related to the routes of the ships that include: Route Cross-check, Route Optimisation, Ship to Ship Route Exchange (S2SREX), Rendezvous (RDV), Navigational Warnings, Chat Service, Enhanced Monitoring, Port Call Synchronisation, Port Call Optimisation, Winter Navigation, Importing Pilot Routes and SAR-Search and Rescue. Each of these services allows:

1. Route Cross-check: A tool to cross a planned route plan with the real scenario corresponding to the same maritime area. The objective would be to verify or detect if crossing both scenarios produces any incompatibility or discrepancy, without offering an alternative. Voyage plan route exchange is also considered an advantage for ships in navigation to be informed, of the routes of those around them (Velasquez Correa et al. 2018), Route Cross-check. Between Ships with STM-enabled on board they could chose to share their voyage plan and verify the route, temporarily, without overcrowding the shipborne navigational displays, and, in the same way, between ships and shore, that is, between ships and VTS centres acquiring situational awareness of the surrounding traffic. The case UKC, Under Keel Clearance is considered, in case of possible variations in depth or areas to be excluded.
2. Route Optimisation: The concept is to provide an optimized alternative route, taking into account variables provided by different providers such as weather forecasts, surface currents, fuel consumption, areas restricted by draft, especially sensitive areas (PSSA) or conflicts with other routes. Taking the weather into account when establishing a maritime route was already reflected through, for example, the IMO Resolution of 1985, the Resolution A.528(13) Recommendation on Weather Routeing, which recognizes that weather routeing - by which ships are provided with "optimum routes" to avoid bad weather - can aid safety (IMO 1983a). Its relevance has been stated in literature by different authors (Martínez de Osés and Castells 2008). It recommends Governments to advise ships flying their flags of the availability of weather routeing information, particularly that provided by services listed by the World Meteorological Organization (WMO). Other investigations have studied the influence of meteorology on navigation. See Martínez de Osés, F.X. (2003).

   Part of the basis of optimization is that, knowing the ship's route plans from land, alternative routes could be suggested, a Route Exchange, based on parameters that could affect them, such as weather conditions, collision risks, forecast of areas with heavy traffic, avoid dangers to navigation and even the possibility of carrying out remote assistance, if requested by a captain can be considered. It would also be a way of detecting ships that deviate from their routes, about to enter dangerous or unauthorized areas.
3. Ship to Ship Route Exchange (S2SREX), route exchange between ships: The objective is to provide a new tool to the watch officer so that they can plan their route in advance, foreseeing possible dangerous situations and reducing diversions after the event due to traffic conditions. Route interchange allows

advance knowledge of other ships intentions and future courses, and adapting the own route to the circumstances, avoiding points of minimum distance or dangerous situations among ships [153].

4. Rendezvous (RDV), this function allows shared parameters such as risks of collision, forecast of zones with heavy traffic and avoidance of navigation hazards. Sailors can view where their own ship will meet a target ship if both ships continue along their monitored broadcasted route at the present speed over ground.
5. Enhanced Monitoring, improved monitoring: A tool for land, so that the VTS centres can verify whether the navigation plan is being fulfilled, according to the planned schedule and route and they can foresee possible conflict situations and suggest, in this case, modifications. Route diversion based on the weather forecast could also be taken into account.
6. Port Call Synchronisation, synchronization of arrivals at port: The objective is to ensure that the arrivals of ships at port are immediate, berthing on arrival, coordinating that operations, terminals, pilots and ship coincide at the same time. Drifting or anchorage waiting would be eliminated.
7. Port Call Optimisation, optimization of operations: A concept in which all the actors involved in the operation of the ship call are synchronized *just-in-time* (JIT), so the information must be shared among all.
8. Winter Navigation, Ice navigation: Study for cases of need for icebreaker services, in which the automation of procedures reduces the workload and the risk of misunderstandings.
9. Importing Pilot Routes, when approaching port, the ship's route can be merged with the pilot's and avoid replanning. This information, shared between the ship and the pilot, provides both with a mental model of the manoeuvre. This service is in practice in Swedish ports.
10. SAR, Search and Rescue, The STM also contemplates that the Rescue Centre can send areas and routes to the SAR units, directly to their on-board electronic charts.

The STM is mainly based on the AIS and therefore on the digital cartography on which the targets are presented, and it is committed to the fact that the information from the traditional Navtex equipment is displayed directly on the ECDIS, an electronic chart [154]. Would this be the beginning of the end for Navtex? Other research lines will examine this, but the end of long paper lists is needed in the era of "please consider the environment before printing this"[155]. Furthermore, the reduction of extra apparatus allows to marshal resources more effectively. The concept of integrating information also lies here.

Test bed results can be used as the basis for full implementation, if successful. The importance of testing, research and practice are key to moving forward and finding implementable solutions. The STM Validation aimed to ensure a greater connection between ships and shoreline, reducing administrative burden, and achieving JIT arrival operations through a maritime digital infrastructure. The assessment was between the

[153] Presentation "In which way can STM improve navigational safety?" by Covadonga Suarez Antón (Sasemar-CESEMI), STM Midterm Conference Workcamp Validation Project, Venice. Italy 12-15 September 2017.

[154] Retrieved from the STM Magazine #1 p.8 "A maritime future without telex?" (STM 2018a).

[155] Registered initiative to be automatically included in the emails through the campaign thinkbeforeprinting.org. Available at: https://thinkbeforeprinting.org/get-the-message.php

principal actors and the interaction with each other was tested, obviously, on the one hand, the ships, and, on the other, the shore. This thesis focuses on the figure of the VTS and identifies it as the main actor, which is why the coastal module has been divided into two: in VTS and on land, on land meaning port operations and the logistics chain (maritime authorities, port control, pilots, tugboats, terminal, consignees, transportation means, other authorizations). The application of the STM in this concept of optimizing efficiency by reducing waiting times by providing fluid connection between the entire port community, so that the management chain is continued and not interrupted, the Port Call Synchronisation concept, is due to the fact that the project, during the entire Validation phase, has carried out various reference studies that support it, offering results with specific figures. They are tangential studies to this dissertation, but they have been detected throughout the STM follow-up. Examples are, the large-scale pilot test of the STM Validation project, which indicated that between 40% to 60% of the time spent in port, depending on the type of vessel, is non-operational time[156]. These studies are connected with the repercussion that this represents, in terms of fuel savings and therefore, in a cost reduction, they show figures of cost-benefit analysis (CBA), such as an average 1% reduction in the distance sailed by ships within the Baltic Sea Region, would save approximately 100 million Euros per year for navigation traffic in the region (Lind 2018). In turn, the STM associates these analyses with a reduction of GHGs (Greenhouse Gasses) and therefore with the protection of the environment in accordance with the guidelines that the IMO began to establish in 2011, where concern has been increasing since the studies carried out by this figure, that the emissions could grow by between 50% and 250% by 2050, according to Resolution MEPC.304(72) of 2018. The IMO included objectives to contribute to global efforts to address GHG emissions from international shipping, which are in the Paris Agreement and its goals and the United Nations 2030 Agenda for Sustainable Development and its SDG 13: "Take urgent action to combat climate change and its impacts "[157]. The final report of the STM shows trade-offs between time saved versus money and emissions reduced. After more than 10 years of collecting information, the analysis shows conclusive results that encrypt savings of up to 20% of CO2 and air pollution from shipping (STM 2019:95).

When a VTS is established, the VTS centre is the first agent that the vessel will share information. (As mentioned in Part II). It should be noted that there is talk to the Shore Centre (SC) and not the VTS centre, because during the tests, the simulators were located in different places. Even in the cases that were done in a VTS centre, the VTS Operator dedicated themselves exclusively to doing the tests. In the future, the STM could be part of VTS tool, but on a larger scale, with a global visualization of maritime traffic and information exchange, therefore the information shared will be referenced as Ships-Ship and VTS-Ship. Considering a PC as a separate unit from the VTS is against the very principles of the STM. Considering a PC as a separate unit from the VTS as defined in the "Voyage management tesbed report"[158] does not match with the very principles of the STM. It is neither safe, nor efficient as it would be equivalent to duplicating

[156] STM Conference. Operational Perspective by José Andrés Giménez, Port Logistics Director. Fundacion Valenciaport. June 3, 2021.

[157] IMO (2018f). IMO (2018) 'RESOLUTION MEPC.304(72) INITIAL IMO STRATEGY ON REDUCTION OF GHG EMISSIONS FROM SHIPS', MEPC 72/17/Add.1. p.4.

[158] Andreasson, Björn et al. (2019) STM Val_D2.6, D2.10 & D2.12. Voyage management testbed report. pp.60-75.

services. Also, most of the shared or suggested routes will have the port as their destination, so the areas covered would be the same in the end. The VTS are the only ones that are enabled and authorized to interact with the traffic [159] which is ultimately where all the ships are heading for.

The information flow between the rest of shore actors is called PortCDM, as stated before. The types of test beds related with share route were voyage management and with the EMSN including those that were made with the simulator network and those that were made between Shore Centres and ships.

The installation of simulators interconnected between several EU countries[160] the EMSN, European Maritime Simulator Network, to test the management of maritime traffic in situations of complex manoeuvres, congestion, and other functions such as rescue and SAR, where a virtual scenario can be simulated as an alternative to face-to-face exercises, saving time, costs and environmental impact, was a great challenge. It was possible to navigate with different nationalities in other countries.

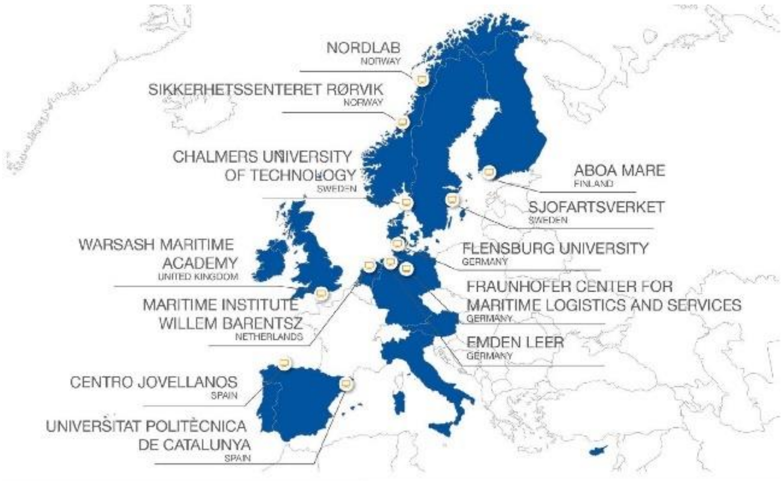

Figure 45. EMSN Simulation Centres map

The connected simulators, Ship Handling Simulators (SHS), involved came from 10 shore centres, with 2 that participated occasionally, from 7 EU countries, with 5 testing weeks (W) scheduled. The SC played the role of vessels (bridges STM-enables) and there were two SCs that served as a standard VTS centre.

Each scenario was 1.5 hours of runtime and, each day, there were two trials with different scenarios. The first 4 weeks scheduled were traffic situations, navigating in different conditions, and week 5 for SAR simulation. (Two more sessions were also held at the end, but with only 2 centres involved).

The weeks were: W1 from 13 to 17 November 2017; And, in 2018, they were: W2: from 5 to 9 February; W3 from 12 to 16 March; W4 from 11 to 15 of June; and W5 (SAR) from 22 to 26 October. Each Centre participated with simulated bridges (depending on available equipment but two-person for each bridge team) and using its own manufacturer of simulator, a clear example of how different brands of equipment can work connected. Hardware-to-hardware compatibility with appropriate software, the perfect interface.

[159] Included in the definition of the Vessel Traffic Services. Resolution A. 857(20) Guidelines for VTS.

[160] STM Validation Project test beds in EU. Available at: https://www.seatrafficmanagement.info/image-gallery/ (Accessed: 10 October 2018).

	Simulation Site	Abbr.*	Country	City	Simulator Type	No.**
1	Aboa Mare	AM	Finland	Turku	Transas	3
2	Centro Jovellanos	CJ	Spain	Gijón	Kongsberg	4
3	Chalmes University of Technology	CTH	Sweden	Gothenburg	Transas	2
4	Flensburg University of applied Sciences	FUAS	Germany	Flensburg	Transas	3
5	Fraunhofer Center for Maritime Logistics and Services	CML	Germany	Hamburg	Rheinmetall	2
					Transas	1
6	Maritime Institute Willem Barentsz	WB	Netherlands	West-Terschelling	Kongsberg	2
7	Sikkerhetssenteret Rorvik	SSR	Norway	Rorvik	Transas	5
8	Swedish Maritime Administration	SMA	Sweden	Norrkoping	Transas	3
9	Universitat Politècnica de Catalunya	UPC	Spain	Barcelona	Transas	2
10	Warsash Maritime Academy	WMA	England	Southampton	Kongsberg	2

**Abbreviation. ** Number of bridges*.

Table 33. Simulation Sites

In these 10 simulation sites (Reimann et al.2019:6), a total of 512 professionals (seafarers, VTS Operators, universities) participated in the simulator sessions and each one was assigned a number of ships to “play”. The tests, or test beds, consisted of navigating through the simulators, under a previously programmed scenario. A specific navigation zone was established beforehand, through which various merchant ships would circulate, of different tonnage and speeds and with also predefined meteorological conditions. Each ship was assigned a different travel plan to execute and all, at the same time, set out to sail the virtual sea. The objective was to see how communications are established, how the computer system supports the STM gear and at what level information can be exchanged over long distances. The EMSN, European Maritime Simulator Network, put this to the test.

The scenarios were located in two different geographical areas, one in the Southwestern Baltic (with dense traffic) and another in the English Channel, (less busy). And each had the respective VTS centre, the one in Southampton and the other in Gothenburg, Sweden, so that the ships could go to each centre according to the area where they were sailing.

		Vessel			
	Simulation Site	**Name**	**Type**	**Imo**	**Flag**
1	Aboa Mare	AM Emma	Tanker	9355782	Finnish
2		AM Jenni	Ropax Ferry	9613290	
3		AM Krista	Cruise	9970322	
4	Centro Jovellanos	CJ Laura	Bulk Carrier	9524288	Spanish
5		CJ Carmen	Feeder Container	9519304	
6		CJ Irene	VLCC	9120934	
7		CJ Alexandra	Tanker	9534244	
8	Chalmers University of Technology	CTH Johanna	Feeder Container	9527941	Swedish
9		CTH Ebba	Bulk Carrier	9168781	
10	Flensburg University of applied Scences	FUAS Svenja	Cruise	9613538	German
11		FUAS Martha	Feeder Container	9451252	
12		FUAS Carolin	Tanker	9926253	
13	Fraunhofer Center for Maritime Logistics ans Services	CML Paula	Container	9721750	German
14		CML Louisa	Tanker	9667509	
15		CML Sarah	Cruise	9203939	
16	Maritime Institute Willem Barentsz	WB Tessa	VLCC	9592321	Dutch
17		WB Amber	Tanker	9698772	
18	Sikkerhetssenteret Rorvik	SSR Nora	Ropax Ferry	9810024	Norwegian
19		SSR Marit	Ropax Ferry	9631252	
20		SSR Elise	Container	9499523	
21		SSR Live	Bulk Carrier	9320388	
22		SSR Tuva	Platform Supply	9580900	
23	Swedish Maritime Administration	SMA Anna	Feeder Container	9938679	Swedish
24		SMA Elvira	Tanker	9749761	
25		SMA Ingrid	Tanker	9659566	
26	Universitat Politècnica de Catalunya (FNB)	UPC Sofia	Platform Supply	9521228	Spanish
27		UPC Paloma	Ropax Ferry	9718648	
28	Warsash Maritime Academy	WMA Admiral Jellicoe	Bulk Carrier	9784167	British
29		WMA Becky	Bulk Carrier	9809485	

Table 34.Participating vessels of Simulation Sites

The table, extracted from the STM-EMSN Summary Simulation Weeks report (Reimann et al. 2019:9) shows the 29 vessels that participated in the simulations for each site, during simulation week 1. As can be seen, the degree of simulation includes providing the targets with a name, type of vessel, IMO number and the flag under which the vessel sails, a scene similar to reality.

It was possible to be physically located in Barcelona or Gijón and navigate for the first time in those seas, something that would excite a sailor, to have the Electronic Navigational Chart (ENC) of the area and be surrounded by "ships-colleagues".

As the ships navigated and followed their routes, they could see each other's and share them, but they could also receive warnings and route modifications from the SC and test communications. While the simulation was running, a questionnaire had to be completed every 15 minutes. The purpose of this was to check if the

STM tool was adding pressure to the bridge team's workload. In fact, the questionnaire already added more pressure than the STM tool. Consequently, it would have been better to have filled it later, as everyone remembers when they have been under stress or overworked.

The comments of each participant from each station were compiled at the end of each session, as a “post-scenario questionnaire”, which asked questions specific to the STM services. There were quite a few coincidences between them, and the main conclusions are summarized in that, in general, all the feelings were positive and indicated a good experience The experience was helpful, very realistic and the simulators provided good insight and were seen to have great potential.

The analysis of the debriefs revealed two common categories when using VTS services. On the one hand, the additional time required and, on the other, usability. Although some training is required and appropriate skills needed, because of the lack of familiarization when the system crashes. It is not always clear what is wrong, whether it is the “operator” or "the computer." Loading, checking and re-planning routes also requires great skill, delving into further details [161] of the main facilities used:

The function of Navigational Warnings (NW) that appears on the screen was useful and made the work easier. It was considered easier and more efficient to check them directly on the ECDIS screen, although some ships already have the Navtex connected to the ECDIS.

The S2SREX tool was highly commented on. Route exchange ran well and it was interesting to see what the other ships were going to do, but involved a higher workload and ability to change routes quickly. When more than one route was selected, it was very confusing and too cluttered on the ECDIS display, making it difficult to identify which route belonged to which ship. However, the opportunity to see planned routes, rather than just a destination, could improve efficiency, as ships could change the route, not only to prevent collisions, but to optimize it or to avoid potential dangerous situations, such as close quarters traffic situations. Another feature that overcrowded the screen was the difficulty in clearing former targets and data.

Suggesting a route from shore centre for long term planning to the ships could be also very useful in some VTS areas, or even beyond, by providing new routes, including possible unknown variables for the ship, can help increase situational awareness.

The chat function is directly related to communications, which are the leitmotif for the entire maritime chain to function. It can be understood as a tool to convey specific messages related to safety, regardless of whether the recipient has received it or not. But if we understand it as a radio communication that requires confirmation, feedback or acknowledgement, when a message is sent, it is not known if the message has been read, since there are no indicators of receipt. So, communication goes from being an auditory to visual issue, in this sense, the majority opinion was that it would distract attention and could overload and disrupt

[161] Data collected during 3rd term-week (March 2018) shared via ProjectPlace. Debriefing from the Maritime Academy and Training Centre, Aboa Mare in Finland; the Warsash Maritime Academy, (WMA), Solent University in Southampton, United Kingdom; the Integral Maritime Safety Centre Jovellanos (CESEMI: Centro de Seguridad Marítima Integral Jovellanos) in Gijón, Spain; and the Faculty of Nautical Studies of Barcelona (FNB), Spain.

the screen. In many cases it is faster to speak than to type, so the possibility that the VHF equipment is made redundant is not considered and, in addition, important information can be heard by all ships in the vicinity. This would be related to the fact that, if the intention is to use the radio less and less, for written messages, the shortest form is the emoticon. Many users of smartphones barely write on their phones. Emojis are sent to express messages or enhance their meaning. But it is not possible to imagine approving a manoeuvre between ships with an emoticon, the COLREG necessitates a more serious and complex communication. Further studies will be able to examine this. It is important to compare these comments with the results obtained from seafarers. Based on the survey results, respondents felt that it is not a good idea to replace VHF voice communications with chat or written text messages (Pawel et al. 2018).

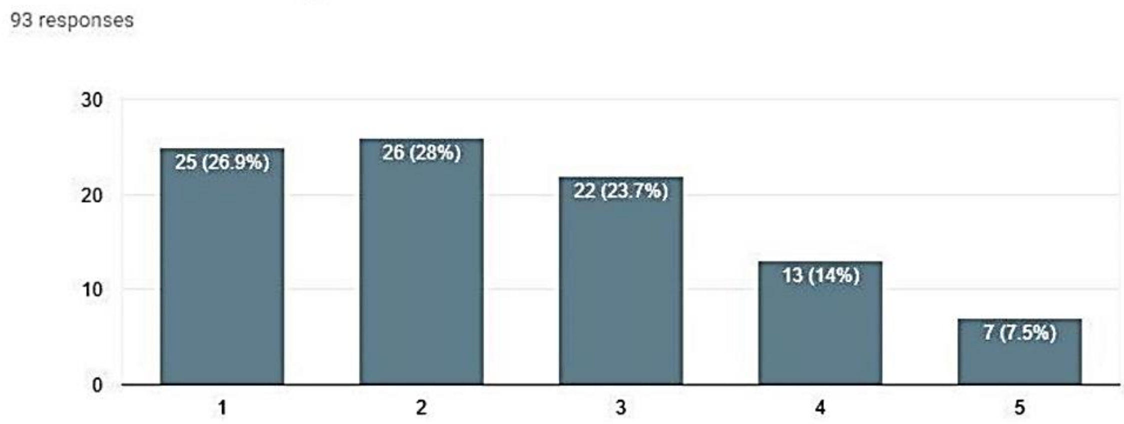

Figure 46. To what extent would you replace VHF voice communications by chat or written text messages?

Another service tested was the adjustment of the ETAs, which can improve traffic flow management, where greater ability to share information and communicate with VTS could mean earlier decision-making by everyone, ports included. This is directly related to the concept of PortCDM.

The STM RDV, Rendez-Vous, function was surprising from a navigator's point of view, since a rendezvous was the meeting point for cargo transfer, from ship to ship or to change the crew, among others. If it is used to learn the Closest Point of Approach, the CPA, following a route plan, which is how it is known on the radar. This would not be identical to that in the ECDIS. Both should be independently visualized and not mixed. It is not only how software is developed, but how the specific maritime science is translated into computer language. E-Navigation must and should always keep this matter in mind. These results can be compared with the data collected (Aylward et al. 2019:13) during 8 days from 2 non-consecutive weeks in 9 simulation centres, and with the participation of up to 30 ship bridges, and the data collected follows the same process.

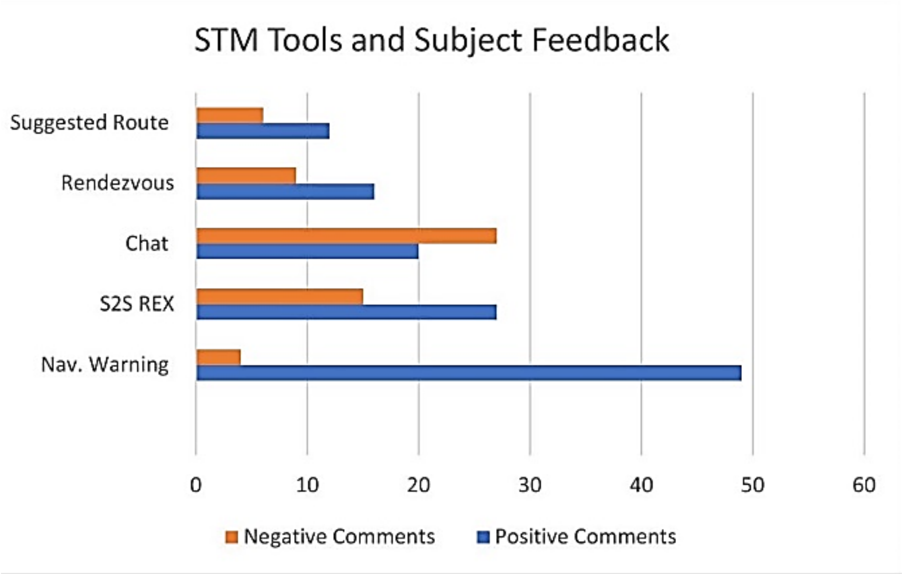

Figure 47. Summary of Positive and Negative Feedback of each STM Service

The demoscopy shows that, in all these analyses, the results tend to be the same.

The exercises required being very attentive to the screen, very reliant on AIS and considerable focus on the ECDIS display, and this brings into question whether there would be time to lookout during the watchkeeping. As has been mentioned in Part II, not all the information remains in the AIS signal and it is not always correct.

The information through a screen that is closest to reality is that shown on the RADAR, which shows, not only the ships that carry AIS, but also possible echoes on the sea surface. Relying only on ECDIS is still difficult or distant, above all because not all ships are equipped with AIS. One might think that in the future, absolutely all ships will carry AIS or another identification device, bringing the image on a screen closer to what is actually out there.

STM is very likely to change the nature of decision-making on board, and also in VTS Centres because the control over ships form shore side will increase. It will require careful use and mastering a large amount of information. The new features must also make work processes easier. But in summary, STM could be a AtoN, but could not replace collision regulations, visual or hearing in a proper lookout [162]. COLREG is an effective, common-sense tool which, in combination with electronic aids to navigation, and supported by services based on maritime cloud, can result in an improved navigation culture, demonstrated for the first time in Europe. Considering that knowing in advance the intention of the other ship, very helpful in avoiding collisions, is something new, it is now no longer a theory, but has been tested during the STM Validation project.

[162] Final conclusions of the workplan presented in the final report by José Andrés Giménez Maldonado, Valencia Port Foundation. STM-MidTerm. 12th and 13th September 2018, Valencia.

Analysing it from a thesis perspective, it can be added that the author participated in four of the scheduled sessions and in two different centres. The virtual exercises made it possible to navigate those seas never experienced before. The virtual world separates it from reality, and therefore it cannot be compared with a genuine experience on the high seas, but technology has been shortening that distance, until they have been brought together in virtual reality, achieving very real scenarios. The network of simulators is not yet at this level of reality, but it did allow navigation with different ships, and this can be of great help and practice for the training of a professional. The concept of carrying out the exercise, in a network, with participants from different "ports" from Europe and in real time, is extremely interesting and exciting. It is an enriching experience that places the "seafarer" as an entity that is part of a great project, coordinating and interacting with professionals from different nationalities. The simulator network could be an excellent tool for training, globally. There could be a network of simulators programmed through connecting centres around the world., with virtual transoceanic navigation worldwide, and the VTS Operators training together across the oceans.

The Voyage Management test beds were a huge milestone. Shore centres, in this case VTS centres, were involved but it was also necessary to equip ships to test the STM system. It was about sharing information from the VTS Operator to the OOW on board of real ships, not virtual ones. The forecast was to equip up to 300 ships for STM test bed. This is highly complex insofar as, unlike the ground centres whose staff is more or less the same, the crews change and are distributed in at least three different guards, every 24 hours. Forecasts estimate that around 2400 sailors would need to be introduced, trained and supported in the use of the STM project.

Six coastal centres (Figure 18)[163] were included for STM test bed and up to 311 participating ships participated. A variety of software was developed for this aim, from different companies (Wärtsilä, Transas, Furuno, Wärtsilä SAM or Kongsberg) using standardized data exchange formats. The set of message formats used were: Route exchange format (RTZ) via internet (IP) or AIS although the bandwidth and time allocation of AIS is limited, Text Message Format (txt), the Standard S-124 for Navigational Warnings and the Port Call Message Format (PCMF).

[163] STM (2019) STM Validation Project. Final Report. Voyage Management Test-bed. p.14.

The idea was to test STM tools, such as route exchange, text messaging, the ability to check routes in advance, and find out how it improves the VTS service.

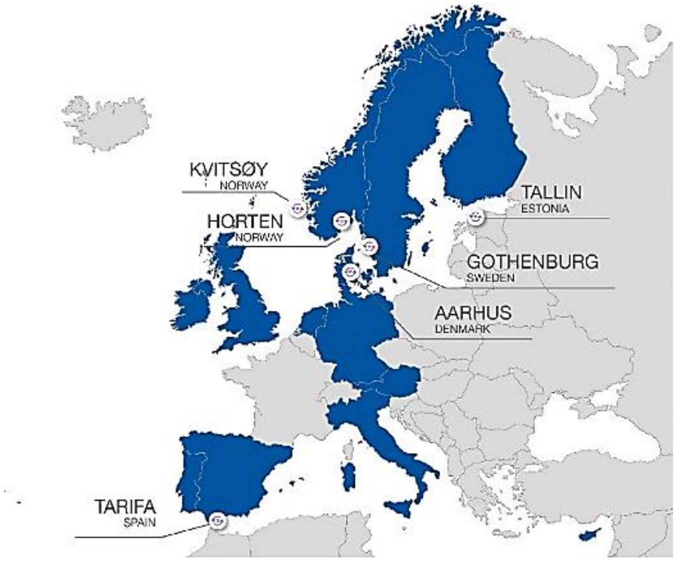

Figure 48. Shore Centres included in STM test-bed

As can be seen from the figure, the six Centres are Kvitsöy y Horten in Norway, Gothenburg in Sweden, Tallin in Estonia, Aarhus in Denmark and Tarifa in Spain. Different tests were carried out from these.

With regard to ship contacts, the Kvitsöy VTS, the Horten VTS and VTS in Tallin had relatively few route exchanges between shore and ships. All centres are equipped with VTS equipment and sensors such as radar, AIS, VHF, DSC CCTV, etc. as well as with STM shore centre system, with the specific software of the STM Shore Centre. Tallin obtained a shared voyage plan of 837 in a period of 2018.

In the shore centres of Gothenburg, which covered the Denmark area, and Tarifa, the VTS operators worked exclusively on the exercise at specific times. The objective was to establish contact with the ships to encourage them to participate in the test bed by sharing their voyage plans. The number of voyage plans shared with Gothenburg reached a peak, in 2018, of 5734.

The MRCC Tarifa, one of the 20 Centres of the Maritime Safety and Rescue Agency that was a partner of the STM project since its inception, and already in the Monalisa, participated in the tests, with a controller in charge who was dedicated exclusively to the project[164]. The recorded results were 1826 RTZ, 1329 txt, 31 S-124, 75 emails, and 90 contacts by VHF and Phone.

As an illustrative example, a case has been chosen in which, replacing the Navtex device, it is shown how this new formula is an improved tool, whereby a written message becomes a graphic image. What it entails is reporting on a shooting exercise area at sea and therefore a shelter area is required, in Navtex language, it extends to giving points in coordinates by latitude and longitude. The image shows that the exclusion zone is transferred in lines on the ECDIS. The dotted line is the ship's path, in this case, the MT Chemical

[164] Eva María Ordóñez Venero, VTS Instructor at MRCC Tarifa.

Voyager, and the solid lines indicate the limits of the firing exercise area. The Tarifa VTS receives the Voyage Plan, (VP) and, when verifying that she will exceed the firing exclusion area, the Center sends the Navtex references that will affect it on her route. Therefore, the ship changes the VP according to information received from Tarifa VTS.

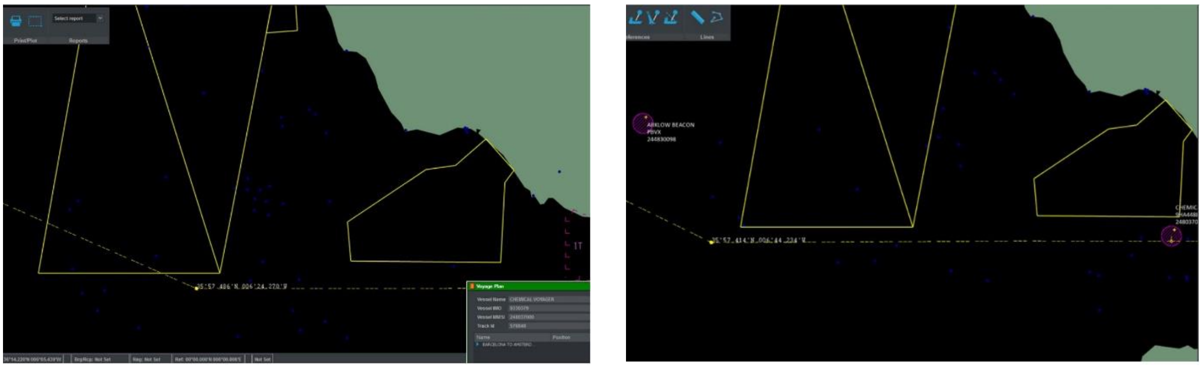

Figure 49. Screenshots of a voyage plan shared with Tarifa VTS

The Enhanced berth-to-berth Monitoring Service function was also tested. From the VTS Tarifa, the route of the ship from port to port was monitored. In this case, from Castellón to Huelva[165].

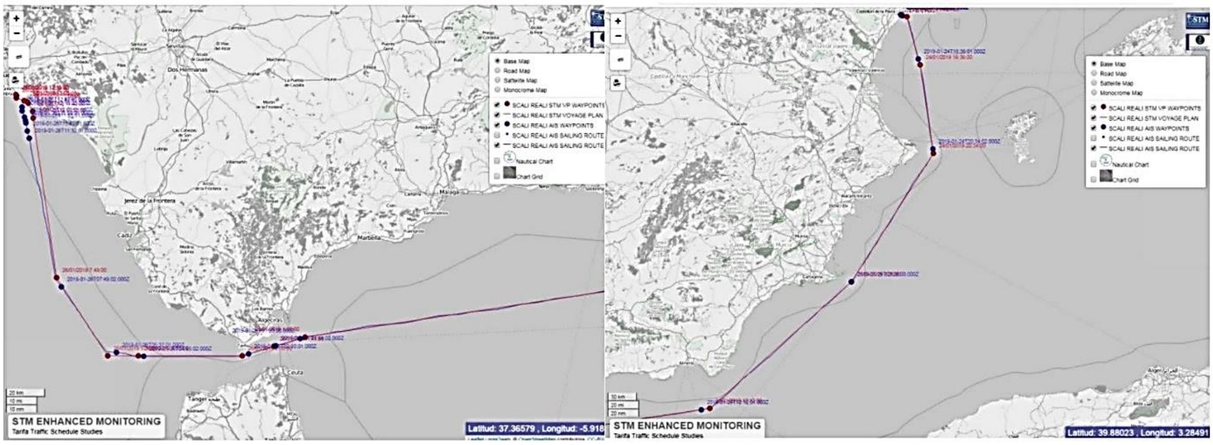

Figure 50. Enhanced monitoring service berth to berth. Ship route from Castellon to Huelva

The ship shared its voyage plan, the red line is the route and the blue line is the ship's AIS tracking. In this example, the ship followed the route and schedule sent by its VTS-compatible navigation system.

This exchange between ships and centres, both equipped with STM, is an improvement of the tracking from land of the ship, the so-called Enhanced Monitoring Service. The Enhanced Monitoring Service is basically the essence of VTS when it was born in 1948. Ships are monitored and watched over by a VTS Operator from shore and, if the ship appears to be in a potentially dangerous situation, the Operator warns the ship or ships. What the STM would allow is the possibility that the VTS operator receives the route that the ship intends to take. If the VTS receives the ship's route in advance, it can be monitored and the ship's intentions can be understood. This gives the VTS Operator the ability to review the ship's planning of its approach to

[165] Anderson et al. (2019). STMVal_D2.6, D2.10 & D2.12. Voyage management testbed report. p.73.

land. If the ship deviates from the planned route, the VTS Operator will be alerted that the ship, for some reason, is no longer following its plan. It is evident that the connection between both increases. This is a clear example of how the port-to-port route can be followed, opening the possibilities to international ports through the open sea.

Results of the PortCDM are more radical, in that the port sector demands digital infrastructure, more communications, less administrative burden and even a change in the mindset within ports. The concept was validated in four ports on a Mediterranean test bed and five ports on a Nordic test bed. More than 80 organizations involved in the scaling process participated. This allowed the participants to start collaborating with actors they had never before communicated with, within the same port community, and this was valued very positively by the majority. Based on the results of the port test bed, 92% of users agreed with the statement that the use of the STM sub-concept, PortCDM, is expected to contribute to a shared situational awareness during port calls, which more than half of them identified as the key to improving collaboration. A large proportion of communication throughout the transportation chain is either manual or based on non-integrated, non-automated and non-documented digital systems like VHF, e-mail, Fax or phone. Sharing information is not only within the same port but from port to port, this is the objective. That is why a common digital platform is so important, where infrastructure provides interoperability within and between service domains, hence the SeaSWIM. All actors can share information in real-time, using a standardized, internationally-recognized, data exchange format.

The port of Barcelona, Sagunto and Valencia in Spain, Stavanger in Norway, Umeå, Gothenburg and Brofjorden, in Sweden, Vaasa in Finland and Limassol in Cyprus, participated in the workshops, sharing data, such ETD and ATD, from ships. For exchange and sharing information, the standard S-100 were used, as they are the key to uniting the maritime community. The specific standard Port Call Message Format (PCMF), enabling the sharing of port call information, is the S-211. This S-211 standard for the exchange of information has been developed, IALA has also been working on this Call Message Product Specification since 2018, the 2019 draft of which, is an 85-page technical document that defines its format and operation.

The test beds served to involve both commercial and public service developers and distributors in building PortCDM Services, and although uptake was high, subsequent surveys revealed that the industry was critical about its functionality. PortCDM functionality will not solve all problems. Its functionality is limited by the lack of users and two-way M2M integrations to the systems of the interested parties. An international framework is required, which includes training and certification (Pawel et al. 2018 131:40). The results also reflected the complexity that arises when the ships that have the Connector installed do not use it, or simply do not call at ports or terminals provided with PortCDM.

The STM Validation Project officially ended on November 13th-14th, 2018 in London[166], at IMO Headquarters with a major conference, the STM Validation Project Final Conference. The expression:

[166] STM Validation's Final Conference held in London. November 13-14, 2018. IMO Headquarters.

"Share & Benefit!" was chosen to emphasize the importance of information sharing through STM, since it brings benefits to all maritime actors.

The presentations by way of conclusions and the leitmotif of the STM project from its beginnings to the end were emphasized: "Sharing information is the key" to integrate it into a platform used globally, "It takes two to tango"[167]. Sea Traffic Management is the idea of sharing information and collaborating to optimize the shipping chain, while increasing safety, efficiency and sustainability. Both on board and on land, the technology has been implemented, but the interconnection is point-to-point and proprietary and prevents the industry from being more efficient (Lind et al. 2016). Shorter routes, JIT arrivals, shorter port calls are factors that will strengthen the competitiveness of the maritime sector. Improved situational awareness on the bridge and knowledge of planned routes will help optimize planning, as well as reduce the number of incidents and accidents. The STM concept encompasses all the actors, actions and systems (infrastructure) that help maritime transport from port to port, making it part of the multimodal logistics chain, which encompasses both maritime and land operations. It is a network-based approach to optimal intermodal shipping that is performed at multiple levels of actors, with each actor involved co-producing traffic management. The high degree of participation, around 350 people and up to 39 technical presentations from professionals in the sector, endorsed the success and high level of the project at the IMO headquarters during the two days that the international congress lasted. It was closed by the Secretary General, Kitack Lim, with the commitment to continue supporting the project, "STM goes hand in hand with IMO goals"[168]. The different presentations highlighted that work would continue on the STM concept. Not at all in vain, the STM project had been one of the largest e-Navigation projects in the world, due to the large budget and great number of countries and entities involved (see next Chapter 6.3.2).

Following the strict definition of e-Navigation, a direct comparison can be made with STM as the table below shows[169]:

E-Navigation[170]	**STM**	
"The harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means (…)"	STM is a concept for sharing secure, relevant and timely maritime information with authorized service providers, by proposing a framework and standards for information management and interoperable services	What and how
"to enhance berth to berth navigation (…)"	A holistic approach to distributed service related to the berth-to-berth voyage enabling the efficient, safe, and environmentally sustainable sea transport	Why
"and related services for safety and security at sea and protection of the marine environment"	The potentials of enhanced information sharing are increased safety, efficiency and less likelihood of an environmental impact.	

Table 35. Comparison between STM and the e-navigation definition

167 Cajsa Jersler Fransson, and Katarina Norén, Director General, both from SMA. STM Validation's Final Conference London. November 13-14, 2018. IMO Headquarters.

168 STM. (2018) Press Release. pp.1-3.

169 Andreasson et al. (2019). STM Val_D2.6, D2.10 & D2.12. Voyage management testbed report. p.11.

170 IMO (2008a) 'MSC 85/26/Add.1 ANNEX 20. Strategy for the development and implementation of e-Navigation', p.1.

The definition of the e-Navigation through the STM, responds to the elements "how" and "why". However, it is the definition part, the 'what', that takes more time than originally anticipated[171]. The "Deployment" phase has not yet arrived in 2022.

After 2018, with the extension of 6 months, that is, until June 2019, the STM has evolved and has been included in projects more focused on areas or types of ships, all of them also with the support of European Union, and European Regional Development Fund, among others. In chronological order from past to present[172]:

- Real Time Ferries, RTF: This project with the motto: *It´s time to get visible!*. Project focused on the ferries that cross the Baltic Sea Region, taking advantage of real-time departure and arrival times of these ships allow optimisation of the intermodal traffic flows.
- EfficientFlow: with the motto: *Making STM happen*. The concept of P*ort Flow Optimisation* between Finland and Sweden ports, enabling just-in-time arrivals and operations reducing transport time. The synchronisation is the strategic key, evaluated in real use, and the enabler *Port Collaborative Decision Making* has been made operational in two ports, Rauma and Gävle. EfficientFlow ran from 2018-2020.
- STEAM (Sea Traffic Management in the Eastern Mediterranean) is a three-year project that started in January 2019. This time the STM concept was established in Cyprus, following the previous steps, when Limassol put into practice the functionality of Port-2-Port Communication, enabling Short Sea Shipping (SSS).
- STM BALT SAFE (2019-2021 with the motto: *Safety of Navigation in the Baltic Sea by Sea Traffic Management* this time focused on tanker ships. Some 80,000 ships passed in and out of the Baltic Sea over one year, many of them tankers with dangerous cargo [173]. There is a need to improve the exchange of information between ships and between ships and shore digitally. Here, the role of the VTS is vital in the ship reporting systems. The aim is to develop automated reporting within the concept Maritime Single Window, MSW, tested in both the GOFREP and SOUNDREP systems. Route optimization will be tested, and the decrease in administrative burden will be measured.

The mandatory capability to share voyage plans, according to defined standards, could also be a means of accelerating adoption on board ships and ensuring long-term sustainable use. This requires regulatory changes. Examples of resolutions and regulations, relevant to a mandatory ability to share voyage plans involve, but are not limited to, the IMO Assembly Resolution A.893(21) on "Guidelines for voyage planning", which highlights the need for voyage and passage planning applied to all vessels, of 1999 and which, in turn, is referenced in the SOLAS V Regulation 34. Also, the Resolution MSC.191(79) "Performance standards for the presentation of navigation-related information on shipborne navigational displays" of 2004, later referenced in Resolution MSC.232(82) of 2006, on adoption of the revised

[171] "The future of e-navigation" by Nick Lemon Manager, Systems Safety at the Australian Maritime Safety Authority (AMSA). International conference "e-Navigation underway. Asia-Pacific 2020". September 8, 2020.

[172] STM projects. All retrieved from: https://www.seatrafficmanagement.info/projects/

[173] 2012 average. Retrieved from: https://www.iala-aism.org/technical/e-nav-testbeds/monalisa-1/

performance standards for electronic chart display and information systems (ECDIS). Functions should also be incorporated, as detailed in SN.1/Circ.243/Rev.2 of 2019 on Guidelines for the presentation of navigation-related symbols, terms and abbreviations.

All this requires a very careful review and further investigation, with the additional consideration that, in regulatory matters, an extensive chain of modifications can be generated, which makes any new incorporation complicated and long.

In this part III of the thesis, the long processes that are required, not even by new regulations, but updates of the existing ones, have been shown. The STM project, which was founded in 2010, has reached its 10 year mark. In this first decade, it has achieved a milestone, which is to be included in the IMO Work Program, within the "Proposal for a new output to amend the revised ECDIS performance standards (resolution MSC.232(82)) to facilitate a standardized digital exchange of vessels' route plans" of 2021. The MSC.104/15/7 submitted by Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Republic of Korea, Romania, Slovakia, Slovenia, Spain, Sweden and European Commission, an example of the number of States that have also been involved, proposes the standardized digital exchange of ship route plans to be included in the biennial agenda of the Sub-Committee for 2022-2023.

It highlights the work of the STM, crossing all the tests carried out with the data obtained. The more than 100 VTS Centres, in European waters where ships are required to report data under the standards of the IMO, whose SRS mandatory collects more than 16 types of reports (R.A.851(20)), link the VTS to this proposal. Digitally exchanged routing plans have various benefits, such as minimizing the notification burden, the VTS works more proactively and creates a common situational awareness that makes operations and monitoring more effective. This is the open road towards the inclusion of the STM in the IMO regulation.

6.3.2. Other e-Navigation Projects.

The STM became more than a project, it became an e-Navigation concept and given its characteristics, durability, support, degrees of international involvement, it has been included in a separate chapter. However, other projects have coexisted which worked on standardized maritime digitalization. Some projects took over and others worked in parallel or focused on specific solutions in stages that have lasted 20 years.

This is with the exception of project "SESAME Straits" e-Navigation Intelligent Ship Traffic Management[174], tested in the Strait of Malacca and Singapore, which was active from 2014 to 2017 within the Funding program and budget of Norwegian Research Council. Subsequently, another Project was budgeted, the "Sesame Solution II. Implementing e-navigation and operator workload" from 2018 to 2021.

[174] Available at: https://www.iala-aism.org/technical/e-nav-testbeds/sesame-straits-project/

Both projects focused on interaction between the ship and the VTS, providing a cooperative platform for tactical and strategic planning for several days prior to arrival. This enabled, at the regional level, the MSPs in the same line as the STM, monitoring ship tracks from land to suggest an alternative route, JIT tracking, optimal transit speed connection, with less GHG and bunkers consumption, efficient traffic flow and better coordination between all port resources. It should be added that JIT and Port Call Optimization are concepts already accepted by the IMO[175], as well as the MSW, via FAL.5Cric.42/Rev.1 of 2021. JIT has a specific guide, based on studies that show results that contribute to the reduction of GHG emissions (IMO 2020).

Looking back, the STM (Monalisa) relieved the EfficienSea from continuing to work on the key of the e-Navigation, to find a common framework in the maritime digital world. The EfficienSea, Efficient, safe and sustainable traffic at Sea, with its motto "*Getting Connected*"[176] in reference to the computer cloud, Maritime Cloud, was captained by the Danish Authorities. It started in 2009 after receiving a budget from the EU: the Baltic Sea Region Programme 2007-2013[177] therefore the Baltic Sea became a pilot region for e-Navigation by establishing e-Navigation test beds. The aim was to investigated possible solutions for collection and presentation concerning Maritime Safety Information (MSI), and the later report showed that good results were obtained (IMO 2011a).

Then evolved into EfficienSea2, a project that received funding from the European Union's Horizon 2020 research and innovation programme, until April 2018, carrying out tests in the Arctic and the Baltic Sea, with the first generation of homogenized electronic navigation between Sweden and Denmark. In 2017, the Maritime Connectivity Platform (MCP), was launched to unify the two European projects, the STM and EfficienSea2, in terms of electronic information (IALA-EFFICIENSEA 2017), in which Korea [178] also joined by expanding the spectrum with its SMART-Navigation digital platform for Non-SOLAS vessels. From 2012 to 2015, ACCSEAS, Accessibility for Shipping, Efficiency, Advantages and Sustainability, aimed to improve maritime access to the North Sea Region (NSR), with partners from Denmark, Germany, Sweden, Norway, the Netherlands, and the UK. Experts from diverse sectors emphasized the value of e-Navigation test beds and demonstrated its ability to improve spatial awareness or information integrity for both the mariner and shore-based authorities, the basis for relieving congestion, bottlenecks and the risk of accidents, thus improving access in that area, which includes the steps to access the Baltic Sea, with sustained cooperation and actions after the project. It is considered that maritime transport faces an enormous challenge in the coming decades, since maritime areas are also affected by changes, such as open waters becoming confined waters, due to wind farms or other structures, as analysed by some of the experts consulted [179].

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175 "Digitalization ship-port interface". Session 4 by Martina Fontanet Sole, IMO Technical Officer. International Conference Digital@Sea Asia Pacific. September 9, 2020.

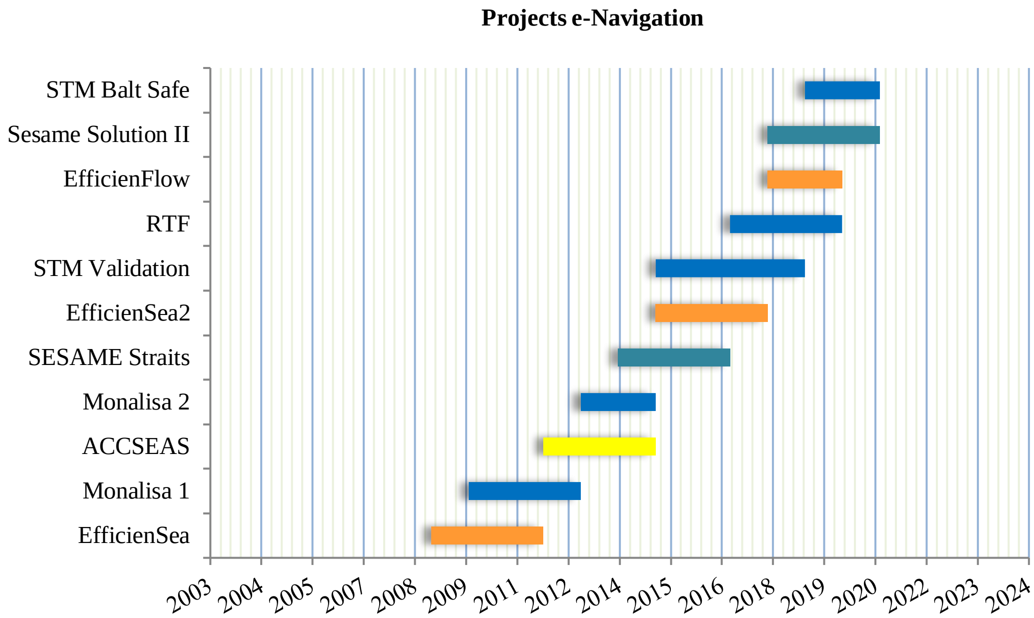
176 Included in the logo of the second version. Available at: https://efficiensea2.org/

177 EfficienSea. Available at: http://efficiensea.org/default.asp?Action=Details&Item=403

178 Korea was chosen to hold the 19th International Conference of the IALA in June 2018.

179 Ph.D. Thomas Porathe. Chalmers University Technology (2013). ACCSEAS Official Film. Min.1:51 https://youtu.be/Go0qyTDG4CM

The projects that have surrounded the STM, endowed with different names and budgets and tested between the years 2009 and 2021, are collected in the following table within the European context. These are projects in which direct monitoring has been possible. This does not mean that there have not been more projects, in other parts of the world, which could be included in another line of research, in Australia, Canada, USA, Japan, South Korea and even in Russia, although despite having its representatives in the IMO and IALA, Russia did not participate in any major international e-Navigation projects, as analysed in the literature on the 10 years of e-Navigation (Rivkin 2016:97).



Note: matching colours unite related projects.

Figure 51. e-Navigation Projects from 2009 to 2020

However, more than 40 regional projects have been registered, which have operated local test beds over the years in the e-Navigation environment. Joint projects from commercial initiatives, organizations, and universities. The following table shows the main ones in alphabetical order[180].

[180] Conference, D. (2021) Digital@Sea Asia Pacific Conference. Sejong, Republic of Korea. p.150. and data added retrieved from IALA web. https://www.iala-aism.org/technical/e-nav-testbeds/yangshan-port-e-navigation/

Name	Description	Year
AMSA VDES	Australian Maritime Safety Authority's (AMSA) Brisbane VDES Testbed	2015
ARCTIC WEB	Arctic (DMA)	2015-2017
ARIADNA	Maritime Volumetric Navigation System	2010-2013
AVANTI/PRONTO	Port of Rotterdam	2015-2016
BALTCOAST	Baltic	2015-2018
DBDD	Dublin Bay Digital Diamon	2013-2015
E-ATON JTCD	Western River Electronic ATON Joint Technical Capabilities Demonstration	2013-2014
EFAIRWAY	Enhanced and electronic fairway information (Norway)	2016
eMIR	eMaritime Integrated Reference Platform	2013-2023
EMSI	Electronic Marine Safety Information (USA)	2015-2017
EUCISE2020	EU	2015-2017
E-YANGSHAN PORT	China	2014-2016
IONO	Ionian Integrated Marine Observatory (Adriatic)	2012-2013
IONIO	Ionian Sea	2012-2013
MEH	Malacca Striats	2010-2012
MUNIN	Maritime Unmanned Navigation through Intelligence in Networks (Germany-Norway)	2013-2016
NORSAT 2	ESA VDE-SAT Downlink Verification. Norway	2017
NORWEGIAN	E-NAVIGATION TRIAL Norway	2015-2016
POLAR ICE	Arctic & Antarctic	2014-2016
SSAP	SMART SHIP APPLICATION Japan	2014-2017
TIANJIN	PORT E-NAVIGATION China	2015-2017
WINMOS	Baltic	2015-2017

Table 36. Instances Regionally e-Navigation Projects around the world

In the framework of the EU, the different projects on e-Navigation were supported with different budgets. The data collected, if the budget of each one is observed and compared over the years, the extent of the STM is clearly appreciated.

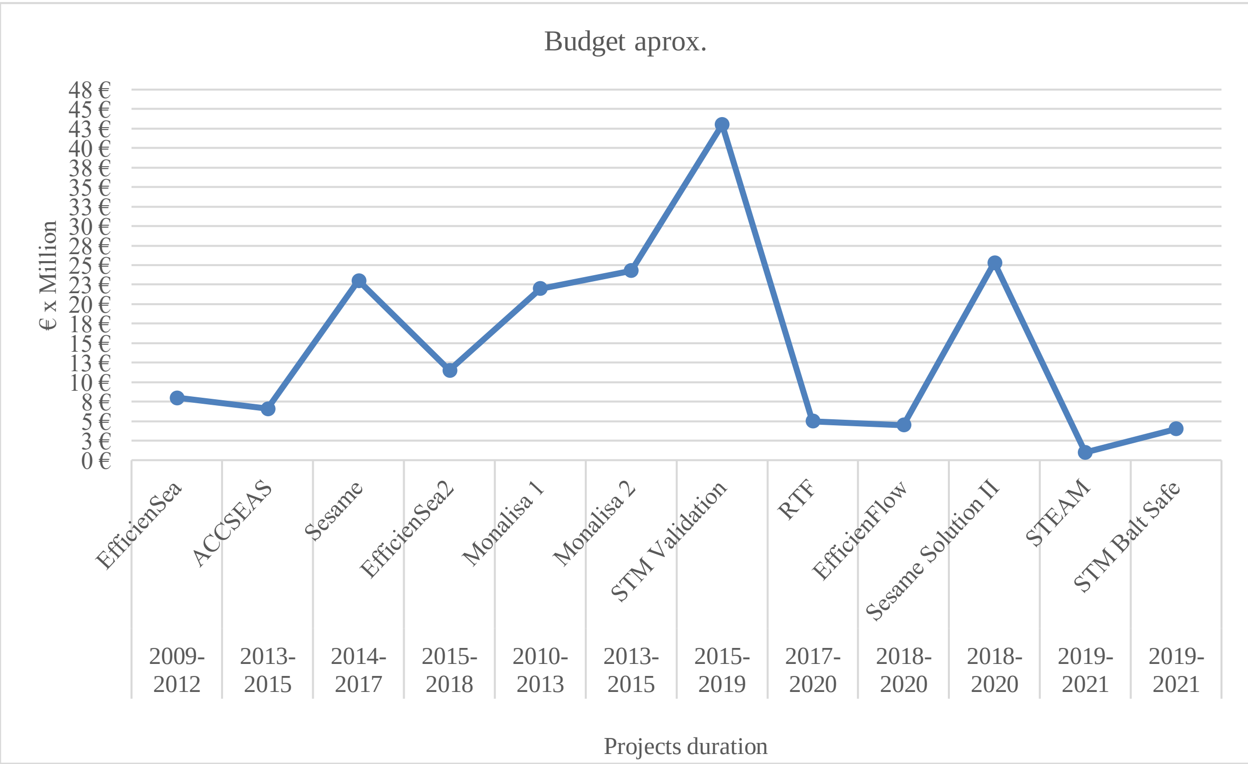


Figure 52. Approximate budgets invested in e-Navigation projects

The Sea Traffic Management project was the embryo of long-range information exchange for the sake of efficiency, economic savings, safety of maritime traffic and environmental protection, a vivid example of what the trend will be. This innovative project, together with the others and the new ones to come, need the constant support of the EU with co-financing and the recognition of the IMO to face the technological challenges that lie ahead, to avoiding becoming isolated projects of limited duration.

The projects shown in figure 52, under smaller budgets, although local, can mean an entire country or a continent, aspire to encompass the entire world, so non-global harmonization was still recognized internationally in 2021. However, a global digital sea route test bed, such as the 2023 cluster, was the highlight of the international congress, projecting a union between e-Navigation projects, this would therefore be the best result of its implementation.

Figure 53. Global Digital Sea Route Tested as Cluster from 2023

A scenario where the connection between continents is contemplated in a shared "cloud", the MCP, through cross-border platforms.

6.4. The satellites.

The name of "Sputnik 1" is familiar to almost everyone. It was the first artificial satellite launched[181] on October 4, 1957, to orbit the Earth. Currently, satellites have been in space for 65 years. The purpose of launching satellites into space is for different purposes on earth. It covers a wide spectrum among which are the 3 totems linked to the VTS, safety, efficiency and the environment. Satellite-linked technology provides position on the ground, aids communications, SAR missions, control and monitoring of marine pollution., as well as being involved in fishing, legislative, customs, and environment CO2 control issues. More than a thousand satellites orbit the globe with a wide range of purposes[182].

The EU was inclined towards having its own independent service covering all its territories. To give legal status to international agreements at a Community level, the Treaty of Lisbon (2007/C306/01) was signed in December 2007. Two space programs were developed: GALILEO, focused on Search and Rescue

[181] Available at: https://history.nasa.gov/sputnik.html

[182] Retrieved from: https://www.livescience.com/how-many-satellites-orbit-earth

(SAR), and COPERNICUS[183] (EU 2017), divided into six services, one of which would be directly related to maritime safety, including the tracking of objects at sea, the tracking of incidents and accidents and the location and identification of vessels. The GNSS, Global Navigation Satellite System, is the generic term for a satellite system that provides specific positions worldwide, time and speed, with multimodal purposes.

The IMO recognized it as a component of the World Wide Radio Navigation System (WWRNS), with the Resolution A.1046(27) of 2011, so that the recipients meet the requirements to provide position. These receivers, combined with other equipment, provide essential information for ships in navigation, Position, Navigation and Timing (PNT), which is why they are deployed as satellite systems that cover the entire planet. GPS and GLONASS can be found, among others, used in the maritime sector to navigate but also to identify onshore who is sailing. There is also Bei-Dou (China), Galileo (EU), QZSS (Japan) and NAVIC (India).

At the European level there is the family of satellites that work for purposes of surveillance, control, analysis, research or services covering aspects such as communications, control of migratory flows, control of illegal traffic, fishing, meteorology, food, pollution, fires, rescue and military manoeuvres, a combination of observation of the Earth, the sea and the air. The COPERNICUS program together with the European Space Agency (ESA) has maritime safety as one of its designated roles (EMSA 2019a).

In 2010, with the improvement of the graphical presentation of data, a new interface arose, the SafeSeaNet Ecosystem Graphical User Interface (GUI) of the EMSA, for the exchange of maritime information within the Union. This could be defined as a technical framework covering the different maritime applications; Integrated maritime data environment (IMDatE), Earth observation data centre (EO-DC) and LRIT cooperative data centre (LRIT CDC). The platform, used in order to control the tracking of ships, improve situational awareness in the maritime domain and provide customized solutions to the authorities,[184] has been referenced. According to the satellites used, the EO-DC has given rise to different platforms. Where the optical satellites combined with the AIS, LRIT, have created SafeSeaNet, a system that requires obtaining active data from ships. Those systems based on simple passive observation, have focused on serving diverse policies such as: protecting the marine and terrestrial environment and biodiversity, combating climate change and responding to disasters.

There is a visual-virtual control of the position of the ships through the information transmitted by the equipment, the AIS, the LRIT and the Global Navigation Satellite System (GNSS) using GPS or GLONASS already exposed; and a visual-real control provided by both terrestrial and satellite Radars and optical satellites.

[183] Previously known as GMES (Global Monitoring for Environment and Security), is the European Program for the establishment of a European capacity for Earth Observation and Monitoring.

[184] The VTMIS Directive (2002/59/EC) was amended by Commission Directive 2014/100/EU.

Monitoring and characterization of oil spills, by means of satellites, in the fight against marine pollution, through EMSA, within the program CleanSeaNet. Images that are captured and sent through the EMSA to the corresponding MRCC, when an oil spill is detected in their area.

Orbital EOS, Earth Observation Solutions[185], based in Valencia, was chosen as the best startup by the European Space Agency in 2020. It uses satellites orbiting the planet every 90 mins to detect spills in the maritime environment. It analyses images from ESA and NASA optical and radar satellites, through their own AI algorithm, safely detecting oil spills in the sea and being able to measure the thickness and therefore the amount of oil spilled. Once detected, drift patterns are monitored and forecast. Detecting marine pollution around the world is a key factor in contributing to cleaner and safer oceans. The objective is to equip the satellites with AI, so that the information is downloaded through this algorithm, which would further facilitate the subsequent analysis[186]. This also opens the field towards other remote sensing applications, such as location and tracking of vessels.

All these instruments, which provide the offices of institutions and organizations with eyes on what is happening at sea, have created further opportunities. One of them is to use this information to manage maritime traffic in a more efficient way. From here, projects that aspire to take advantage of this aerial maritime information on a global scale speculate that the exchange of information between ship-to-shore can be a very valuable factor for the maritime industry, aim to optimize it and to include two other major components, the protection of the marine environment and the increase of safety. But there is a third factor in that control, which is communications that move towards satellite and digital technology. The Internet is already navigating all over the world but, at sea, it requires an extra boost for the maritime sector to incorporate it.

It is estimated that within 5 years, 80% of the world's companies will use some type of data or technology related to space, whether using telecommunications, earth observation or different types of materials.

6.4.1.VDES.

VDES is an example of the "old" technologies that, perhaps, have not been able to reach the maximum development of their potential benefits, being supported by the new technologies, which contribute to their subsistence. In this case, the VDES contributes to the radio and the AIS. The VDES comes, on the one hand, from the AIS, and, once implemented and coined by the IMO, the IALA also included it in its committee, the IALA AIS Committee, and deployed specific guidelines for the maritime sector from the beginning, G1019 (2001), G1028 and G1029 (2004), G1059 (2008). But, later, it was included in a new Committee, the ENAV, whilst also included in the VTS and ARM, since they all work on the AIS issue. AIS has also been listed by IALA as AtoN. So finally, they are together, the AIS, the VTS, the AtoN but also the VDES, to which IALA has also dedicated technical documentation such as the R1007 "The VHF

[185] Available at: https://www.orbitaleos.com/

[186] Pablo Benjumeda. Plaza 4.0. "Orbital EOS, elegida como mejor startup por la Agencia Espacial Europea" PlazaTV. min. 15:40. July 22, 2021. Retreived from: https://plazatv.valenciaplaza.com/plazatv-orbital-eos-satelites-agencia-espacial-europea.

data Exchange System (VDES)” (IALA 2017j) or guidelines such as G1117 “VHF data Exchange System (VDES) Overview (2017) or “The Technical Specification of VDES” of 2019 (IALA 2019a).

The VDES is presented as a system that provides a new technological concept applied to the maritime sector and that will be able to face future challenges in terms of communications. However, it is not a question of any specific innovation, but of the combination of two already existing ones: the AIS and VHF channels, maximised by the performance of cutting-edge digital technology, therefore it can be affirmed that the VDEs are the fusion of the past and the future and could end up being part of a SOLAS chapter (Uyà 2021:19).

The fusion of these two maritime VHF data exchange systems is supported by a transceiver and software, configured to evolve over time, upgradeable and therefore future proof. If the inclusion of satellites is added to this, a global communications system is obtained, with greater transmission and reception capacity, safer and more reliable.

When the IMO began to recommend the use of AIS to ships in 1998, through Resolution MSC.74(69), its great potential was already glimpsed, as a tool for VTS and a navigation aid, for being a unidirectional monitoring system, which transmits information visible to all nearby vessels via VHF broadband. Today, it is part of Chapter V of SOLAS which, in its Regulation 19, governs mandatory use for ships whose convention is applicable to them. Its original purpose was to facilitate the position of ships, but it is also an effective means of transferring other data, such as identity, course, speed, load, destination, among others, which contribute to the work of the VTS themselves, SAR missions, tracking, pilotage and research, among other objectives, as stated above. After 14 years (from 1986 to 2000) of discussions, promotions, drafting and decisions, the unique and incomparable AIS was achieved (Heijden 2020:35). Yet, after more than a decade, it has been noted that the risk of AIS degradation seems to be increasing

In 2013, a study by the International Telecommunications Union (ITU) revealed that the extensive use of AIS, the increase in stations and the massive exchange of information have overloaded the VHF Data Link (VDL) in some areas and, depending on the situations of maritime traffic, have exceeded the critical threshold of 50% system load. Currently, more and more vessels are installing it on board, although it is not mandatory by law, and it is being incorporated into more devices such as MAtoN[187], MOB, SART or EPIRB, the last three of which are part of the GMDSS, so that, in the future, it could, together with the VDES, belong to the global maritime distress and safety system. The trend is, therefore, that the risk of AIS degradation increases.

The AIS manages its information in an access mode that follows the protocol called TDMA, as has been pointed out in Part II, which allows the continuous flow of data between stations; the system assigns time intervals, "time slots", for each broadcast. If there are temporary coincidences, the “slot” is automatically redistributed, so that they do not interfere. A collision of emissions in space could result in loss of

[187] MAtoN is defined as a non-fixed or un-moored AtoN described in the IALA G1154.

information and have a negative impact on the safety of navigation, leading to a collision at sea. This protocol TDMA is the abbreviation of SOTDMA[188], that coins the suffix Self-Organised because the use of time slots is organized by the user itself, not by a central network with base stations (Heijden 2020:27). The AIS also has a negative connotation, because it is an open system, not encrypted or codified, and so it is more vulnerable to attacks of piracy: identity theft, spoofing; signal hijacking, among other examples. All this has led to rethinking the AIS as a means to share information. The development of a transceiver that allows information exchange (Data Exchange, DE) with high capacity and reliability in the metric wave spectrum, gives rise to VDE. It forms the binomial VHF-Data Exchange, acquiring the acronym VDE. This is achieved by quadrupling the bandwidth, which goes from 25kHz for AIS, to 50kHz and 100kHz, notably increasing its capacity and possibilities. In addition, it makes it compatible with the ASM (Application Specific Messages) subsystem, presenting itself as the solution to ensure that the existing Data Link (DL) is not overloaded.

The ASM integrates specific binary messages for which the ITU reserves two channels, and which also contribute to overloading the AIS, channel ASM1 2027, 161.950MHz and ASM2 2028, 162.000 MHz. They have been standardized for more than a decade by the IMO (SN.1/Circ.289) and currently the IALA, as its delegate, continues to collect proposals from companies and organizations to develop new ASMs that adapt to the needs of the sector, IALA Recommendation e-Nav-144 (IALA 2011b). The perspective of MASS is not so far away, and ASM messages are also a solution with a view to covering the operation of MASS.

The conjunction of the three systems: VDE, AIS and ASM, is defined by the acronym VDES (VHF Data Exchange System). Due to the applicability of satellites for AIS, VDE includes an agreed ground element (VDE-TER) and a satellite under development (VDE-SAT), with global communication capabilities, including the polar regions. In order to cover the needs of the system, as early as 2015, the ITU reserved for VHF marine band, six duplex channels to transfer digital data, two channels for each use of AIS and ASM, and approved a standard for VDES (Recommendation ITU-R M.2092-0). At the 2019 World Radio-communication Conference (WRC-19), the channels for satellites were agreed (S1 and S2).

	AIS		ASM		VDE						
Terrestre	AIS1	#2087	ASM1	#2027	VDE1-A	#1024	#1084	#1025	#1085		
	AIS2	#2088	ASM2	#2028	VDE2-B	#2024	#2084	#2025	#2085		
SATELLITE	AIS1	#2087	SAT up1	#2027	SAT up3	#1024	#1084	#1025	#1085	#1026	#1086
	AIS2	#2088	SAT up2	#2028	SAT dL*	#2024	#2084	#2025	#2086	#2026	
	S1	#75									
	S2	#76									

*dL: DownLink

Table 37. Channels AIS, ASM and VDE

188 The invention is attributed to Mr. Hakan Lans from Sweden circa 1992.

It can be summarized that there are notable advantages for the installation of the VDE, not only because of the greater data transfer and its potential uses, or because of the estimated range of up to 50 miles, but also because it seems inexpensive and easy to install and implement, in ships, as well as on land. VDESs may use the AIS system wiring and antennas. They need hardware to receive and transmit on assigned channels simultaneously, and add a PKI (Public Key Infrastructure) unit for station authentication and encryption capabilities. This will allow isolation of communications between stations and signal tracking, among other improvements. In order to face this new challenge, the IALA G1117 guideline shows an estimate based on four operational phases for the introduction of VDES[189], which is projected until the year 2023.

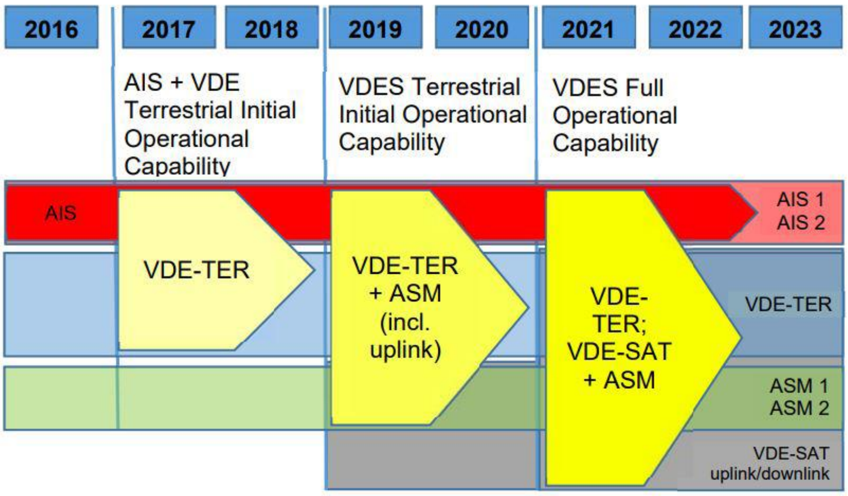


Figure 54. Implementation of VDES

The range from 2021 to 2023, the current one, is when a satellite service is developed, the full operational capacity of VDES, including satellite frequencies, can be achieved.

The VDES also has potential use cross-referenced to the MSP defined by IMO e-navigation SIP (NCSR1/28/Annex 7, p.11) and listed with the 16 different MSP, types in this chapter. This means that route-exchange included in the STM Project would be supported by the VDES (IALA 2017:21) as well as during the whole transit of the ship, and port-to-port navigation that involves a flow of diverse information, depending on the location of the ship. When outside the reach of other Communications, the VDES would be the communications exchange platform.

VDES is part of e-Navigation, with its incorporation of digital and satellite technology to improve communications. And therefore, it has also been included in various projects and test beds that have later been examined, in technical sessions organized by IALA and others, and included in international conferences on e-Navigation.

[189] IALA (2017d) 'G1117 VHF DATA EXCHANGE SYSTEM (VDES) OVERVIEW', IALA Guideline, 2.0. p.6.

The current world situation has disrupted any calendar or forecast, but even so, during the years from 2019 to 2021, different countries have continued working to make the VDES a reality in the near future. Despite COVID-19, conferences, webinars, and workshops have been able to take place online, thanks to the degree of development of technologies -specifically digital-, so, despite everything, progress has continued. Some notable examples are listed below.

The 26th session of the IALA ENAV (ENAV26) Committee held between September and October 2020, addressed the issue of VDES. Several technical presentations examined the advances and test beds.

Sternula "Connecting the Oceans", is a Danish protocol based on VDE-SAT, Low Earth Orbit (LEO) microsatellites, which travel approximately 27,400 km / 650 to 800 km above the earth's surface. As an example, it shows how information from the specific standard S-124, corresponding to hydrographic data, that is, Navigational Warnings, would be distributed and displayed on an ECDIS, although any other standard that is developed may apply[190]. The project showed that it would cover the areas from A1 to A4, integrated in the MCP/MMS concept Prospecting the future, (depending on the support and implications of entities and governments), in which, by 2028, there would be more than 40 orbiting satellites with global coverage in real time.

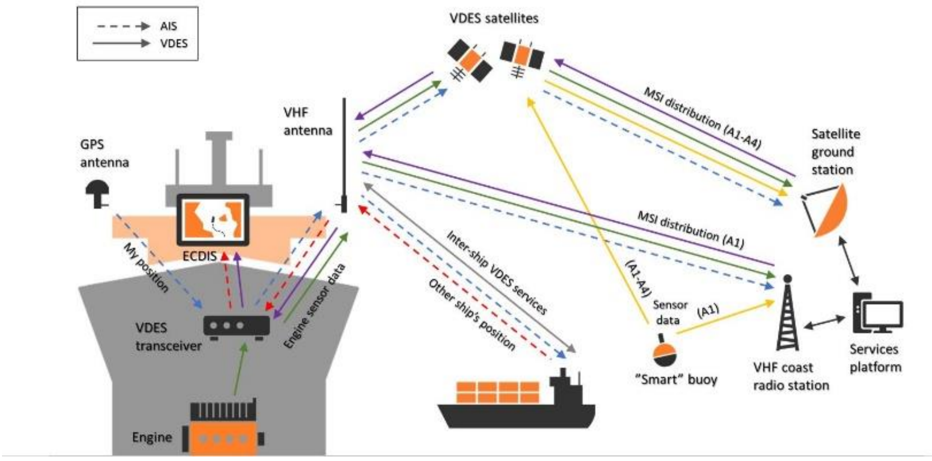


Figure 55. VDES Exchange of data for any digital service

The proposal will deploy its satellites and satellite ground stations with communication links compatible with the e-Navigation concept.

Other tests with VDES were carried out in China, from The Navigation Guarantee Centre of the North China Sea, including three base stations constructed in the project, one VDES base station temporarily built in Tianjin port, one VDES management centre and VDES shipboard equipment. Data transmission time between base stations and shipboard terminals was tested at different distances from shoreline.

190 Presentation during the IALA ENAV26 Virtual Committee. "Global VDES coverage" by Stefan Pielmeier. September 29, 2020.

The Ocean Policy Research Institute, the Sasakawa Peace Foundation[191] in Japan, published "Proposals on the Use of Satellite VDES" with a mutually coordinated navigation perspective, using Satellite VDES with a wide spectrum of uses and applications that could be applied.

A Spanish project, POLARYS 2018, in which Gradiant, Cellnex Telecom and the Telecommunications Technology Center have participated, reported the results in an extensive study published under the title "The digitalisation of maritime communications"[192]. A series of tests were carried out with satellite AIS, concluding that the reception, at that time, was functional and operational.

ESA (European Space Agency) also contributes, with the Norwegian NORSAT-2 satellite, which is currently used to test the downlink segment of the VDES data exchange system, and with the Copernicus program "Prepare Ships".

EMSA also addresses the challenges for implementing e-Navigation with new technologies and sees huge potential for VDES (VDES-SAT), in particular, in providing the means to enable a ship to transmit and receive data packets to and from the National Single Windows (NSW) that were set up to implement Directive 2010/65 /EU.

If VDES come from old technologies, it is consistent to say that advances in science can often be attributed to earlier innovations. Now it is to be hoped that, when this fusion of the past and the future begins to settle, the regulations will arrive, mandatory in, use to continue advancing the maritime journey of the global world. VDES will become an urgent need in the foreseeable future, the VDES will be installed aboard and also in VTS Centers.

[191] By Dr.Junji.Fukuto.

[192] Gradiant (2019) 'The digitalisation of maritime communications. Study of the evolution of maritime communications: from voice to e-Navigation', pp. 1–98. Available at: https://www.cellnextelecom.com/content/uploads/2020/01/The_digitalisation_of_maritime_communications_1stEd_EN.pdf.

Chapter 7. Global maritime surveillance.

Currently, it is possible to observe the global ship traffic shown by the AIS signal and obtain an image of the maritime density from home. This information is obtained through the internet, in real or near real time, and free, by consulting the pages of MarineTraffic, as an example, which was launched in 2007. Since then, other projects have been opened with different names but offering the same possibility, to see the "AIS" at sea, with greater possibilities available through registration and prepayment.

This has been possible thanks, firstly, to AIS-T, then AIS-S, the Internet and generalized computerization. Internet AIS provides more of a worldwide tracking picture, when compared with long-range AIS, since the information comes from AIS stations spread all over the world. Therefore, going further, Member States, through the SSN of the EMSA, can obtain various data from both AIS and LRIT, Long-Range, in near real time and also historical data. This is also because all merchant ships are now equipped with global tracking systems. Therefore, ships can be located while sailing around the earth, and this trend is increasing, not only because it is mandatory under SOLAS, but also because of the increasing use of AIS equipment on board different ships, and not only merchant ships, thus providing increased security of navigation levels. This information is the greatest tool of the VTS. Operators can monitor vessel movements in local coastal areas and also have the technological capability to track vessels internationally by having access to the LRIT platform and therefore, monitoring can be done beyond coastal waters.

The implementation of a VTS is mandatory only within the territorial sea of the coastal states, as regulated by the SOLAS Chapter V, Regulation 12; thereby, it already excludes international waters. The Convention of the UNCLOS'82 is the cornerstone that defines the jurisdiction of the coastal states, endowing them with the power to adopt laws for the safety of navigation and regulation of traffic[193]. Currently, the maximum range of a maritime traffic control system, as stated in Chapter 5, in any case, can only be exercised while the vessels are in inland waters and not beyond the TS, Territorial Sea, that is, 12 miles. For controls within the EEZ, Exclusive Economic Zone, up to 200 miles, and international waters, the approval of the IMO is necessary for VTS, and in many cases, exist within the TSS, areas of passage with mandatory reporting. As has also been shown, the new resolution[194] already contemplates a VTS beyond TS, "A VTS may be established beyond the territorial seas of a coastal State on the basis of voluntary participation."[195]

IALA also extended its guidance as early as 2009 and recently updated, "The establishment of a Vessel Traffic Service beyond territorial seas" (IALA 2009a) where the need to extend or establish a VTS beyond territorial seas has been identified. As an example, it shows areas where the SRS takes place in international straits or simply beyond the territorial sea. These are still examples of offshore areas monitored by a VTS.

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[193] United Nations Convention on the Law of the Sea. Part II. The Territorial Sea and the Contiguous Zone. Section 1. General Provisions. Section 2. Territorial Sea Limits. Article 3. Width of the territorial sea and Section 3. Innocent Passage Through the Territorial Sea. Article 21. Laws and regulations of the coastal State regarding innocent passage.

[194] Resolution A.1158(32) Guidelines for Vessel Traffic Services.

[195] IALA (2021a) 'Draft Assembly Resolution on Guidelines for Vessel Traffic Services', Annex, p.9.

The trend is to have more and more control over the fleet of ships. The figures point to the sea as the main route of world trade, whose percentage is around 80% of the volume of international trade in goods currently, according to UNCTAD. In addition, although it remains relatively static, for the fifth year in a row, world fleet growth has started to decelerate (UNCTAD 2017:38). Whereas, control over the fleet has increased.

The world fleet from 2005 to 2019 (Equasis 2005-19), considering the total number of ships, by type and size, from less than 500 GT until up to more than 60,000 GT, can be shown as a graph, derived from data contained in the statistics from Equasis database[196]. The Figure 56 does not show that the world fleet is growing, but it does show that the registration and control of ships are increasing. Equasis provides data from most of the world's merchant ships (EMSA 2019b).

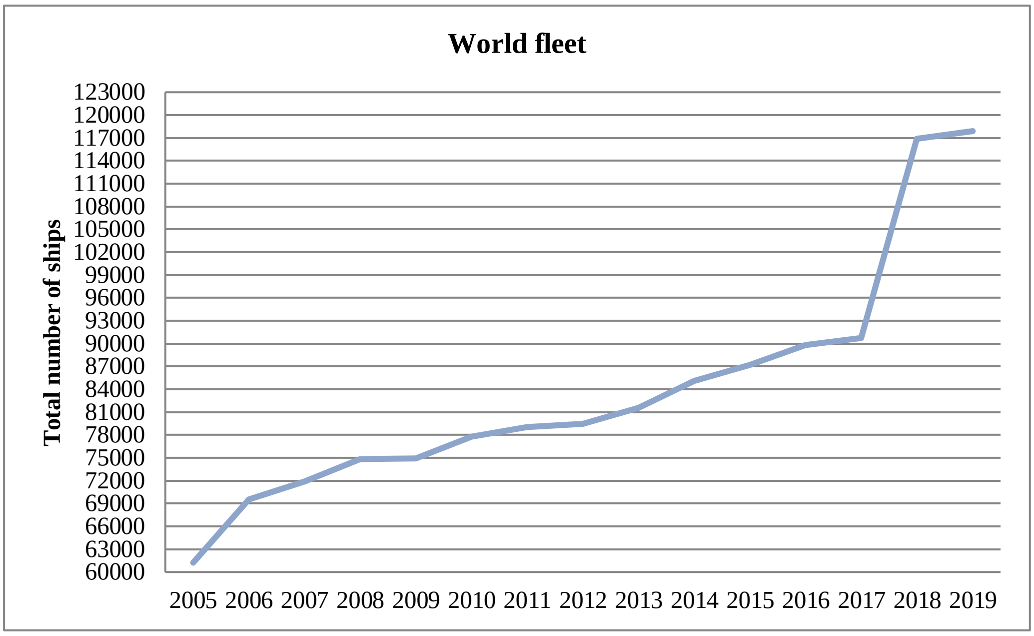

Figure 56. World fleet. Source EMSA annual report published from 2005 to 2019

Thus, different methods of global control or surveillance over the planet, and specifically, over the sea and what happens in it, can be observed.

7.1. The Oceanic VTS.

From the first IMO resolution for maritime traffic services to the last one, the VTS was considered under zone and area. This is how the port VTS began, then the Coastal VTS and now the service that can reach beyond the territorial sea. The purpose of the VTS is defined in reference documentation, in G1089, and its role is referred to in the new Resolution for the VTS, as "to contribute to safety of life at sea, improve

[196] This report provides a picture of the world's merchant fleet derived from data contained in the Equasis database. Ship types are general cargo, specialized cargo, Ro-Ro, bulk carriers, oil and chemical tankers, gas and tankers, passenger ships, offshore vessels, service ships and tugs.

the safety and efficiency of navigation and support the protection of the environment within a VTS area by mitigating the development of unsafe situations."[197] However, the situation of the seas demands control to ensure the welfare of the entire planet, so the VTS area, as a contributory part of that control, extends to the oceans and ,as already stated, there is only one ocean.[198]

The VTS area now is defined as "the delineated, formally declared area for which the vessel traffic service provider is legally empowered to deliver a vessel traffic service". If the area is no longer limited, because a VTS can monitor a ship along its whole route, from port to port, logistically, the area would be the entire ocean. If now the VTS no longer distinguishes between port and coastal, it is a new dimension of operation that requires a new name.

IALA also considers that the VTS plays an important role in risk management, not only on behalf of maritime traffic safety and fluency, but also on behalf of the continuity of the maritime transport chain. Therefore, with a broad perspective, the VTS could interact with other services outside the VTS area (IALA 2013b). This is another area to consider, where a VTS can act beyond a previously delimited area.

As far back as 2012, a global network of networks for exchange maritime information was contemplated (G1086), in which the VTS was included (IALA 2012).

The future scenario of e-Navigation goes beyond 12 miles and the areas monitored by a VTS. The e-Navigation raises VTS communications as a key factor and also contemplates long range without determining distance, but it identifies six areas to provide a maritime service: port areas and approaches; coastal waters and confined or restricted areas; open sea and open areas; areas with offshore and/or infrastructure developments; Polar areas and other remote areas. Communications equipment also includes long range, such as HF and satellite systems, (IALA 2013). Therefore, a long-range VTS is expected. However, in the e-Navigation Strategy Implementation Plan of the IMO (2018), MSC.1/Circ.1595, page 12 stated that a key factor in the e-navigation concept is to identify the possible communications methods that might be used , including test beds which required regulatory framework and technical requirements for implementation. The status of test beds is under consideration, due to what is considered an embryonic phase, as indicated by the status of the table of the same circular 1595 (IMO 2018d), but it already represents progress.

The Global VTS (GVTS) takes the form of a counterpart at sea, such as the Global Maritime Distress and Safety System (GMDSS). The future VTS services will manage information and communications at any point on the maritime surface and will, therefore acquire a greater geographical dimension, which goes beyond the coastal VTS. For this reason, the creation of the role of the "Oceanic VTS", as a new formula to approach the planetary paradigm, is proposed for the first time (Martínez de Osés and Uyà 2021). The name "Oceanic VTS", comes with the idea of establishing agreement of the exact meaning of the definition

[197] IALA (2022b) 'G1089 PROVISION OF A VTS', Guideline 1089, 2.0(January), p.6.

[198] One Ocean Summit, held in Brest, Brittany on 9-11 February 2022. Retrieved from: https://www.oceandecade.org/events/76308-one-ocean-summit/

of the word itself, registered by the IMO defining navigation as “the process of planning, recording and controlling the movement of a craft from one place to another” in the Resolution A.915(22), and as a tribute to one of the three navigation phases (IALA 2018c), navigation in restricted waters, coastal navigation and oceanic navigation[199].

The current VTS centres would continue to perform the same functions, with more modern equipment, sharing information with the same actors in the maritime industry, but in a more digitized and standardized way. Maintaining these strategic positions in port areas or points on the coast will be highly qualified and qualified personnel, with full accreditation under the auspices of the IALA. The IMO, which is the main authoritative body and recognizes the only officially defined VTS acronym, will simply have to address the global system and the Oceanic VTS. Nowadays VTS plays an essential role for safety in the geographical areas it manages, but this will be even more so, as it reaches the Oceanic dimension that is proposed, sharing information among other VTS centres.

To sequence and summarize all the evolution of the VTS and the new proposal included, the table 38 has been configured.

[199] Navguide 2018. 8th Edition. Chapter 2 – Concepts and accuracy of navigation. 2.3 Phases of navigation. Pag.13.

	PAST: 1948-1996	PRESENT: 1997-2021	PLANNED FUTURE: 2022-2030
	Terrestrial	Terrestrial-Satellite	Satellite
References	**1968** Resolution A.158 (ES.IV) Recommendation on port Advisory Services (PAS)		
	1985 Resolution A.578 (14) Guidelines for VTS		
	1993	1st IALA VTS Manual	
		1997 Resolution A.857 (20) Guidelines for VTS - SOLAS Ch. V Regulation 12.	
		2000 Revision of SOLAS Ch. V Rg.19 (AIS for ships)	
		2004 Resolution MSC.211(81) (LRIT)	
		2007 COPERNICUS	
		2008 MSC.85/26/Add,1 Annex 20	
		2014 MSC 94/18/8 Development and implementation of e-Nav.	
		2018 IALA Navguide 2018	
		2021 Resolution A.1158(32) Guidelines for VTS	
Means	**VHF**	**VHF / HF**	**VDES**
	RADAR	**RADAR**	**RADAR SAT**
		CCTV (Close circuit TV)/FLIR (Forward-looking infrared)	**CCTV/FLIR**
		Computers	**Computers**
		PHONE	**PHONE/Smartphone/Satellite**
		AIS	**AIS SAT**
		ECDIS	**ECDIS**
		LRIT	**LRIT**
		NAVTEX	**STM**
	Port	Territorial sea (TS)	Beyond TS
	PORT VTS	COASTAL VTS	**OCEANIC VTS**

Table 38. Synthetic table within the VTS

From the VTS in Inland Waters, Ports/Harbour, Coastal and area, there is a greater dimension, the ocean. Among the seas, there are the international waters, where the UNCLOS'82 convention must address the responsibilities of monitoring ships without maritime borders.

This would not be detrimental to free movement on the seas. However, a revision of the laws that govern the sea will be necessary, so that this desirable progress is not blocked. At this time, the idea of revising an international treaty that is approaching 40 years of age, even if it is from the United Nations, seems more than convenient. Moreover, it will be essential for this ocean-scale exchange and traffic management system to be carried out with guarantees and confidence for all the coastal states. What is proposed is that, for a VTS to be able to interact with a ship, regardless of its position, or what would be from port to port, it must be protected by law, starting with the UN, continuing with the MOU, Memorandum of Paris and Tokyo on Port State Control (PSC), which should combine all the regions so that port control could be coordinated and standardized, and ending with an update of local laws, if the laws are understood as a descending pyramid.

It is not about the sea becoming an area outside the walls of legalities, but rather establishing itself as a harmonized space in its management, due to the international nature of maritime transport. The movement of ships through the seas in the most fluid way possible, following their course without noticing borders, obeying safety, efficiency and environmental parameters, will also represent protecting the seas not only in areas near the coast, but also across the entire planet.

7.2. Future Challenges for VTS.

e-Navigation has motivated the development of digital and satellite technologies. Changes and new challenges that will affect the VTS can now be glimpsed. As was stated at the beginning of e-Navigation, in 2005 (MSC.81/23/10), if this technology is not coordinated, there will be a risk of the future of the global maritime industry being hampered by lack of standardisation, on board and on land, and a risk of incompatibilities between ships and of those difficulties increasing.

From the IALA, through the VTS Committee, issues that will involve the VTS are addressed. One of the working groups (VTS50) has focused on “Future VTS”. IALA recognizes that the implementation of VTS is increasing each year and there will be new trends to address. The volumes of maritime traffic generate a more proactive management and also within this, the VTS. Developments related to e-Navigation, such as STM, Maritime Services, JIT, Artificial Intelligence (AI) or MASS, will intersect with the key role played by VTS with respect to safety, efficiency and environmental protection. But other innovations, such as new sensing technology for nearshore and port waters, have already been covered in the “Future VTS” discussion paper (IALA VTS50a 2021). Monitoring systems in coastal waters and ports, are based on high-range CCTV and UAV (Unmanned Aerial Vehicle) technology that allows 360º monitoring within 8nm range, but there are expectations of higher ranges and longer distances, with remote transmission technology, which can facilitate the effective monitoring of ships’ dynamic movement. One more example of the attempt to reach more controllable space towards the sea.

Other technologies that interact in the maritime scenario that have been indicated are drones, enhanced vision, identification of ships without AIS and the Internet-based AIS, with the challenge of compatibility with the current VTS system. The collection of static and dynamic information from ships without AIS equipment, via a mobile communication station or a satellite communication station, is still under development.

Connecting digital ships and the digital shore systems will involve interacting objects. This needs an ecosystem where objects are able to interact with each other, not only passing messages but "intentions", objects that specify behaviours that the receiver is expected to perform.

The functions of the VTS will be increased, becoming an information centre (information hub) that will have to be verified at all times, in a flexible and rapid manner. To do this, undeniably, communications must also be flexible and rapid.

To reflect all these challenges, IALA has also been preparing a document, the "living document" on "Future VTS" (VTS50), to provide, with precision, high-level references regarding the latest trends in technology and emerging practices that will impact VTS. In addition, to detect problems or gaps that may arise, thereby to find answers that facilitate global harmonization.

A topic that deserves special attention in the Artificial Intelligence (AI) as a Decision Support Tool (DST). This will represent, in the first instance, the revision of the IALA G1110 and G1045 guidelines, focused on planning more strategically and increasing the safety and efficiency of ship traffic.

The AI is intrinsically linked to the MASS, since it will be part of one of the degrees. The arrival of the MASS is already in the spheres of the IMO and the IALA.

As on previous occasions, the IMO agreed to consider the proposal made by different Member States to address the issue of MASS. Different technologies were being developed very quickly and the MSC recognised that the IMO needed to direct how to include them in its instruments, so the MSC included it in its agenda for 2017, the 98th session[200]. That same year, the biennial IMO Assembly, the highest Governing Body of the Organisation, adopted the "Strategic Plan for the Organization for the six-year period 2018 to 2023" via Resolution A.1110(30). In this resolution, in table 2, appearing within the Strategic Directions (SD) number 2, to integrate new and advancing technologies in the regulatory framework, is the "Regulatory scoping exercise for the use of MASS", with a target completion year in 2019.

The Maritime Safety Committee (MSC), at its 100th session, December 2018, proposed that, to facilitate the process, four degrees of human interaction should be taken into account, via MSC.100/20Add.1 Annex 2 "Framework for Regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships (MASS)", Regulatory Scoping Exercise (hereinafter referred to as RSE). MASS is defined as "a ship which, to a varying degree, can operate independent of human interaction"[201]. The degrees were grouped in two,

[200] Available at: https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MSC-98th-session.aspx

[201] IMO (2018b) 'Framework for The Regulatory Scoping Exercise for the Use Of Maritime Autonomous Surface Ships (MASS)', MSC 100/20/Add.1, Annex 2, p.1.

with crew members on board and without crew members on board. Degrees 1 and 2, with crew members on board, differ in that at 1, there are automated functions on board and, therefore, they are not carried out directly by the crew, and at grade 2, it is a remotely controlled ship. Degrees 3 and 4 differ, in that, 3 is a fully remote-controlled vessel, and 4, is an "intelligent" system capable of making decisions and determining actions by itself.

These considerations open up a wide field of possibilities, where the main international agreements such as COLREG, SOLAS, SAR, FAL, Load Lines or STCW (full list in the Appendix 1), will be influenced, since they all cover aspects of maritime safety and security. To facilitate the analysis of the implication of the MASS, a table (Appendix 2) was included in the document to relate, according to each of the four degrees of MASS, to what extent it would effect on a scale of four, from A to D. If MASS was applied to them, they could indicate potential gaps. An Appendix 3 is also included, to provide a work plan for RSE, based on 2 phases. These are, a first step to review the IMO instruments and a second step to analyse the most appropriate way to address the new effects caused by the MASS. This second step is also under four possible actions, from I to IV.

To be able to coordinate all the contributions and comments on the new instrument regarding MASS from the voluntary participants, who are IMO Members (Member Governments, associated Member Governments, intergovernmental organisations with observer status and non-governmental organisations in consultative status), the IMO opened a platform (website) developed by the Secretariat as part of a new GISIS (Global Integrated Shipping Information System), with a timeline throughout 2019.

In June 2019, the MSC, at its 101st session in June, published “Interim Guidelines for MASS trials” via MSC.1/Circ.1604 with the aim of helping those who carry out trials with the MASS and, under the three constant criteria that the IMO displays in its instruments, always to do so safely, securely and with due regard for protection of the environment. In addition, any risk associated with the trials should be measured and reduced as low as reasonably practicable (ALARP). Here, again, the need to carry out risk assessments in VTS areas appears. This remains as a future research paper. Subsequently, in July, the report of MSC.101/24, in its 101st period of sessions, included in section 5, documents to be taken into account were presented by different countries, based on the framework for RSE (MSC 100/20/Add.1). Among them were comments and proposals from China, Finland and Republic of Korea. Once the drafts were collected, a meeting of the MASS Working Group was convened, to be held in September 2019 and work sessions were provisionally scheduled for 2020.

Due to the pandemic in the middle of the year, the MSC disseminated the results of the RSE for the use of the MASS in 2021, via MSC.1/Circ.1638. The result is an extensive document of more than 100 pages, where, for example, Spain contributed to the analysis of the effects of the MASS in the SAR’79, STCW and COLREG Conventions. There is no direct reference to the VTS, but to the SOLAS V instruments whose participating members were from China, Denmark, Japan and Singapore (IMO 2021b:15).

IALA incorporated MASS into its working sessions. In the VTS50 Committee, held in March 2021, the working document had the title "Gxxxx. Guideline on the implications of MASS from a VTS perspective" (pending numbering), and, here, how the MASS will affect the VTS is directly addressed (IALA VTS50 2021c). It is recognised that issues will need to be resolved on how ships and MASS will interact in a VTS area, the exchange of information between all those involved and how, according to the established role of the VTS, VTS will exercise its functions when this type of new vessel arrives. One of the main considerations is that the MASS must participate with the VTS in the same way as the rest of the vessels. And then, outcomes from the RSE must be taken into account, which IALA documentation will be subject to review, such as G1089, G1141 (under the S1040), G1110 or G1132, in terms of the IMO with its instruments, and if there will be conflict with the IALA documentation (IALA VTS50 2021b). There is a list of documents whose scope covers up to 5 Recommendations and 8 Guidelines, but more will be included (IALA 2021g).

For the first work session, a series of documents were presented with the aim of being studied and being commented on. In addition to the draft guidelines, a report from the Netherlands and a scoping exercise on the implications (SEI), in line with the IMO, on MASS, using the VTS Guideline G1141 as an example, carried out by China MSA were presented. The objective was to prepare a scope document on the implications associated with VTS, with the merging development of MASS, and therefore, implications globally, as it may affect all VTS. MASS will also be included in other IALA committees, such as ARM (impact on AtoN) and ENAV (Maritime Safety Information). Communications technology will enable wireless control and monitoring functions with ships, such as Route Exchange (STM), or MSI within the MCP, that although digital connectivity is led by each private industry that develops its MASS, must be harmonised with ground services. If communications are based on VHF, the exchange with the MASS awaits the development of VDES and other technologies such as 5G (IALA VTS49 2020) to ensure ship-shore data exchange capability. From 3G with 384Kbps in 2001 to 5G with 10Gbps in 2020[202]. The VTS will exchange data, rather than send safety messages, where this data exchange is related to the final outcome that the ship completes its entire manoeuvre safely. Terminology and common standards for communications will be established. The checking of the VTS will be involved in a complete digital situational awareness, supervising the interactions, and, if the MASS uses AI for its route prediction, the VTS must also be able to anticipate the decisions to be made. The analysis carried out by China MSA was a qualitative analysis, detecting any inapplicability of the guideline, on the issues identified above, that the guideline itself deals with.

– The communications that are replacing by the traditional one based on VHF, will need large data transmission (IALA VTS50 2021b). VTS equipment shall be adapted to MASS compatible technology including VTS network security and future large-scale data transmission (in line with e-Navigation such as the STM).

[202] Webinar Nautical Institute. "Maritime communications. Going Digital" by Jillian Carson-Jackson. June 1, 2020. Kbps: Kilobits per second. Gbps: Gigabits per second.

- The VTS is analysed as having to adapt to the challenges of the MASS (and not the other way around). But, any degree of MASS that interacts with the VTS should never impede the functions of a VTS.
- The cooperation between the crew and the VTS Operator will be broken, so the VTS faces another kind of interaction, such as VTS personnel with the remote-control personnel (MASS degree three).
- The SAR emergency services are based on rescuing the crew, so there will be another concept of "rescue" and, therefore, other procedures (MASS degree three and four).

In addition, other issues of great importance are being examined, such as cyber risk management, under reliable cyber security systems, for the operation of MASS. Behaviour in TSS and port areas will be one of the greatest challenges of MASS, since they are basically being trialled on short voyages, such as SSS.

The issue of responsibility is also a broad field but, although the 4 degrees involve the human factor in a different way, considering negligent behaviour in a traffic pattern, there will always be "someone" behind to assume responsibility, another formula of "nothing…change the Master's ultimate responsibility".[203]

The differentiation of 4 types of MASS ships generated, and will continue to generate, extensive debates, since it represents having a wide field of possibilities to take into account. A simplified way could have been to establish ships with or without crew, and therefore, degree 1 and 2 would remain in one category, regardless of the number of crew on board or the type of automated functions that the ship has, therefore, would not cease to be a "normal" ship. And in reference to the two degrees without crew on board, it could also have been considered as only one. If there are no crew, there is no direct ship-to-shore interaction. But the case between a remotely manned ship and an intelligent ship could be differentiated. However, it is understood that the variety of business models that are being tested cover a wide spectrum and, for this reason, the IMO has proposed the 4 degrees as a way of understanding that this new technology will gradually infiltrate the maritime sector. The expected timeframe is over 5-20 years.[204]

The task plan for the 2022-2026 work period will further discuss the impact of MASS on the operation and management of VTS and, if deemed helpful, include actions that VTS may need to take in response to MASS.

There are still issues to address, such as the training of each participant, including seafarers. This is an *evolution*, not a *revolution*, and it will be gradual. Seafarers are ready to be trained in new technologies and automation, and will continue to be a key factor in shipping, as concluded at the 2018 MSC special session[205]. It should be added that, likewise, the VTS remain key, either because of their marine nature or because of the intrinsic ability to learn and adapt to new procedures.

As in other work sessions, IALA gave the opportunity to initiatives from various sectors, industry, universities and organisations, to make technical presentations. It should be noted that models corresponding to IMO degree three are being developed, inspired in turn by air navigation, acquiring the

[203] Resolution A.1158(32).
[204] Template for identifying, assessing and monitoring emerging practices, technologies and trends. IALA VTS50. March 10,2021.
[205] Retrieved from: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Autonomous-shipping.aspx (Acceded March 14, 2021).

cockpit as an example of a console for Remote Control Centre (RCC). Autonomous technology is advancing in road and aviation travel, benchmarks that will serve the maritime sector.

While the IALA and IMO rush to cover new technologies and include them in the maritime sector, the Japanese will publish, in 2022, the MEGURI 2040 project, a project that has already tested the navigation of a MASS ship, degree 4, along a 130nm route.

The debate of the MASS rises to its link with the COLREG, how the interaction with traffic will be achieved, and in the TSS. The problem is that, if MASS vessels must navigate under COLREG and the regulation is interpretative as stated above, therefore, analytically, it can only be addressed under AI, predominantly in cases of MASS degree 4. Making any changes to COLREG is no easy task, as such an essential tool should ensure that it reaches all seafarers. Carrying out an in-depth study of how new technologies impact the regulation would be interesting, if not necessary (Salinas 2004a). When the regulation was made, the ships sailed at an average speed of 12 knots, now there are ships that travel at 60. As already stated, not only do VTS have a direct relationship with collision avoidance, but also other systems, such as AIS, ARPA, HSC, WIG and MASS.

Conclusions and recapitulation of PART III

The arrival of the third resolution for the VTS registers a gap of 25 years since the earlier resolution, now revoked. This fact shows the long processes in legislative updates and the difficulty to achieve it. Organisms involved, the IALA as a delegate of the IMO in its key role, invest great efforts to make this possible through several working sessions from the committees running over draft-layers. A wide sector is invited to be involved in the maritime sector to participate in the process of updating the resolution in order to give it the greatest possible plurality. These long processes involved in regulations, however, can mean that once they are updated, they are already outdated, due to new technological advances. They are currently the greatest influence of this century, and new applications, devices, equipment arrive before their regulation.

The value of the VTS system is unquestionable. It is supported by the IMO, the IALA, and Governments and Authorities that implement the service on their coasts and port areas, but the globalization and harmonization of the maritime sector leads the VTS towards a broader management.

Gateways between ships and shore agents are an essential service for the efficient, organised and safe management of ship traffic. From its origins, when radio equipment and radar screens were used to combine real-time traffic control, through a screen and the possibility of voice interaction, 73 years has passed. Now it is not attempted without an AIS device, based on VHF signals on an electronic chart. Nevertheless, the use of the digital data and satellites is steadily increasing its reach over the entire planet, creating a world stage. The maritime sector has identified the need for e-Navigation to achieve global coverage with these new technologies, whilst seeking to exchange information in a secure manner, to standardise procedures and coordinate relations between all those involved in port operations and ships. With this image of ship traffic in real time and on a large scale, the scenario is a global VTS system, with a view to a wider spectrum, beyond the 12 miles, without geographic limits, following scales of ships and ports of departure and arrival.

The acceptance of the global VTS system, endows the VTS with a new role without geographical limits, and the Oceanic VTS will have to address the same tasks using new technologies, interacting with a ship regardless of its position, or from port to port. This approach is what is required to create an Oceanic VTS, where all personnel would exchange information, without state borders, between ships and shore centres around the world. This also raises the question of how a new technological paradigm will fare against old barriers of legislative reach. So, it must be contemplated in the law, beginning with the United Nations, continuing with the Paris Memorandum, which must unit all the regions, so that port control can be coordinated and standardised, and ending with a update of local laws, if the laws are understood as a descending pyramid.

The final chronological scheme, where the updates of the resolution on guidelines for VTS are protagonists, includes the main international conventions and resolutions on maritime matters. the right part referenced and directly involves the VTS, and the left part, other conventions that also influence but tangentially.

International Conventions		Years	About VTS
The United Nations		1945	
IMCO		**1948**	**RADAR+VHF**
3rd SOLAS		1948	
		1950	VTS Centres
		1957	IALA Established
4th SOLAS		1960	COLREG
		1965	FAL
Load Lines (LL)		1966	
		1967	TSS Dover-voluntary
		1968	R. A.158 (ES.IV)
	37 years	1972	COLREG
MARPOL		1973	
SOLAS, as amended		1974	
		1976	Convention (IMSO C)
SMNV		1977	TSS Obligatory
STCW		1978	MARPOL 73/78
		1979	SAR
IMO		1982	UNCLOS
		1983	R.A. 531 (13) SRS
		1985	**R.A.578(14) Guidelines for VTS (1st)**
GMDSS		1988	
GMDSS began		1992	
		1993	IALA 1st Ed. Manual VTS
	12 years	1994	R.MSC.43(64) SRS
STCW (amended)		1995	R. MSC.46(65) RS
		1996	
		1997	**R. A.857(20) Guidelines for VTS (2nd)**
		1998	MSC 74(69) AIS
		2000	SSN
			Resolution MSC.99(73) (10,11 Y 12)
			MSC/Circ. 952 IALA VTS Personnel
			MSC.111(73) SRS
		2001	R.A.918(22) SMCP
D 2002/59/EC AIS on board		2002	EMSA SSN
			MSC/Cric.1065 IALA VTS Personnel
		2004	AIS 31.12.2004
		2005	MSC.81/23/10 e-Nav
		2006	MSC.202 (81) LRIT Global, space.
		2007	EMSA
	25 years	2008	MSC 85/26/Add.1 SIP for e-Nav
		2009	SSN fully
		2010	Monalisa 1.0
			GIS Graphic Interface
STCW / D 2010/65/EU SSN		2011	e-Navigation 1st Conference IALA + DMA
		2012	Monalisa 2.0
		2014	SIP-MSC.94 e-Navigation
		2015	STM - Validation
		2016	e-Navigation Underway
			IALA VTS Personnel: V-103-5
		2018	EMSN
		2019	STM - Development / e-Navigation Underway
		2021	**R.A. 1158(32) Guidelines for VTS (3rd)**
		2030	STM - Deployment

Table 39. The strengths achieved in the context of the VTS chronologically 1945-2021

The last remarks include Wha*tsApp, Satellite, Digitalization STM route exchange, VDES,* not because they are included in the new resolution, but because the equipment that is part of the VTS is not specified, it remains open. Obviously, it refers to the IALA, which is the one who establishes them through its technical documentation. But WhatsApp and satellite phone are already used in some VTS Centres, and route sharing and VDES will arrive in the near future.

Remarks:
New Guidelines for VTS (3rd) 7p.
IALA change status from ORG to IGO and it gets right behind the IMO.
The VTS service is recognized as a value for safety, efficiency and the environment
Mandatory in territorial waters, voluntary beyond TS
Lack of standardization is recognized (still)
VTS equipment
VTS Service (as a whole)
VTS area
Wha*tsApp, Satellite, Digitalization STM route exchange, VDES.*

Table 40. Remarks Resolution A.1158(32) Guidelines for VTS

Globalisation and the widespread use of the internet are changing global perceptions and strategies. That is why the concept of e-Navigation had already emerged in 2005 Since then, various initiatives have emerged, from all over the world, that, albeit with the same "script", each one has been developed individually. This has shown that it is not only developing a concept, the e-Navigation, but also the need to find a global harmonisation, such as the maritime sector. The most important project that was conceived in the European environment was the STM.

The ESMN, the network of simulators, was an example that it is possible to work together, being a cooperative project, between the entities involved in different countries. Hundreds of documents were generated with the aim of planning, designing and structuring group exercises, in addition to organizing information sessions as briefings. During the exercises, a follow-up was made of the dynamics, of the performance, checking that they went well and that there were no computer failures. Here is an example of high-level coordination work between centres spread across Europe. Although it operated on the same platform, teams from different brands acted. Digital technology was adapted to different teams to break the monopoly of the major brands in the market, working with diversity for a diverse world but, at the same time, united.

After the exercises, the task continued with the execution of reports, requesting evaluation questionnaires from the participants and preparing statistical reports, to reach conclusions. An evaluation from start to finish was undertaken, in which the project was highly valued, especially by the agents involved on the ground.

The use of the STM on ships will require more effort, due to crew changes and the fact that, if it was based on concepts of good will to use it, it would not be operational. Higher levels of standardisation and use agreement must be reached. Here, the IMO plays a decisive role, apart from training and certification for seafarers, which will also be necessary. STM is based on the information from the AIS, but the AIS is not ready yet, due to the intrinsic errors it carries. The inclusion of VDES will improve that interface, however it is not a substitute for radar. A great effort can be attributed to this project, for not giving up in the attempt, to transform the maritime sector into something current, and not into something eternally outdated. it denotes how difficult it is to overcome all the obstacles in the maritime field, ranging from a traditionally conservative mentality of “it has always been done this way” or reluctant to change “we have never done that before”, to an incompatibility of digital systems. In between are the approvals, legislation, training, budgets, and other issues which seem to be in the background, but are essential for the project to move forward. EU co-financing is essential, but so is continuity. It is logical to think that subsidising different projects expands the opportunities for other proposals, projects or businesses, but it is also logical that, when a project has been successful, it will continue to be supported., as in the case of the STM.

This scenario is hopeful on the one hand, but on the other, it has thus fallen far short of the original ambition. It will be interesting to analyse if this gap will be prolonged in time and instead of talking about 2030, we should aim for 2050, for example. Another aspect that this dissertation will initiate is that of discerning how many marine services this current is going to maintain or lose, moving towards the era of e-navigation. If the STM, in its embryonic phase, already plans to eliminate such mythical and iconic marine equipment as Navtex or VHF radio in the marine band, or paper nautical charts, the Pilot Charts, it is interesting to consider what will remain of the former nautical world, apart from the sea. This is another line of investigation.

The progress on e-Navigation and results have been reflected in articles, workshops and conferences, awaiting the day when regulations would be mandatory and therefore its implementation would be extensive and real, something that only the IALA and the IMO can do and also coordinated with other international organizations such as ITU, IEC, IHO or WMO. It will be essential to activate all legislative and operational resources to regulate this technology including the training of the personnel that will use it in all areas, both on board and on shore.

The MCP, accessing the SW, a Single Window that leads to each of the tools that are needed to exercise a guard, currently seems intangible and unrealised. But it is evident that gathering tools makes work easier, eliminates the need to print or have paperwork, solves the problem of incompatible systems and software, reduces mental workload (or leaves it for more important issues). In addition, it provides cybersecurity on a trustworthy and reliable platform. However, there are still barriers against connectivity at sea, in terms of technology and business, because of expensive bandwidth. The use of different communication links between ship and ship/shore still needs to be harmonised.

Satellites cover a wide field of needs, such as communications, but their great potential still requires implementation in the maritime sector. Satellites bring both sensing and communications technology. Synthetic and optical aperture radars allow the observation of earth and data, such as the surface image of world maritime traffic or the state of ocean pollution, to be obtained. The ability to monitor and analyse broader traffic images is already tangible.

The role of the VTS is unquestionable in the maritime sector. It has been widely recognised and the trend is that it will be greater, since governments are recommended to implement said service, but also, the paradigm of going beyond, not only through the oceans, and to manage new functions.

The VTS will take onboard new functions, such as the supervision of all the digital information that it will have to handle, which will not only be the checking of ship routes, but also that the chain, in the PortCDM, flows and there are no obstacles that impede its efficiency. The idea of JIT arrival is not new in the STM. The idea has already been examined, referring to "direct traffic" as a solution when studying the efficiency. There is no “safety versus efficiency” problem because, the shorter the queue of waiting ships, the lower the danger of collision (Buller et al. 1986). Arrival at the port and anchoring can be identified as a "rest" space for the crew, but efficient management includes a continuous operation of the logistics chain and also other workload regimens for the crew. New formulas, will apply, such as shorter boarding times, shorter guard times and also longer rest times, without a reduction of crews for more shifts. There are aspects to be taken into account in other avenues of research, which are of a different nature to JIT.

It should be borne in mind that new challenges are approaching which will need to be addressed. The global maritime fleet continually increases, although it might have peaked, and the maritime sector needs to unify and standardise procedures and processes, optimising connections to the logistic chain between ports. Unmanned vessels and drones will be increasingly common and all will interact with the VTS system in the near future.

Environmental awareness has increased proportionally to the deterioration of the planet. The concern to protect it should be noted with each new initiative, procedure or technical development.

The emergence of new projects must not complicate the system or the implementation of digital technology in the maritime sector, it must facilitate it. It is brought about through sharing, cooperating, and working together, rather than individually. The technologies themselves have created these spaces, separated by sectors, now they must be harmonised.

The involvement of the MASS will require changes in the role of the VTS and will affect a wide spectrum of the reference documentation, both from the IMO and the IALA. Ports must comply with the established standards of work carried out by the IMO and IALA, if they want to develop global standards for interoperability among different VTS around the world.

FINAL CONCLUSIONS

Each of the parts, Part I, Part II and Part III, has had its conclusions in order to assess each specific stage, according to the assigned time scale. These final conclusions link the three parts in the long evolutionary path that the VTS has experienced. The final understanding of the VTS complex present is explained, through the connection with its antecedents and projection of the consequences.

1. The VTS

1.1. From its beginnings in the 1950s, it started locally with just two pieces of equipment, the radar and the VHF radio. Its spread was rapid, it immediately spread throughout ports around the world. It took almost 20 years for the first recognition of the IMO as a valuable advisory service to contribute to the safety of ports and their approaches. It took 37 years for the first IMO VTS guidelines to arrive, but the VTS went from being seen as an advisory service, to being an asset directly linked to the contribution of improving safety, traffic efficiency and environmental Protection. Linked and rooted in these three parameters, the VTS would continue to evolve in its functions. Traffic management was in need of surveillance and routing, given the degree of accidents that occurred, so the RS was born. Then, mandatory reports were established for ships, according to navigation zones, giving way to the SRS. Both, whose practice was acquired by the VTS, were regulated internationally through the IMO. A long process of Resolutions ended with the recognition of the VTS as key pieces in the monitoring and reporting of ships.

1.2. VTSs were proliferating all over the world due to an evident need, working practice demanded them, due to the undeniable benefits that ships acquire when sailing with VTS support, with proven and internationally recognized benefits. Therefore, they were a consequence of the evolution of maritime activity in the technological coordinates of our time. Carrying out risk analysis, whether qualitative, quantitative or both, helps to better understand the parameters of a specific area. They can also be valid when evaluating how the flow of traffic can be affected by potential changes, such as structural changes in a port, a change in the type of fleet or an increase in the number of ships.

1.3. IALA acquired an important role as a result of the first VTS manual but, over time, it developed technical reference documentation for the VTS. Its work, recognised by the IMO, and role as a delegate of this international organization, has been vital for the recognition of the service worldwide. In addition, VTS Operators have been approved as a new profession, with internationally regulated qualifications and certifications, while also founding the WWA. The definitive consolidation of the VTS personnel, therefore, is due to professionals who have received specialised and appropriate training for their VTS tasks.

1.4. To be or not to be a sailor is an issue also addressed by the IALA, concluding that, although anyone with the appropriate training and characteristics can be an Operator, nautical experience is always considered a plus (Hughes 1998).

1.5. New formulas for gaining experience enrich the tasks to be performed. Practices in simulators are an example. Others could be developed, such as accompanying a pilot during port entry and exit manoeuvres (this is just a proposal, to be developed from the synergies, which are taken for granted in praxis but would need debate).

1.6. The level of training should therefore be under the same standard throughout the world, however, it is complex given the existing inequalities. In the case of the training of seafarers, in some countries this is below the standards and they cannot be employed on board EU ships, (for example), so the training must also be up to higher standards, such as STCW.

1.7. The Maritime Operator model was inspired by the air traffic controller. Their development marked clear differences, but the new technologies and management systems, which are more globally coordinated, bring them closer in management and coordination aspects. Air traffic controllers who determine traffic and routes do not ask if goods or people are travelling on board. The VTS will manage this information in an increasingly computerised manner and handling traffic management will be essential.

1.8. Although navigation is very old and the VTS arrived very late in comparison, VTS has operated for more than 70 years to become understood as a generic acronym without specifying range. Perhaps now, this merits recognition through the creation of an International VTS day, as ATC already have.

1.9. Today the VTS are unquestionable, and their purpose is to contribute, inter alia, to safety, life at sea, the efficiency of navigation and the protection of the environment.

2. REGULATIONS

2.1. The in-depth study of the process of regulations and resolutions, both in their birth and in their updates around the VTS, has made it possible to verify that they are long processes and that some have been the aftermath of major disasters. From tragedies, human and ecological, history has shown that one learns and, from tragedies, new conventions and regulations arise, as well as technology, in order to advance in this world, promoting the security of everyone and everything: people, environment and ship. There are many examples, the Exxon Valdez and Bear ships motivated the AIS; the Erika, the SSN, 9/11 in the USA, the LRIT.

2.2. The more security, the less accidents and the regulations always advance to ensure that security and safety. The verification analysis regarding the long periods in reference regulations for the VTS, have shown that the technology advances at a higher speed. A long-distance race that is far from finishing on par, technology always reaches the finish line first, and regulations lag behind. On the other hand, the ability to closely follow the updates and preparation of new IALA guidelines for VTS has made it possible to understand that any review, update or preparation of new reference documentation requires great efforts and long work sessions. There is a rigorous and meticulous process until the final document is achieved.

2.3. Work is done on tectonic layers of drafts where all the members of the work committee, which is specific to each group, contribute comments, improvements and ideas, to achieve a final reference document that also reflects the plurality of the maritime sector. It involves long sessions of analysis on a draft-skeleton, whose participants are members of the IALA committee that brings together representatives of governments, organizations, the commercial, industrial, and academic sectors. Finding the formula to define a new resolution does not always have to have negative connotations due to its longevity, but that "slowness" can mean that it is scrupulous in analysing everything to find the best solution.

2.4. This is an era where everything has a rapid expiration date. Technological advances are constant and accelerating, while regulations lag behind. This fine-tuning of the regulations should consider the concept of speed, or the disparity will be increasingly disparate.

2.5. The legislator, the parliament, adapts the laws to the times, and flexibility is the margin that opens up to the future. The more flexibility, the more durability (American constitution is an example). And the opening of the latest updated Resolution A.1158(32) for VTS makes it possible to adapt new inputs. The more complicated the technology, the “simpler”, in the sense of precise, the regulations should be.

2.6. The IMO is the highest representative in maritime issues, but it does not represent the entire planet. It currently comprises 174 Member States and three Associate Members, and has 85 international non-governmental organizations (NGOs) contributing to discussions at the IMO. In 2022, it announced amendments to the IMO Convention that will expand the Council from 40 member states to 52. The fragmentation of political maps, which require negotiations and consensus, makes legislating slower. However, the growth of IMO, reveal that global collaboration is on the rise.

3. FUNCTIONS

3.1. The technology will also bring new attributions for the VTS. From the early role of providing information, they now cover functions of data collection, navigation assistance, traffic organization, support for allied activities, such as pilotage services, port services, maritime security, prevention and control pollution and search and rescue; convene and request the action of the rescue and emergency services and, where appropriate, participate in the actions of these services.

3.2. During the first stage of landing, that 1983 resolution already requested unifying procedures, making a single report over a radio channel, messages adaptable over time, and sharing a navigation plan. At that time, sharing a navigation plan between ship and shore was reduced to knowing the ETA and whether the manoeuvre was to anchor or berth.

3.3. Now the expectations are to share the ship's route throughout its entirety, develop routes and propose them as a suggested solution, a reality tested by the STM and therefore feasible. The VTS is now considered an AtoN, capable of interacting with traffic and responding to traffic situations that develop in the area.

4. TECHNOLOGY

4.1. The VTS started with Radio and Radar. The inclusion of AIS on ships was seen as a tool for surveillance from land and soon became part of the VTS.

4.2. AIS was developed as a short-range identification and tracking tool for coastal areas, but has evolved into a longer range identification and tracking system. Satellites, able to capture AIS signals, allow for long-range ship tracking and surveillance and have led to the creation of new equipment such as LRIT and VDES. The latter will be the solution to the limitations of AIS, with the improvement of enabling global coverage. The satellites provide images of the sea surface, allowing the monitoring of ships, both at night with radars and during the day with optical satellites, constellations of families of satellites, thematically specialised.

4.3. IP-based digital technology collides with technology through radio links like AIS/ASM, VDES. How to integrate NAVTEX and AIS with the maritime cloud IP domain are the topics of special research. The STM when integrated, changes technology.

4.4. New technologies will bring new regulations, as noted above, and new issues such as liability must also be addressed. Confidence in a new technology places the responsibility on two actors, the one who has made it and the one who uses it, already a subject of study (Tsimplis and Papadas 2019). Here, more humanistic planes, such as the legislative and even the ethical-moral or cultural ones, are considered. Ground will be gained in terms of scientific progress, but, in turn, it will be necessary to highlight what will be lost, or what should not be lost, in traditional terms.

4.5. Sailors know that on board, almost everything has some form of backup. If there is a failure in one piece of equipment, there is another to replace it, due to the need to cover the isolation of the maritime environment. Global communications coverage makes it possible to eliminate that isolation. Relying on satellites and the internet also allows the seafarer to continue with current technologies, as jury.

4.6. Smartphones were already linked to SAR missions in 2012 (IMO 2012). However, geolocation does not work on the high seas, unless it is via satellites, which is still unavailable to users, due to the high cost. High availability implies a substantial investment. Users know how to share it through WhatsApp but, if the App "crashes", they are left without a position.

4.7. Technology has increased the amount of equipment to handle and therefore, the screens. The information that needs to be processed has increased with the advent of new technologies. Today there are often more screens than eyes, a situation which both the sailor and the VTS must handle[206].

[206] Retrieved from: https://www.sintef.no/globalassets/project/hfc/documents/0-presentation-vincentius-rumawas-for-hfc-17-oct-2017.pdf

Figure 57. Eyes vs screens

The VTS started with the radar screen, currently it works with multiple screens. In the author's 10 years' experience in VTS, there was a change from 3 screens to the current 6, not including the sub-screens to work on other platforms. The trend is that technology is already integrating equipment, unifying connections, looking for Wireless and reducing screens, whose touch feature makes it easier to obtain information on demand. From the joystick, to the button, from the button to the keyboard, from the keyboard to the finger on the screen, myriad screens or, larger screens with interfaces, the possibilities are expanding.

4.8. The advancement of technology, which is necessarily recurrent in this work, is clearly evident in everyday uses and customs. It has gone from telephone booths and typewriters to carrying everything integrated into a device that can be carried in the pocket, offering telephone, watch, PC, Internet, GPS, applications that monitor health, credit cards, plane tickets, camera, diary, library, news, calculator, flashlight, recorder, scanner, radio, appliance control and even medical history. The list continues, depending on the applications installed, all digital. Such power and versatility generated by two numbers, 0 and 1.

4.9. Technology must serve humanity and offer an easier life, not enslave. It must provide reliable, high-speed, stable and consistent cyber security. Network means connectivity. The USB is increasingly dispensable, thanks to the clouds, Cloud, Drive and, in the maritime sector, the MCP. All uploaded information can be accessed from any computer and, therefore, also shared.

5. E-NAVIGATION

5.1. The e-Navigation project was born from the need to include new technologies and digitisation in the maritime sector that had not yet been included. The IMO promotes it as a concept, with its own brand, to cover a wide spectrum of needs in the maritime world.

5.2. That, "on the margin" meant that digital integrations were very advanced on land, but not at sea. The key is to include everyone and share technology and information.

5.3. E-Navigation must be consistent with the entire maritime chain, from navigation services to commercial activities and government cooperation, globally, without borders. Greater cooperation between shipowners, charterers, port authorities, terminal operators and port service providers is key and a prerequisite for safer and more efficient port calls. With the JIT concept, the IMO illustrates a reality that is not operationally optimal, where "hurry up and wait" is the current model, with reports of maximum 2h in advance, the ship is told to continue and, when it is 4 miles away it is told to go to the anchorage to wait (IMO 2020:3). In the *Global Village*, holistic discipline is a must.

5.4. This is the concept of "sharing", so that there is fluidity and, in which, new acronyms, such as JIT, PortCDM, STM enter.

5.5. It brings technology and global reach, as shown through the various projects developed under this umbrella.

5.6. The STM was an example of cooperation, investment in coordination and a demonstration that, working with the same technology and different equipment, it was possible to navigate digitally interconnected. It allows sharing of information from ship to shore from any position of the ship, including the high seas.

5.7. It is clear that a tool based only on AIS signal will not be able to replace the radar, for the moment, and that its implementation must be accompanied by the support of the IMO under resolution, since, for it to prosper, use "at will" is not enough. The new maritime needs require the action of the IMO. The inclusion in the ECDIS to make amendments to the nautical equipment will have taken more than 12 years, if counting from MONALISA, 2010.

6. HARMONISATION

6.1. The concept of "sharing" is associated with harmonisation, a global compatibility that is not even found in the same country. Currently there is no harmonisation in the same port. Information is duplicated and even tripled, and redundant processes are reproduced.

6.2. Digital technology brings many offers. Everyday life has been experiencing a lack of harmonisation for years, through incompatibility of software and connections. It is necessary to create compatible solutions. Digitisation is not a competition, it is a common solution. Many initiatives and projects have been co-financed by the EU or others, but harmonisation is still being sought in the face of commercial opportunities.

6.3. The digital age, at sea, involves marine computing, a specialisation adapted to the particularities of the maritime sector, and not the other way around, with a 100% usability that facilitates the work, not complicates it.

7. AREA

7.1. Harmonisation without borders means global connection and communication. The VTS, in its key role of connection between ships and land, will be able to establish that function without restricted area.

7.2. The VTS area is something that has always been analysed and considered within the Territorial Sea. The action of "reporting" is established more in time than in distance., where the ship is 1 hour or 2 hours away, rather than where it is sailing in a specific location. This leaves the geographic framework of the VTS area open, limited only by UNCLOS'82 to the MT. However, even in the cases of VTS areas outside the territorial sea (such as TSS), vessels must follow the rules of the VTS[207].

7.3. However, the SAR area is much greater than 12 miles and is agreed between countries. There are VTS that perform both functions, as in Spain, but in those cases that do not, the VTS are also linked to SAR functions. They all have, therefore, a greater scope in terms of area to cover and interaction with the traffic, other than that reported, all beyond the TS.

7.4. There are other examples of distribution of areas at sea, such as the global Navtex Wx Service with 21 Navareas[208] but there are no agreed VTS areas around the world.

8. OCEANIC VTS

8.1. The VTS began in port, expanded to coastal and is currently operating and has the technology to follow a ship around the world. The perspective is that the same functions defined for the port and coastal VTS will be extended to a greater scope. In the necessary and essential operation of naming new phenomena, either with neologisms, new meanings to old words, acronyms or trademarks, this thesis has proposed to name this global dimension of the VTS as the Oceanic VTS. An Oceanic VTS in the global sense, as in the GMDSS agreement. According to the type of navigation characterized in e-Navigation, as ocean navigation and according to the growing trend of having global control and surveillance. A third dimension that will allow contact and interaction with ships from any location. Ubiquity is one of the phenomena of these times and it must consequently include the vision of the seafarer.

8.2. The evolutionary steps have been, thus far, the Radar, showing the echo of the ship, then the AIS, showing which ship it is and the STM, indicating what plans it has and sharing its route. On land, navigators are used to seeing, in advance, what route is going to be taken. The rest continues at sea, not only knowing which route is going to be carried out, but also what routes the other ships will carry out.

8.3. Herman Melville wrote, in 1851, that the whales would never become extinct because of their numbers and the difficulty of hunting them with a manual harpoon[209]. He could not have foreseen technological advances, such as self-firing harpoons or detection technology. In 1946, the International Whaling Commission (IWC)[210] had to be created to regulate their hunting. Currently there are more than 5 different species on the brink of extinction. Technology opens fields, perhaps unattainable at the present time, but reduces the possibilities of "unpredictability", due to its omnipresence in almost all fields.

8.4. The Oceanic VTS will have much more information to manage traffic more efficiently and safely, and it faces higher levels of supervision of electronic information.

[207] DIRECTIVE 2002/59/EC Article 8.
[208] Available at: https://iho.int/navigation-warnings-on-the-web
[209] Moby Dick. Chapter 105. "Does the whale's magnitude diminish? Will he perish?".
[210] Retrieved from: https://iwc.int/home

8.5. From its local position, with global views, it is therefore also involved in the protection of the entire sea. VTS operators of the world are connected, sharing information without borders on maritime traffic from port to port. Thus, it continues to monitor and survey in international waters, which will open debates on the law of the sea, as future lines of research.

8.6. It has been shown how the VTS coordinates congested areas near the coast, which is also where most incidents/accidents occur. Offshore accidents are fewer, but more catastrophic. However, as has been demonstrated in this thesis, the role of the VTS is not only security, it covers broader and more complex aspects.

9. FUTURE

9.1. The future oceanic VTS that will interact with ships from any point of the sea, will need to implement new equipment, thanks also to technological advances, as the Fourth Industrial Revolution ushers in a new wave of intelligent, automated and autonomous digital technologies.

9.2. The MASS are already a reality, and the IMO is working on the regulations for the tests carried out in areas under the surveillance of a VTS. It is possible to imagine a sea with autonomous ships transporting goods, so supervision from land will be even more important.

9.3. This does not mean that the seafaring profession will disappear. There will be new ways to manage shipments and new opportunities for seafarers in new professional formats. Sailing will never end. “Primun Navegare” but perhaps it will be a more regulated profession with new requirements.

9.4. The MASS are also an opportunity to standardise and harmonise digital technology, since a MASS ship would be unworkable if it could not operate in a port due to digital incompatibilities. In the cases of unmanned degree 3 and 4, the issue of a next-generation "expert" Pilot ,"Pilot 5.0" could be requested to board and solve an emergency situation, such as loss of control or collision. Other related issues, include compliance with the COLREG for each established degree of the MASS.

9.5. The situation of the planet also demands greater and better protection against pollution, degradation and elimination of species. The concept of "grow" is no longer to evolve, because the discourse of sustainability has surpassed it. Harmonisation is the expected evolution. The seas are not only for trade, or even recreation, they are a source of life for myriad species. The oceans are huge, complex and, to the greater extent, isolated, covering 140 million square miles that need protection.

9.6. Ships sailed until steam power arrived. They then established themselves as the most efficient transport for moving large amounts of cargo over long distances. Passengers and merchandise travelled together until they began to separate. General cargo ships were replaced by ships specialized in merchandise (bulk, containers, cars, liquids and other products) and passenger ferries and cruise ships. Now the question arises around propulsion systems using alternative fuels that respect the environment, without polluting emissions.

9.7. Satellites provide the full range of detection features, being able to better survey the earth and therefore monitor it. This includes monitoring of the atmosphere, monitoring of weather changes, marine environmental monitoring, pollution detection, ship tracking, location of emergencies and piracy and of course, global communications.

9.8. In the middle of this sea is the VTS. Between the current system and what is shown in the famous Roll Royce video[211] on VTS Operators (everything very digital, but the operator has a pen in his hand), which seems more science fiction than reality, there are still intermediate steps, if this is the trend. However, the image of ship traffic in real time, and on a large scale, moves in the parameters of globalisation, where all maritime traffic meets and interacts with a VTS.

These conclusions are the final *quod erat demonstrandum* of this thesis, with the desideratum that academic reflection contributes to improving navigation conditions for its own benefit and to the benefit of the oceans, which are, quantitatively, the most accurate way of assessing the planet. Reality implies liquidity, and life, essentially, is liquid.

[211] Rolls Royce future Shore Control Centre. Available at: https://www.youtube.com/watch?v=ALwx5VP8kWA

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