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SESSIONS 9 – 12

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FOREWORD

This volume is one of five volumes of conference proceedings, including the 4th IALA Heritage seminar proceedings, and contains abstracts, biographies and full papers, where these have been prepared and provided. We hope they enhance your conference experience and act as a useful reference source for future discussion and research in the Marine Aids to Navigation sector.

The volumes are compiled as follows:

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"S2.4 Case Study – Inspection of floating AtoN by drone (153)"

is session event 2.4 and the unique paper number is 153. Any sessions with numbers 1 to 16 formed the main auditorium programme, whilst sessions starting 101, 102 etc. formed the Speaker's Corner programme held concurrently. Papers, where submitted are included, otherwise the paper abstract only is included. These can be found by session number through the main table of contents or by their unique conference paper number via the index at the back of the document.

Tenga en cuenta que a lo largo de las deliberaciones, el título del documento está precedido por el número de evento de la sesión de la Conferencia y seguido por el número único del documento entre paréntesis, por ejemplo:

"Estudio de caso S2.4 – Inspección de AtoN flotante por dron (153)"

es el evento de sesión 2.4 y el número de papel único es 153. Las sesiones con los números 1 a 16 formaron el programa principal del auditorio, mientras que las sesiones que comenzaron 101, 103, etc. formó el programa Speaker's Corner celebrado simultáneamente. Los artículos, cuando se presentan, se incluyen, de lo contrario solo se incluye el resumen del artículo. Estos se pueden encontrar por número de sesión a través de la tabla de contenido principal o por su número de conferencia único a través del índice en la parte posterior del documento.

SESSION 9 – VTS OPERATIONS AND TRAINING

S9.1 Poseidon VTS e-learning (126)

Andreas Keller, Head of VTS Training NNVO, Netherlands

ABSTRACT

We developed an E-learning (Poseidon) with 3 main topics, geography, basic simulator operation skills and basic communication skills. With this e-learning the students are able to practice basic VTS skills without the use of a VTS simulator at a time and place that they prefer. The look and feel is exactly the same as on the simulator. When we introduced this E-learning we were able to skip 3 days of simulator training. We found out that the students where better prepared and the communication skills were on a higher level than before.

This E-learning is very flexible and can be offered in any language and every VTS-area. The E-learning is web-based so the only thing that a student needs is an internet connection and a computer.

(No paper submitted)

AUTHOR BIOGRAPHY

Andreas Keller is the current Head of VTS Training at the NNVO in the Netherlands. In recent years the NNVO developed an E-learning (Poseidon) for VTS trainees where they are able to train basic skills that are usually trained on a simulator. Last November Poseidon won two golden Learning Technology Awards in London. Andreas has been a member of the Dutch IALA delegation in working group 3 VTS training, since 2021.

S9.2 English proficiency evaluation of VTS operators based on artificial intelligence (054)

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ABSTRACT

This research paper is focused on the application of artificial intelligence technology to the creation of an automated English language proficiency assessment system for Korean VTS operators. The VTS specific language proficiency oral test was developed and administered based on the IALA VTS VHF Voice Communication Guideline 1132 (IALA G1132, hereafter) with the concrete assessment criteria including the message structure, the correct and/or appropriate use of phraseology from the IMO Standard Maritime Communication Phrases and IALA G1132, and the interpretation of the situations from the authentic audio-visual VTS scenarios requiring VTSO's oral engagement. 336 Korea VTSOs participated in this investigation, and their scores were validated both by human professionals and by an AI-automated scoring system. The results of the analysis, which will put on its focus on AI results, showed that scores varied by center, position, gender, age, and work experience. Through the findings of this study, it has been determined that English proficiency evaluation criteria should be further refined and an AI-based control evaluation system for VTSOs should be developed in order to further enhance the validity of test results through rapid and accurate diagnosis. The research paper offers policymakers, educators, and practitioners in the field of vessel traffic service valuable insights for achieving the IALA Recommendation 1012 objective of harmonizing VTS communication.

KEYWORDS: Vessel Traffic Service, English proficiency assessment, English speaking test, VTS standard phraseology, artificial intelligence

1 INTRODUCTION

The maritime industry has become increasingly aware of the importance of English language proficiency for VTS operators, as a growing number of seafarers from non-English speaking countries are rapidly joining the industry, comprising the vast majority of our service recipients. In this regard, the customer-oriented communication service, which should be clear, effective, and concise, with the use of standardized phraseology with the application of mutually understandable delivery techniques (for example, speech rate, emphasis, and pause), should all be maintained at a satisfactory level in order to ensure the safety and efficiency of vessel traffic at port through the VTS. Nonetheless, assessing the quality of English service, particularly on a large and validated scale, has presented a number of difficulties due to the lack of an English language testing system tailored to the VTS context (otherwise existing in the aviation industry) based on the field's specialized nature, which requires multiple in-depth technical knowledge and experiences on VTS, navigation, English linguistics, language education, and testing. In response to these obstacles, this study conducted a trial of an AI-based VTS English proficiency assessment English evaluation system and a test with 336 Korean VTSOs to validate and verify its efficacy in the hopes of providing a future solution to Korean VTS operators.

The primary objective of this study is to develop a framework for assessing the English proficiency of VTS operators using AI technology. The research has two primary goals: (A) analyzing and assembling standardized phrases for Korean VTSOs from the IMO SMCP and IALA G1132, considering the Korean VTS context (e.g., no convoy operations and ice-breaking situations); and (B) conducting an oral English proficiency assessment of Korea VTSOs in order to provide policy recommendations for future VTSO's English education, training, and revalidation based on the research results.

This paper is structured as follows: after the introduction, the methodology employed in this study is illustrated in two ways: a) the compilation of standardized phraseology for the Korean VTS context; and b) the actual assessment procedures of the VTS English proficiency assessment for Korea-based VTSOs, followed by a discussion of the AI-based evaluation system. In the results and analysis section, the distinctions in scores based on variables such as VTS centre, position, gender, age, and work experience are highlighted. The study concludes with policy recommendations, suggestions for future actions, and suggestions for additional research.

2 THE RESEARCH FRAMEWORK FOR EVALUATION

This chapter focuses on the configuration of the evaluation framework, which is necessary for evaluating the English proficiency of VTS operators utilizing AI technology. The evaluation framework seeks to address current challenges in the industry, such as the absence of large-scale and professional evaluation systems, as previously mentioned. In the following sections of this paper, the methodology used to establish standardized VTS phraseology for Korean context and to develop an AI-based evaluation system will be described.

2.1 Standardized Phraseology for Korean VTS Context

In order to develop an effective assessment tool, the first step to figure out is the standardized phraseology for Korean VTSOs by analyzing the syntax of VTS communication from IMO SMCP and IALA G1132 in order to develop an effective assessment instrument. As a result, a total of 398 standard phrases that reflect the specialized routine and emergency language needs of Korean VTS operators were identified. These phrases are categorized as follows:

Table 1: The phrases types for evaluation

Category	Number of Phrases
Key VHF phraseology	35
Warning	13
Weather	31
Pilotage	16
Lighthouse/buoy	13
Berthing/departure	18
Emergency	5
Information/warning	70
Fishing boats/nets	10
Distress	18
Anchoring/heaving up anchor	24
Navigation	145

2.2 Developing the AI-based English Proficiency Evaluation System

The second step of this study is to develop an AI-based English proficiency evaluation system that will provide a more accurate and efficient method for assessing the English level of VTS operators. The development of this system commenced with an online oral language test administered by VTSO. Text-to-speech technology was used to transcribe the electronically stored test recording data, followed by the application of NLP-based algorithms for post-editing improvement. In this procedure, *Videoask* technology was used in administering tests and acquiring test data, thereby providing participants with a more interactive and engaging assessment experience.

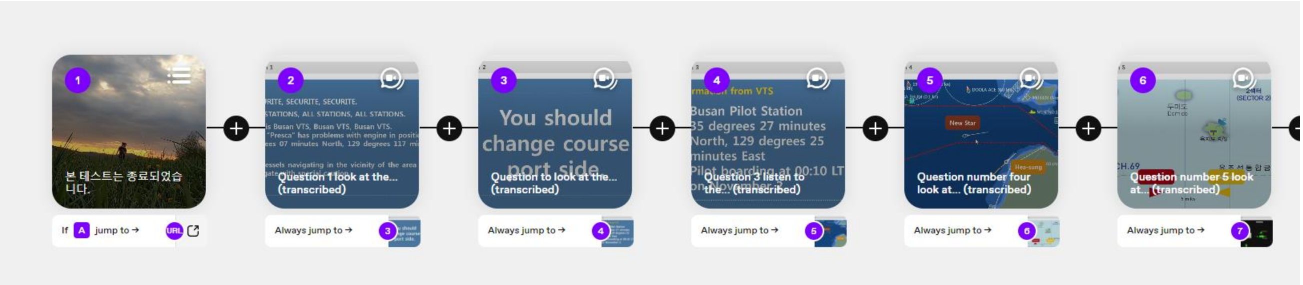

Figure 1: AI-based Evaluation System with videoask.com

2.3 Assessing Participants' English Proficiency

To effectively evaluate the English proficiency of VTS operators, the research team developed evaluation criteria based on IALA G1132, which will be presented in a separate paper at this VTS conference titled "VTS English Communication Proficiency Assessment Criteria Based on G1132 VTS VHF Voice Communication and its Practical Applications." Briefly, the evaluation criteria include a variety of aspects specified in IALA G1132, such as general principles, message structure, standard phraseology, language delivery, interpretation and monitoring in large, and sub-criteria such as speech rate, voice tone and volume, and read-back skills and use of message markers.

3 ASSESSMENT

The results of the assessment are as follows:

3.1 The Overview of the Assessment

336 Korea VTS operators from 21 distinct VTS centres, including Port VTS (244, 72.6%) and Coastal VTS (92, 27.2%), participated in this study. The participant distribution was as follows: male (291, 86.6%) and female (45, 13.4%). Less than 5 years (166, 49.4%), 5+ years to 10 years (87, 25.9%), 10+ years to 20 years (44, 13.1%), more than 20 years (28, 7.7%), and not specified (13, 3.6%).

3.2 Score Analysis

The average score for the participants was 56.22 points. The distribution of scores is shown in the table below:

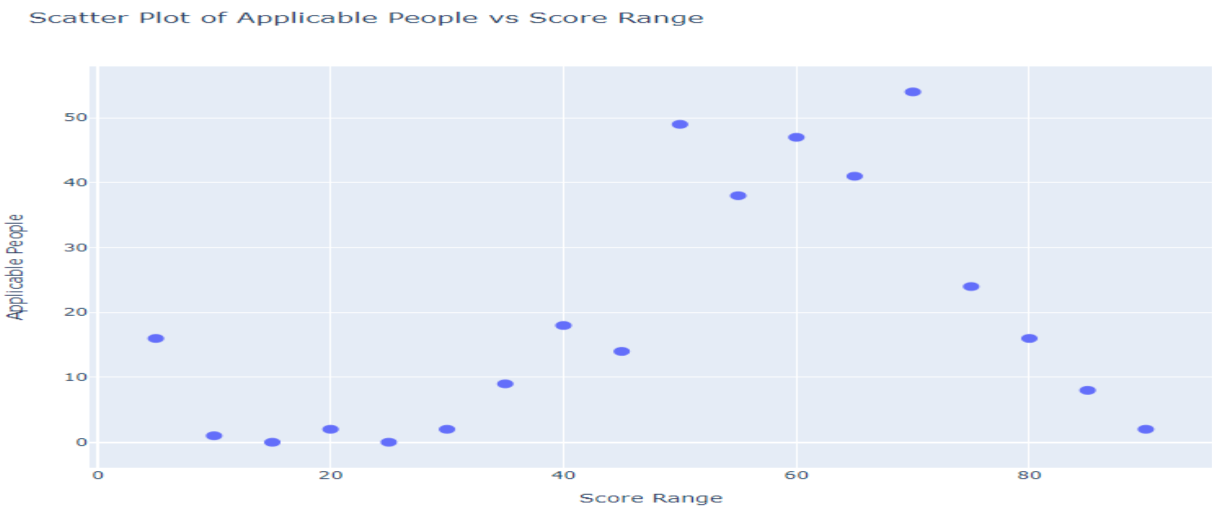

Figure 2: Scatter Plot of Applicable People vs Score Range

Table 2: Evaluation Results of Score Range

Score Range	Applicable People	Percentage	Cumulative Ratio
85 to 90	2	0.6	0.6
80 to 85	8	2.4	2.9
75 to 80	16	4.7	7.6
70 to 75	24	7	14.7
65 to 70	54	15.8	30.5
60 to 65	41	12	42.5
55 to 60	47	13.8	56.3
50 to 55	38	11.1	67.5
45 to 50	49	14.4	81.8
40 to 45	14	4.1	85.9
35 to 40	18	5.3	91.2
30 to 35	9	2.6	93.9
25 to 30	2	0.6	94.4
20 to 25	0	0	94.4
15 to 20	2	0.6	95
10 to 15	0	0	95
5 to 10	1	0.3	95.3
0 to 5	16	4.7	100

The majority of operators scored between 45 and 70 points, with a mean score of 56.22. Several interpretations can be drawn from the score distribution table: the level of scoring standard must be adjusted to accommodate lower level test-takers, given that the level of below average (56.22 points) was also quite acceptable and reasonable to be given positive evaluation, according to the consensus of human professionals from the navigation, VTS, and language training fields; Otherwise, over 60 out of 100 points are considered "passed" in VTS language-related subjects in Korea VTS training; therefore, it is necessary to offer supplementary courses for operators who desire to improve their VTS language skills. Lastly, this AI-based testing system does not have sufficient time to learn Korean linguistic characteristics, which can be naturally reflected on the use of English accents and pronunciations (even though a number of VTSOs voluntarily participated in training AI (50,000 phrase recordings of vessel traffic operators' samples) to familiarize 200 sample VTS phraseologies with terminologies in Korean pronunciation prior to assessment), the time for training AI to learn VTS phraseology and terminology with a wider range of linguistic accommodations is insufficient).

When examining the scores by gender, females scored higher on average (60.96) than males (54.55). This could be an indication that targeted training programs need to be developed, taking gender differences into account.

Table 3: Score Analysis by Gender

Gender	Score
Male	54.55
Female	60.96

The age-based score analysis indicates that younger operators (those between the ages of 20 and 30) tend to have higher scores than their senior counterparts. Younger operators may have benefited greatly from the increased emphasis on speaking-based English training in recent years. Nevertheless, it is essential to address the disparity in language proficiency between different age groups by providing senior-level operators with tailored training programs to assure a higher level of communication proficiency when performing their VTS responsibilities.

Table 4: Score Analysis by Age

Age Group	Score
20s	68.27
30s	60.13
40s	52.99
50s	42.38
60s	39.75

Those with less than five years of experience have the highest average scores (60.18), whereas those with more than twenty years of experience have the lowest (40.96). This suggests that VTSOs should receive continually updated instruction and refresher courses on VTS English proficiency throughout their career lifecycle, regardless of their years of experience.

Table 5: Score Analysis by Work Experience

Work Experience	Score
Less than 5 years	60.18
5-10 years	54.53
10-20 years	53.82
More than 20 years	40.96
Not specified	55.62

The score analysis by VTS center type reveals that Port VTS operators (57.68) outperform Coastal VTS operators (52.68) on average. The difference in scores between port and coastal VTS may be attributable to factors such as age, gender, and the frequency with which they are exposed to English in their workplace, as well as with whom they primarily interact (domestic vessels and/or ocean-going vessels). To address this deficiency, additional needs analysis of English usage between port and coastal VTS should be conducted, and training schemes for these two should be established in a clearly defined and practicable manner, and implemented in on-the-job training by VTS on-the-job instructors.

Table 6: Score Analysis by VTS Canter Type

VTS Center Type	Score
Port VTS	57.68
Coastal VTS	52.36

To increase the overall English proficiency of VTS operators, it is crucial to design specialized training programs that take into account variables such as age, gender, work experience, and the types of VTS centers. In addition, an education and training strategy based on the career lifecycles of VTSOs, including refresher courses and English trainer courses for on-the-job-trainers, must be established and provided on time in order to maintain the quality of vessel traffic language services worldwide.

3.3 Implication of Evaluation System between AI and Human

Implementing an AI evaluation system for assessing the English proficiency of VTS operators has significant benefits and implications The AI evaluation system is based on a model that has undertaken extensive data collection, speech-to-text technology application, and the development of an AI automatic scoring evaluation model. This procedure involved using NAVER's speech recognition system to convert speech to text and applying a text correction model trained using 50,000 phrase recordings of vessel traffic operators' samples.

In comparison to human evaluation, the AI evaluation system demonstrates a high level of accuracy, according to an analysis of evaluation results. The standard deviation for each question is 0.45 points, and the average absolute error for each question is only 1.4% per 10 points. This demonstrates that the AI evaluation system is statistically significant and characterized by a standard normal distribution.

Despite the fact that the mean absolute error for each question is not substantial, there are instances in which significant gaps exist between human and AI scores (for example, 10 points by human professionals and 0 points by AI). This suggests that there is room for development in the accuracy of the AI evaluation model (N.B. AI does not appear to have the ability to accommodate English such that Korean linguistic characteristics are reflected; however, humans are generally acceptable for this). By consistently refining the AI machine learning process, the precision and reliability of the model can be improved.

AI evaluation is anticipated to offer greater objectivity, consistency, and scalability than traditional human evaluation methods, allowing for a more efficient and trustworthy assessment procedure. It can also reduce the burden of human evaluators and minimize biases that may arise from subjective assessments.

In conclusion, the AI evaluation system is a useful instrument for evaluating the English proficiency of VTS operators. By continuously enhancing the model's accuracy through AI machine learning, this system are able to offer a robust and dependable alternative to traditional human evaluation methods, thereby contributing to more effective communication in the maritime industry.

4. CONCLUSION AND FUTURE WORKS

In comparison to conventional human-driven evaluation methods, our research demonstrates that AI can provide an evaluation process that is more impartial, reliable, and scalable. By refining the process of AI machine learning, the enhancement of the accuracy and dependability of the model, which will ultimately lead to improved communication in the maritime industry, seems to be quite achievable. Our findings also shed light on a few potential new areas for research and development in the future:Enhance the accuracy of the AI evaluation model by addressing instances with large gaps between human and AI scores through continuous machine learning.

1. Improve the STT model's understanding of Korean-speaking English for VTS-specific purposes by developing an AI model that complements the existing STT system.
2. Develop a flexible scoring evaluation model capable of adapting to new test questions and integrating a variety of quantitative indicators, such as the rate of speech rate, volume, and tone.
3. Standardize evaluation indicators and develop an English oral proficiency assessment test for VTS by assembling an internal and external advisory group of linguistics, VTS, and AI experts.
4. Develop standardized guidelines for responding to the VTS English oral proficiency test, including test methods, evaluation criteria, scoring, and general test preparation guidance.
5. Establish VTS English language Train-the-Trainer courses to develop instructors at each VTS center and maritime training institutes.

4 ACKNOWLEDGEMENTS

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AUTHOR BIOGRAPHY

Sungchul Choi is an associate professor at the Department of System Management Engineering at Pukyong National University, Republic of Korea. He received his Ph.D. in industrial management engineering from POSTECH in 2012 and has worked as a technology strategy manager at Samsung Advanced Institute of Technology. Dr. Choi's research focuses on patent analysis, technology roadmap using text mining approaches, and the application of machine learning and deep learning approaches to academic big data. He has conducted various research related to natural language processing and artificial intelligence. Notably, he is developing a technology that can build a virtual world by fusing AI and digital twins, enabling various AI simulations on the virtual world.

Dr. Seung-Hee Choi is an associate professor at the Korea Institute of Maritime and Fisheries Technology, which is the government maritime training institute of the Republic of Korea. She is in charge of the maritime English education and training program for VTS operators, mariners, and professionals in shipbuilding industry. Dr. Choi is an alumna of the University of Birmingham in the United Kingdom where she earned her MA and PhD in the field of English Applied Linguistics with the specialization of teaching successful cross-cultural communication strategies across the world maritime industry. As an external expert consultant, she provides advisory services for Korea VTS Competent Authority in the field of VTS English education, training, and evaluation. In addition, she is actively involved in national maritime language research projects such as the development of national maritime English testing system for Korean mariners, online learning system for life-long learning of the maritime professionals, and the standardization of e-Navigation text messages. As a local organizer of technical cooperation programs, she has been successfully leading a number of capacity building activities with the international organizations such as IMO Technical Cooperation Programs and APEC projects. She continues to devote her interests and energy in international cooperation, maritime English training, curriculum development, train-the-trainer course, testing and evaluation.

S9.3 Concrete concepts in a Virtual Environment - moving VTS training 'online' (154)

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ABSTRACT

During the past years we have seen significant progress as we embrace tools enabled through the Digital Transformation of the Maritime Environment. While we were unable to meet in the same 'physical' environment, we learned to meet, communicate and collaborate using different online tools. This included the need to come up with innovative solutions to providing critical training – such as VTS training – online. The presentation will focus on the concrete benefits of putting VTS training 'online' focusing on the successful online delivery of VTS On-The-Job Training (C0103-4, formerly V-103/4), VTS Operator (C0103-1, formerly V-103/1), VTS Supervisor (C0103-2, formerly V-103/2) and VTS Recurrent (C0103-5, formerly V-103/5) training in a virtual environment. The paper will include the move to full online VTS training simulation, replicating the VTS centre, including team training, through a combination of different online technologies.

By looking at what went well and what was revised in the course of multiple course deliveries over the past years the presentation will identify options for further work in this area, including approval process for online training delivery; further development of online training; and next steps as we learn from the Covid Pandemic to move into a post-pandemic era.

KEYWORDS: VTS Training, Innovative solutions, VTS Training simulation, approval process

RESUME DE L'ARTICLE

Au cours des dernières années, nous avons constaté des progrès significatifs en adoptant des outils rendus possibles par la transformation numérique de l'environnement maritime. Alors que nous ne pouvions pas nous rencontrer dans le même environnement « physique », nous avons appris à nous rencontrer, à communiquer et à collaborer en utilisant différents outils en ligne. Cela comprenait la nécessité de proposer des solutions innovantes pour fournir une formation essentielle - telle que la formation VTS - en ligne. La présentation se concentrera sur les avantages concrets de la mise en ligne de la formation VTS en se concentrant sur la prestation en ligne réussie de la formation en cours d'emploi VTS (C0103-4, anciennement V-103/4), Opérateur VTS (C0103-1, anciennement V-103/1), VTS Supervisor (C0103-2, anciennement V-103/2) et VTS Recurrent (C0103-5, anciennement V-103/5) dans un environnement virtuel. Le document inclura le passage à une simulation de formation VTS en ligne complète, reproduisant le centre VTS, y compris la formation en équipe, grâce à une combinaison de différentes technologies en ligne.

En examinant ce qui s'est bien passé et ce qui a été révisé au cours de la prestation de plusieurs cours au cours des dernières années, la présentation identifiera les options pour des travaux supplémentaires dans ce domaine, y compris le processus d'approbation pour la prestation de formation en ligne ; poursuite du développement de la formation en ligne; et les prochaines étapes à mesure que nous apprenons de la pandémie de Covid pour entrer dans une ère post-pandémique.

MOTS CLÉS : Formation VTS, Solutions innovantes, Simulation de formation VTS, processus d'approbation

RESUMEN DEL ARTICULO

Durante los últimos años, hemos visto un progreso significativo a medida que adoptamos herramientas habilitadas a través de la Transformación Digital del Entorno Marítimo. Si bien no pudimos reunirnos en el mismo entorno "físico", aprendimos a reunirnos, comunicarnos y colaborar utilizando diferentes herramientas en línea. Esto incluía la necesidad de encontrar soluciones innovadoras para brindar capacitación crítica, como la capacitación VTS, en línea. La presentación se centrará en los beneficios concretos de poner la formación VTS 'en línea' centrándose en la entrega en línea exitosa de la formación VTS en el puesto de trabajo (C0103-4, anteriormente V-103/4), Operador VTS (C0103-1, anteriormente V-103/1), VTS Supervisor (C0103-2, antes V-103/2) y VTS Recurrente (C0103-5, antes V-103/5) formación en entorno virtual. El documento incluirá el

paso a una simulación de formación VTS en línea completa, replicando el centro VTS, incluida la formación en equipo, a través de una combinación de diferentes tecnologías en línea.

Al observar lo que salió bien y lo que se revisó en el curso de múltiples entregas de cursos en los últimos años, la presentación identificará opciones para seguir trabajando en esta área, incluido el proceso de aprobación para la entrega de capacitación en línea; mayor desarrollo de la formación en línea; y los próximos pasos a medida que aprendemos de la pandemia de Covid para pasar a una era pospandémica.

PALABRAS CLAVE: Formación VTS, Soluciones innovadoras, Simulación de Formación VTS, Proceso de homologación

1 INTRODUCTION

The maritime industry is one of the most critical and complex industries in the world. The Organisation for Economic Co-operation and Development (OECD) notes that around 90% of traded goods are carried by ship [1]. The UNCTAD Review of Maritime Transport 2022 note that ships delivery over 80% of world trade and highlight that disruptions in ports and shipping lanes mean food, energy and medicine shortages [2]. In addition, businesses and production lines that have limited access, or delayed access, to raw materials and supplies results in soaring prices for consumers.

Ports, shipping companies and transport operators need to chart a new course to support resiliency, including ensuring adequate and skilled labour. Vessel traffic services (VTS) are a crucial aspect of the safe, efficient and pollution free operation within ports as well as coastal areas. The traditional approach to VTS training has been in-person training, which has its limitations, including the availability of training facilities, time, and resources. The COVID-19 pandemic further amplified these limitations, driving the need for alternative training methods.

This paper aims to explore the challenges and opportunities of implementing concrete concepts in a virtual environment, specifically in the context of putting maritime education and training (MET) online, including simulation training. The example used will focus on the move by the AMC Search (AMCS), the training and consultancy division of the Australian Maritime College (AMC) at the University of Tasmania, to move the training of Vessel Traffic Services (VTS) personnel from a 'physical' synchronous training environment to a 'virtual' synchronous training environment. The paper discusses challenges of moving the training online; the solutions implemented to address these challenges and the advantages of creating an interactive virtual training environment, including simulation training.

By examining the concrete concepts in a virtual environment, we hope to shed light on the potential of virtual training simulators and how they can be utilized to enhance the training of seafarers in the maritime industry.

2 CHALLENGES FACING MARITIME EDUCATION AND TRAINING DURING COVID

When it became apparent that there were going to be severe disruptions due to the global pandemic, the maritime industry, like many other industries, faced a range of challenges. For maritime education and training (MET) these included:

[1] **Health and safety concerns**: Training centres had to implement new health and safety measures to ensure that students and trainers were protected from the virus.

[2] **Distancing Requirements**: To address the health and safety concerns, training centres that did remain open had to deal with the requirement for social distancing or implementation of measures to separate trainees with physical barriers. (Figure 1)

[3] **Reduced capacity:** Those training centres that were able to remain open had to reduce their capacity to comply with social distancing requirements. This led to longer wait times for students to attend training.

[4] **Travel restrictions:** The pandemic led to widespread travel restrictions, which made it difficult for students and trainers to travel to training centres. This was particularly challenging for students and instructors who

needed to travel internationally to attend training. Within some countries significant travel restrictions were in place within the country, in some cases cities or areas within a city faced focused lockdowns.

[5] **Reduced availability of trainers:** Many trainers were unable to work due to illness, quarantine, or other pandemic-related reasons. This led to a shortage of available trainers and made it difficult for training centres to operate at full capacity.

[6] **Closure of training centres:** Many maritime training centres were forced to close due to lockdown measures and travelling restrictions. This made it difficult for students to complete their training and for new students to begin their training.

[7] **Difficulties for audit and accreditation:** Maritime education and training is provided to meet the requirements of international, regional, and national standards. This means the training institutes, and the training programs themselves, must be audited for accreditation. Onsite visits for audits became impossible during the lockdown periods.

Figure 2: VTS OJT Zeebrugge, February 2021, with physical barriers (photo courtesy of Stefaan Priem)

Overall, these challenges made it difficult for maritime training to continue as usual during the pandemic. However, developments in technology and the rise in use of the existing online platforms, such as MSTeams, GoToMeeting and Zoom meant that many training centres were able to adapt and offer online or remote training to students.

3 DEVELOPMENTS IN TECHNOLOGY

While COVID-19 pandemic created numerous challenges for the maritime industry, including disruptions to traditional training and education methods, it also provided an opportunity to 'pivot' work processes to make best use of technology. Technology developments helped to mitigate the many challenges facing maritime training organisations using virtual environments and online platforms. In some cases, the technology was already being used while in others the technology was developed rapidly to meet the demand.

Some of the key developments in technology that helped mitigate the challenges of MET during the pandemic include:

- Learning management systems
- Virtual and online learning platforms
- Online / cloud-based simulation

- Augmented and virtual reality
- Remote assessment

4 LEARNING MANAGEMENT SYSTEMS

A Learning Management System (LMS) is a software application that facilitates the delivery of educational courses, training programs, or learning and development programs. The LMS provides an online platform for instructors and learners to communicate, collaborate, and manage course materials and assignments. The system can be used by educational institutions, corporations, and government agencies for the delivery of training and education programs.

LMS based on software were initially introduced in the 1990's where files and data could be accessed by teachers and students, with private email and public forums [3]. Over the decades the capability of LMS has grown, with the first LMS hosted in an online 'cloud' environment from 2012.

LMSs typically offer a wide range of features, such as course creation and management, assessment and evaluation tools, reporting and analytics, and communication and collaboration tools. These features enable instructors and learners to work together in a flexible and efficient manner. Instructors can upload course materials, create and grade assignments, and provide feedback to learners. Learners can access course materials, complete assignments, and collaborate with peers and instructors. LMSs can be used in a variety of settings, from traditional classroom-based education to online and hybrid learning environments.

Prior to the pandemic, the AMCS VTS training was already using the University of Tasmania LMS 'MyLo' as the repository for reference material, access to the classroom activities, including power points as presented, and managing student marks for assessments and tests. During the pivot to online training, the role of MyLo remained, continuing to act as a focal point for the sharing of classroom activities access to course material, including assignments and assessments, was possible through the ongoing use of LMS.

4.1 Virtual and Online Learning Platforms

The use of virtual and online learning platforms has been essential in supporting learning during the pandemic, providing a way for instructors and learners to continue with their courses and training despite physical distancing requirements and travel restrictions. They provide an opportunity to facilitate interactive and engaging synchronous training sessions, using communication tools that allowed trainees to participate in collaborative learning experiences remotely.

Some features to support effective learning interventions include: [4] [5]

- Flexibility and Support – access to course materials and activities such as course notes, presentations, videos, sound files
- Collaboration – ability to interact with instructors and other course participants with visual, audio and text based interactions
- Usability – supporting an interactive learning environment including breakout rooms, shared whiteboards, annotated screens
- Bandwidth – recognising limitations in internet speed, and minimizing the platform requirements to maximise the learning experience
- Security – ensuring a secure link, but also ensuring secure and safe learning environments.

Another important benefit of virtual and online learning platforms is their ability to support a range of learning styles. These platforms can offer a range of resources, including videos, podcasts, interactive simulations, and quizzes. This variety of resources helps to engage learners and accommodate different learning preferences.

4.2 Cloud-based Simulation

Cloud-based simulation refers to a simulation process that is performed on remote servers over the internet, instead of being run on local hardware. Prior to the pandemic work was already underway to move maritime simulation technology to a cloud-based environment; the pandemic accelerated adoption of the 'cloud' concept, as part of the pandemic 'pivot' of digital transformation and digitalization. Cloud based simulators use cloud computing technology to process complex computations and simulations by distributing the workload across multiple servers. Within a few months of the pandemic, Microsoft CEO Satya Nadella noted that the company had seen two years of digital transformation in two months, with more customers adopting cloud solutions [6]

Using simulators in a cloud environment provides the opportunity for trainees to gain practical experience in a virtual environment, joining from different locations in different timezones. By using cloud-based simulation, organizations can avoid the need to invest in expensive hardware and software infrastructure for simulations. Instead, they can rent cloud computing resources on a pay-per-use basis, allowing them to scale their simulation capacity up or down as needed. This can lead to significant cost savings, increased flexibility, and faster simulation times.

The AMCS VTS Training was already using the Wartsila NaviHarbour VTS simulation tool. When the training was put online, the same tool, with the existing simulation exercise stack, was used with access to physical machines at a remote location, accessed through TeamViewer. More recently, the simulation tool is via RDP (remote desktop protocol) to cloud based instances of the same simulation tool. An example of online simulation is provided in Figure 2.

Figure 3: Online VTS Simulation Training Activity, AMCS VTS Supervisor Course, March 2022

4.3 Augmented Reality and Virtual Reality

Augmented reality (AR) and Virtual Reality (VR) technology have also helped with maritime training during the pandemic. By overlaying digital information onto the real world, AR allows trainees to engage with training materials and simulations in a more immersive and interactive way. VR technology can provide an immersive environment where trainees address specific emergency situations.

VR based simulations take simulation training to the next step, providing a highly engaging learning environment with a psychological presence of 'being there'. Through connectivity, students at different locations can participate collaboratively in hands-on learning activities.

4.4 Remote Assessment

The use of remote assessment tools has also been critical in enabling maritime training during the pandemic. These tools allow trainers to evaluate trainees' knowledge and skills from a distance, using virtual simulations and real-time feedback mechanisms. This technology has helped to ensure that trainees receive accurate and timely feedback on their performance, even when in-person assessments are not possible.

Within an LMS, the use of online testing and assignments are common. These tests tend to focus on the types of questions that can be automatically assessed – true/false; multiple choice; multi choice (chose all that apply); listing or ordering questions; matching questions and some key word short answer questions.

Key concerns with remote assessment include how to invigilate (monitor) an assessment and how to assess performance.

Invigilation: Invigilation can be done using software that monitors the learner's computer and internet activity, with remote proctor software or the use of synchronous tools, such as confirmation of workspace and then physically monitoring students during tests visually (webcam).

Performance assessments: Performance assessments involve evaluating the learner's practical skills through remote means. For an online assessment this can be done through video recordings of the learner performing tasks or simulations that evaluate the learner's ability to apply knowledge to real-world scenarios.

5 PUTTING VTS TRAINING 'ONLINE'

The maritime industry has always relied heavily on in-person training, and it is not hard to see why. When it comes to training Vessel Traffic Services (VTS) operators, the importance of hands-on experience cannot be overstated. However, the COVID-19 pandemic challenged the traditional approach to VTS training.

5.1 Challenges of online VTS training

One of the most significant challenges of online VTS training is the (perceived) lack of hands-on experience or student/student, instructor/student interaction. More traditional approaches to distance or e-learning has been predominantly asynchronous (not in 'real' time) with little interaction between instructor and student, and between students themselves.

This leads to the challenge of addressing the practical aspects of VTS when provided through online tools using cloud-based simulation training. VTS operations require constant communication between operators, vessels, and other stakeholders using VHF radios, telephones and digital communications such as email. In an online environment, the challenge is to replicate this level of communication and interaction.

With training available 'anywhere' the global nature led to challenges of participation from different time zones and circadian rhythms with some students commencing their training 'day' at 0500, while others may be starting at 1900. Other concerns include eye strain and 'zoom-fatigue' as well as technical issues from personal digital intelligence to internet connectivity. Figure 3 presents some of the comments commonly shared at the beginning of the course, using the interaction tool 'Mentimeter'.

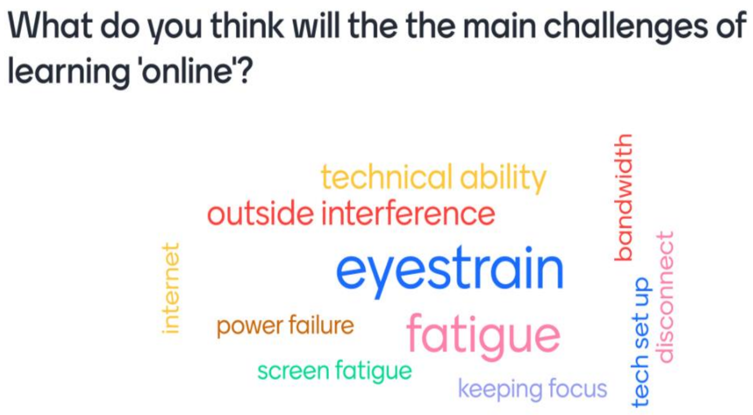

Figure 4: Word cloud from the beginning of the training on 'challenges'

5.2 VTS Training online – the reality

To provide an effective learning environment, putting training 'online' needs to consider the core focus, goals of the 'in person' training. The focus is always on quality training to meet stated objectives and adult learning theory, or andragogy, with a structured approach to experiential learning. [7]

In essence, there is a need to consider how to make online learning, including online simulation training **STICK:**

- addressing the **Sequencing** of the learning making use of both synchronous (in real time) and asynchronous learning opportunities;
- providing the **Technology** to support the learning environment;
- focusing on **Interaction** to enrich the learning process;
- ensuring the objectives are addressed through relevant **Content**; and
- providing opportunities to implement, and measure, the **Knowledge** transfer. [8]

Through an ongoing focus on the objectives of the training, the presentation of the material can be provided in an interactive and engaging manner. The discovery learning approach, with a focus on experiential learning theory, provides the students with the opportunity to achieve the higher order thinking skills identified within the IALA VTS Training model course. Table 1 provides an overview of the physical training space requirements and opportunities to address these in the online environment and the approach used in the AMCS VTS Online Training.

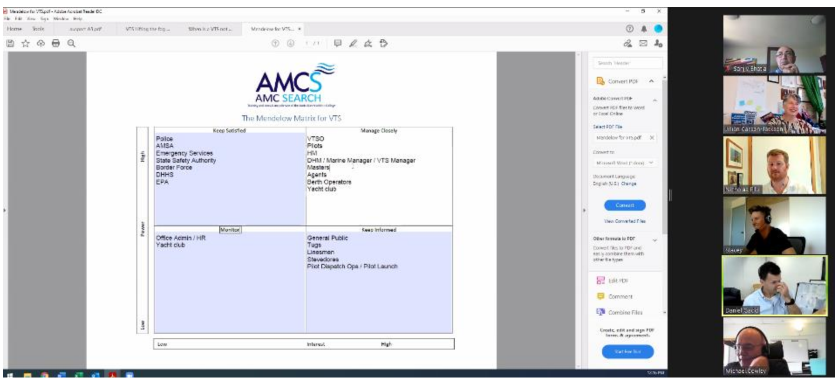

Figure 5: Online interaction – building a Mendelow Matrix for stakeholder engagement, AMCS VTS Supervisor Training, December 2020

Table 2 Physical training requirements with Online Training equivalent

Physical Training	Online Equivalent	Tool used in online VTS Course
For theory presentations / classroom activities		
Learning Management System	Learning Management System	LMS 'MyLo'
Training space with reference materials	Virtual learning space with reference materials	LMS 'MyLo' with reference section updated for each course
Full classroom interaction	Virtual classroom with video and audio feeds	Zoom, including video, audio and chat box Mentimeter polls, rating statements
Small group discussion / activities	Breakout room option within the virtual classroom tool	Zoom break out, students use tools available for share screen, annotate, chatbox
Brainstorming activities using white boards or flip charts	Whiteboard feature in virtual classroom too, Use of mindmap software shared online	mindjet mindmanager (results put into MSWord and then uploaded to MyLo)
Demonstration of information / sharing of ideas using white boards or Flip chart activities	Collaboration tools in virtual classroom tool - annotate feature / white board	Zoom annotate feature and white board feature (captured and included in ppts, which are then uploaded to MyLo)
Guest lecture / expert presenters	Guest lecture / expert presenters	Zoom (provides increased opportunity to access expertise)
Ongoing review of content presented and preparation for tests	Verbal and breakout room review activities, online 'quizzes'	Zoom, break out rooms Kahoot quizzes prior to each test
Interaction / sense of being part of a cohort (incidental learning during breaks, after hours)	Opportunities for interaction, sharing of knowledge and experience	Zoom, including breakout rooms; group activities; building in 'fun' to course What's App group for out-of-hours interaction (also used to support technical issues when they arise)
For simulation training		

Physical Training	Online Equivalent	Tool used in online VTS Course
Simulated VTS Decision Support Tool	Simulated VTS Decision Support Tool	Wartsila cloud based VTS simulator
Simulated VHF radio	Simulated VHF radio	Zello (free app for smart devices)
Simulated telephone lines	Simulated telephone line	Skype (free app for smart devices or computer)
Time of day activities – adjustable clock in simulator	Time of day activities	Microsoft XNote Stopwatch / related 'time' app that can set custom time (free app for smart device or computer)
Training spaces for: • VTS Centre • Simulation control room • Outside world / Port Team	Breakout rooms for: • VTS Centre • Simulation control room • Outside world / Port Team	Zoom (set up of breakout rooms for each simulation activity)
Peer Monitor (Student as Peer Monitor sits in the VTS Centre and monitors the activity, making notes as per Peer Monitor Form)	Peer Monitor (Student as Peer Monitor monitors the activity in the VTS Centre, making notes as per Peer Monitor Form)	Zoom (peer monitor placed in the VTS Centre, student being monitored shares their screen, peer monitor listens to VHF communications on the identified channel using Zello, making notes on the Peer Monitor form)

5.3 Benefits of online training

There are many benefits to online training, including: accessibility, flexibility, time and cost benefits, and support for diversity, equity and inclusion. These benefits have been seen in the online VTS training:

Accessibility: One of the most significant benefits of online VTS training is accessibility. Online training allows trainees to access training materials from anywhere in the world, as long as they have an internet connection. This is particularly beneficial for trainees who may not have access to training facilities or who are unable to travel due to restrictions. As VTS is a shift-work environment, the impact of time zones was minimized by the concept of doing training on 'night shift' or 'morning shift'. During the courses students share their own tips and tricks to manage their fatigue.

Flexibility: The flexible access to VTS training provides an opportunity for global participation. With the online training provided through the AMC Search, for example, students cohorts for VTS training have included all areas of Australia working with students from Brazil, Papua New Guinea and Saudi Arabia. The sharing of experiences from across the globe supports consistent provision of VTS based on the international standards and best practices.

Time and Cost benefits: Online VTS training can offer overall cost savings. Without the need for travel, accommodation, and other associated expenses, online training can be significantly cheaper than in-person training. Time is saved through travel to/from the training centre. For instructors, the increased use of automated marking tools can assist in managing the time to ensure focused online interactions.

Support for DEI: The accessible nature of online training can support diversity, equity and inclusion for students who may be limited in travel due to carer duties or health issues. The use of multiple engagement tools can be less confronting to some learners, who may have language difficulties. Through peer-to-peer interaction, students can develop networks that remain after the training has been completed.

While technical challenges do arise and are recognised, the VTSO already deals with a significant amount of technology – including the DST with fused data from radar and AIS, radio and recording tools, logkeeping applications and more. One of the 'incidental' learning outcomes of the training online is increased digital intelligence and confidence. Comments from both learners and organisations for the online training continue to be positive (Figure 4)

The benefits of online training continue to be realized in the post-pandemic environment. Learning from the challenges of the covid 'pivot' we are able to make use of technology to respond to the demand for maritime education and training.

> *"Very comprehensive and kept interesting for the entire workshop. [I] Struggled with the technology at first, but got into the swing." (VTS Training participant)*
>
> *"It allowed our staff to interact with and learn from students and instructors from around the country. We found the simulation component just as engaging as in person training and were very impressed with the standard of the overall product." (VTS Provider)*

Figure 6: Comments from students VTS Provider regarding the online VTS training

6 ACCREDITATION AND APPROVAL FOR ONLINE TRAINING

The accreditation of training is a fundamental component in MET. Specifically, for VTS, accreditation and approval are critical components of Vessel Traffic Services (VTS) training, as outlined in IALA Guideline 1014. The accreditation for the training organisation, with approval for each of the specific training programs, has been developed to ensure that trainees receive a high-quality education and that training programs meet international best practice and industry standards.

"Accreditation is the formal endorsement by a competent authority that a training organization operates under a quality management system to deliver effective training" [9]

Accreditation and approval of online training should continue to reflect the same process as for 'physical' training, with audits including:

- Leadership and commitment
- Policies
- Risk management, including actions to identify and address risks and opportunities
- Educational organisation objectives
- Resources, competence and awareness
- Planning and monitoring
- Training material development, documentation
- Delivery
- Continuous improvement

The accreditation and approval process for online training is therefore consistent with the accreditation and approval process for 'physical' training programs. The revision of IALA G1014 includes reference to the use of online simulation technology. Noting the increased implementation of online training technologies, it is proposed that the IALA VTS Committee prepare guidance on remote training in VTS during the 2023-2027 work programme.

7 CONCLUSIONS

In conclusion, technological developments have played a vital role in facilitating maritime training during the pandemic. By enabling remote and virtual learning environments, cloud-based simulation, augmented reality, and remote assessment tools, technology has helped to ensure that maritime training continues to meet the highest standards of safety and efficiency. As the maritime industry continues to evolve, ongoing investment in technology development will be critical to ensuring that training programs continue to reflect clearly identified objectives, are delivered in a manner that meets the needs of the students and the industry, and are accessible to all.

Online training, like any training program, requires careful consideration of the objectives and approaches taken. Within the online environment, the concept of STICK – sequence, technology, interaction, content and knowledge transfer – is critical. Through effective integration of different tools to address specific learning outcomes there is opportunity to develop training programs that are engaging and appropriate to meet the required competence levels.

Looking ahead, the maritime industry is facing an ongoing challenge to provide training in a world that has changed due to the global pandemic. While online training offers many benefits, such as accessibility, flexibility, and cost-effectiveness, it also poses challenges that need to be addressed, including technology access, bandwidth requirements and instructor skill sets. However, with the right tools and interactive facilitation, online training can provide a viable alternative to traditional 'in the physical' training. As the industry continues to embrace digitalisation, it is likely that online training will become an increasingly important part of maritime education and training.

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AUTHOR BIOGRAPHY

A transplanted Canadian, now living in Australia, Jillian Carson-Jackson has almost four decades of experience in the maritime industry. She has experience both afloat and ashore, she has management experience in different government areas, including aids to navigation (AtoN), Vessel Traffic Services (VTS), shore station radio operations, regulation of maritime pilots, vessel tracking and maritime technology related fields.

Jillian is passionate about education and training, diversity, equity and inclusion, with a focus on the maritime industry. Jillian continues to work on matters related to the digitalisation of the maritime industry, risk assessment and mitigation, and maritime education and training. She is a Director of GlobalMET, an adjunct senior researcher with the University of Tasmania (Australian Maritime College) and a Board member of Captains without Borders.

Jillian is the immediate Past President of the Nautical Institute (International) and an active member of the NI South East Australia branch. Jillian's expertise in navigation, education, vessel tracking, and maritime radio communication technology has been recognised by the award of Fellowships with both the Royal Institute of Navigation and the Nautical Institute. Over the past three years Jillian has been actively promoting alternative approaches to the provision of training, including online, hybrid and just-in-time training initiatives.

S9.4 Characteristic of Inexperienced VTS Operators in Japan and Introduction of Education using ship-handling Simulators (027)

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ABSTRACT

By performing interviews on inappropriate behavior observed in inexperienced VTS operators to VTS supervisors etc., we have classified the results of such interviews for each module indicated in IALA Model Course V-103/1. Utilizing inappropriate behavior indicated in each table as a guideline, we have proposed to efficiently improve the skills of such inexperienced VTS operators by implementing VTS simulator training specialized in improvement of their behavior. However, Module 4: Nautical Knowledge included many matters where we cannot expect improvement by VTS simulator training. Because of this, we have introduced the examples that have adopted methods for education and training using ship-handling simulator to education for VTS operators.

By implementing education and training using ship-handling simulator, it became possible for us to make VTS operators understand the necessity for information provision from the viewpoint of shiphandlers.

KEYWORDS: IALA Model Course V-103/1, module, nautical knowledge, information provision, training

10 INTRODUCTION

Japan Coast Guard that control Vessel Traffic Service Centers has been providing education in line with IALA Model Course V103 Standards, depending on the position of VTS Operators since 2010. For those who complete the training, examination on VTS Training Accreditation shall be implemented and, for those who pass the examination, Certification of Approval of VTS Training Accreditation shall be issued.

Additionally, as recommended by IALA Guideline No.1027 [1], Japan Coast Guard has introduced VTS simulator. In order to enhance skill training for new VTS Operators and team management skills on the job site of VTS operation, other than the education and training in Japan Coast Guard School (including Moji School Branch), by introducing VTS simulator to all Vessel Traffic Service Centers, training has been implemented in the intervals of navigation supervision and control operations.

Besides, in IALA Model Course V-103/1 [2] (hereinafter described as “V103/1”.), a specific subject representing a requirement or function of a VTS Operator is classified into eight modules. The items of Module 1 to 8 shall be listed as below:

Module 1: Language	Module 2: Traffic Management
Module 3: Equipment	Module 4: Nautical Knowledge
Module 5: Communication/Co-ordination	Module 6: VHF Radio
Module 7: Personal Attributes	Module 8: Emergency Situations

Each module mentioned above contains a subject framework stating its scope and aims, a subject outline and a detailed teaching syllabus. In the education and training using VTS simulator, as it is possible to prepare the scenario specialized to the module desirable to be learnt and evaluate the training and competence, the concept of module itself has excellent compatibility with the education and training using VTS simulator.

In the education and training using ship-handling simulator for ship officers, the same concept has been developed as Nine Elemental Techniques by Kobayashi et al. and been put into practical use [3][4].

However, the contents of each module described in V-301/1 are forced to be the standardized ones for VTS education of member countries, such contents are slightly lack in embodiment. Therefore, the instructors in education and training institutions or on-the-job training (OJT) are required to embody the contents of modules upon implementing education and training for new VTS operators. Especially for the instructors in OJT whose time cannot be spared only for education, as such instructors are required to provide education and training efficiently, it has become an issue for them to extract the skills to make such new VTS operators learn on a priority basis. In order to resolve these issues, the author decided to perform interviews on inappropriate behavior indicated by inexperienced VTS operators and to classify the results of such interviews for each module.

11 PRECEDING STUDIES ON MARITIME EDUCATION AND TRAINING

In maritime education and training, in order to attain embodiment and rationalization of STCW Code [5] adopted by IMO, Kobayashi et al. performed task analysis on the competence required for captains and navigating officers [3]. The results of such analysis were classified into Nine Elemental Techniques as "Planning", "Lookout", "Position fixing", "Maneuvering", "Observing laws and regulations", "Communication", "Instrumental operation", "Emergency treatment" and "Management". Nine Elemental Techniques have been put into practice to maritime education and training using ship-handling simulator [4]. Each elemental technique may be likened to module described in V-103/1.

Additionally, Ito and Kobayashi clarified the characteristics of inexperienced navigating officer in order to improve the current situation where the behavior of inexperienced navigating officers in practical operation often impede safe navigation of vessels [6]. Additionally, those characteristics of behavior were classified and organized by Kobayashi for each elemental technique [4]. So far, not only the subject requirements required for beginning navigating officers but also the ones required only for the captains or senior navigating officers were included. However, as the characteristics of skills at which in experienced navigating officers including beginning ones are especially poor were organized, it became possible to develop training specialized in overcoming the skills at which inexperienced navigating officers are poor. This is expected to contribute not only to education and training using ship-handling in the training facilities but also to optimization of OJT.

12 RESEARCH ON CHARACTERISTICS OF BEHAVIOR BY INEXPERIENCED VTS OPERATORS

The procedures of the preceding studies on maritime education and training mentioned in the preceding chapter is expected to be applied to education and training for VTS operators. Accordingly, interviews have been performed on unsatisfactory behavior indicated by inexperienced VTS operators to 30 VTS Supervisors (these persons are VTS supervisors who have considerable experience.). The results of inappropriate behavior obtained by the research were classified for each module indicated in V103/1 and their characteristics were discussed.

However, since the results of the research on Module 1 (Language) have already been reported by Takagi et.al [7], and Module 7 (Personal Attributes) was determined not to be subject to the research as it has little relevance with the length of experience period of VTS operations, these modules were determined to be excluded from subjects of the research.

13 CHARACTERISTICS OF BEHAVIOR INDICATED BY INEXPERIENCED VTS OPERATORS

This paper will discuss Modules 2 to Module 4 due to space limitations. In Table 1 to 3, the examples of inappropriate behavior indicated by inexperienced VTS operators which VTS supervisors pointed out for each module. The characteristics of inappropriate behavior for each module are as follows:

Table 3 Module 2: Characteristics on Traffic Management

<Matters that could fall under VTS in general>

Inexperienced VTS Operators

- ☐ fail to confirm vessels scheduled to navigate before their duty.
- ☐ take long time to determine if the vessel is required to organize navigation or not.
- ☐ cannot arrange the order for entering traffic routes appropriately as they unnecessarily stick to the predetermined one.
- ☐ fail to confirm the time to enter traffic routes for multiple vessels at the same time.
- ☐ cannot predict the presence of change in the scheduled entry time of vessels into traffic routes as they fail to confirm the position of the vessels in the distance by AIS.
- ☐ fail to pay attention to the vessels navigating the outer edge of the information service area and the edge of traffic route, or the vicinity of the median line.
- ☐ hesitate to warn the vessels that violate navigation rules, even though they recognize such violation.
- ☐ yield to acceptance of inappropriate request by pilots as it is.
- ☐ cannot foresee the vessels that are likely to send position reporting.
- ☐ cannot identify newly occurred danger as they do not read CPA and TCPA after ships alter her course or change her speed.

<Matters specific to sea areas>

Inexperienced VTS Operators

- ☐ inadequately understand the relevant laws and regulations established for each sea area and administrative guidance.
- ☐ fail to understand receiving period specified.
- ☐ accept the time to enter traffic routes by ignoring specified time intervals.
- ☐ fail to completely understand the rules to switch signals for entering and leaving from traffic routes.
- ☐ fail to understand operation places of fishing boats depending on the tidal currents.
- ☐ cannot predict the time for entering and leaving from traffic routes by type of vessel and current velocity of tidal current.
- ☐ fail to memorize the names of places including the names specific to the regions, numbers of light buoys and names of berths.
- ☐ cannot predict the presence of change in the time to enter traffic routes from the situations of leaving from ports in the vicinities of ports.

Table 2 Module 3: Characteristics on Equipment

<Inappropriate use of the graphic display>

Inexperienced VTS Operators

- ☐ fail to tune their radar accurately.
- ☐ fail to confirm change in shape of radar echo by magnification of video by which changing course of vessels may be grasped earlier than by target tracking.
- ☐ use display range and area without changing to the optimized ones.
- ☐ tend to excessively concentrate on narrow range without widely monitoring sea areas.
- ☐ cannot simultaneously monitor multiple vessels due to paying too much attention to one event.
- ☐ cannot make an accurate prediction of future situations as they fail to use the vector length without selecting optimized one.
- ☐ cannot reassign ID for lost target.
- ☐ fail to use the past track display functions effective for distinguishing between echo and false image.

<Inappropriate use of the character display>

Inexperienced VTS Operators

- ☐ spend too much time on data entry.
- ☐ cannot monitor the graphic display and listen VHF while entering data.

<Inappropriate use of Industrial Television (I-TV) or binocular glasses>

Inexperienced VTS Operators

- ☐ do not make efforts to confirm names of vessels and actual status by using I-TV and binocular glasses.

<Others>

Inexperienced VTS Operators

- ☐ cannot integrate information obtained by multiple devices.
- ☐ take too much time to fix their eyes on any one device.

Table 3 Characteristics on Module 4: Nautical Knowledge

Inexperienced VTS Operators ☐ sometimes call the vessels by radio intending to provide low-priority information deliberately while vessels are altering their course, due to lack of understanding of work situations within the vessel's bridges near the point of veering. ☐ fail to understand the difference in views of other vessels from the bridge in daytime and at night. ☐ fail to understand the impact on ship maneuverability by the disturbance such as winds and tidal currents. ☐ fail to understand the blind area for look-out from a vessel due to geography. ☐ fail to understand accelerating/decelerating performance for each type of vessel. ☐ cannot specify a type of vessel from a name of vessel (for example, "~ BRIDGE" is a container carrier operated by K-Line, "~ LEADER" is a PCC operated by NYK etc.) ☐ fail to understand nautical terminology for seaman (single up, UKC etc.)

13.1 Module 2 : Traffic Management

"Traffic Management" has the largest number of the matters pointed out as inappropriate behavior. These matters pointed out can be divided into the ones common to Vessel Traffic Service Centers and the ones specific to sea areas.

The matters pointed out common to Vessel Traffic Service Centers include the ones concerning advance preparation for and decision on arrangement of the order for entering each traffic route and the ones concerning the prediction of future situations of the vessels navigating the traffic route and the vicinities.

The matters pointed out specific to sea areas include the ones related to the rules for each sea area, the ones resulting from the tidal currents specific to the sea areas and the ones related to the geographical names specific to the sea areas.

13.2 Module 3 : Equipment

The module that had the second largest number of matters pointed out is "Equipment", which are pointed out here as common to all Vessel Traffic Service Centers. Especially, there are many matters pointed out regarding inappropriate use of the graphic display (refer to Figure 1) as the equipment that is mainly used by VTS operators. Additionally, there are also the comments regarding decision on the difference between information obtained from other equipment and the one obtained from the graphic display.

Figure 1: Equipment

13.3 Module 4 : Nautical Knowledge

The matters mainly pointed out for "Nautical Knowledge" are as follows: lack of understanding of ship maneuverability and the impact on ship maneuverability by the disturbance such as winds and tidal currents, and lack of understanding the duties of lookout for bridge. It is assumed that such matters have resulted from most of VTS operators having little experience of vessel navigation. As mentioned below, the matters pointed here include the ones that are difficult to make VTS operators understand by the use of textbooks and VTS simulator.

13.4 Summary

Inappropriate behavior observed in inexperienced VTS operators shall be summarized for each module. In general, in the case of OJT, when compared to the facilities specialized in education and training, time available for education and training is limited. Utilizing inappropriate behavior indicated in each table as a guideline, by implementing debriefing after their duty or implementing education and training specialized in each behavior improvement, it is expected that the skills can be efficiently improved. Under these circumstances, if possible, by preparing the checklist using the contents of the tables as reference and evaluating the skills using VTS simulator, the skills at which VTS operators are poor can be further extracted.

However, the matters pointed out for "Nautical Knowledge" include the contents that are difficult to make VTS operators understand by use of textbooks and VTS simulator. In the next chapter, I will discuss about this while introducing the examples of training for VTS operators using ship-handling simulator.

14 TRAINING FOR VTS OPERATORS USING SHIP-HANDLING SIMULATOR

For the purpose of deepening VTS operators' understanding of "Nautical Knowledge", in the past, there used to be an opportunity provided in order to understand the actual situations of navigation of large cargo vessels from viewpoint of ship operators by making VTS operators board a large cargo vessel navigating the sea areas monitored by each Vessel Traffic Service Center with a pilot. However, as the situations to be experienced by inexperienced VTS operators do not necessarily rise in the training while boarding the large cargo vessels, its effects were limited. Because of this, at present, by using ship-handling simulator shown in Figure 2, the training has been implemented for VTS operators to experience ship-handling of cargo vessels virtually.

Figure 2-(a) is the mock-up bridge to receive ship-handling training, and Figure 2-(b) is the console in the operators' room to control the simulator. In the operators' room, as well as VTS operations, instructors can monitor the movements of all the vessels navigating the sea area. Additionally, between the mock-up bridge and the console, communication is available by VHF radiotelephone.

(a) Mock-up bridge

(b) Console in operators' room

Figure 2: Ship-handling Simulator

In the training for VTS operators, VTS operators shall be divided into two groups, one of which shall be assigned to the mock-up bridge and another to the console. VTS operators assigned to the mock-up bridge shall handle the cargo vessel while being briefed by the instructors specialized in ship-handling training, whereas the VTS operators assigned to the console shall provide information of sea areas to VTS operators on board by VHF radiotelephone in the same way as they do in their normal control operations. VTS operator on board can judge if the contents and timing of information provision are accurate or not, from the viewpoint of ship operator. In this article, two training scenarios shall be introduced.

14.1 Necessity to provide information by taking into account the difference between daytime and night

One of the authors is specialized in marine accident analysis of vessel collision. Especially, while the movements of adjacent vessels at night shall be judged by the view of legal lights that they exabit, it is clarified that there are some cases where the said view may be the trigger for misjudgment [8][9]. Judging from this, even if the situations of vessel navigation are completely the same, it is supposed that the contents of information provided by VTS operators and the timing of such provision needs to be optimized according to daytime and nighttime.

As an example, Figure 3 shows the situation where a roll-on/roll-off ship (Ro-Ro) altered her course to starboard at the bending point of the traffic route after the Ro-Ro overtook a general cargo ship from the port side within the controlled traffic route. Additionally, Figure 4 shows the Ro-Ro altering her course to starboard seen from the bridge of the general cargo ship.

In the daytime, the navigation officer on duty of the general cargo ship can easily judge the situation where the Ro-Ro started turning around by the apparent change in her aspect. On the other hand, at night, they must judge the same situation only one sternlight of the Ro-Ro as her body cannot be seen. As Figure 4 suggests, even if the change in the situations can be grasped in a short time during daytime, such change in the situations may be delayed or may not be completely noticed at night. That means that information needs to be provided earlier than in daytime, and also assuming that the counter party has not grasped such change in the situations.

VTS operators grasp the movements of vessels mainly by the graphic display shown in Figure 1. Because of this, it is difficult to understand how the quality of information that ship-handlers can obtain differs according to day and night. In order to make VTS operators understand such circumstances, education and training using ship-handling simulator is effective.

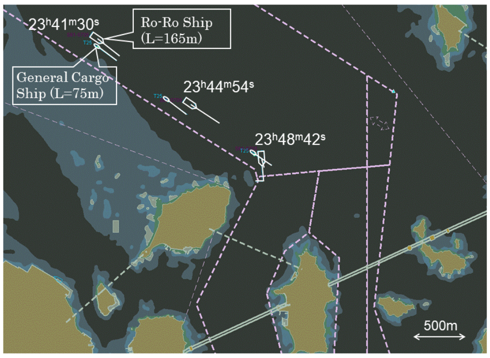

Figure 3: Collision status after overtaking

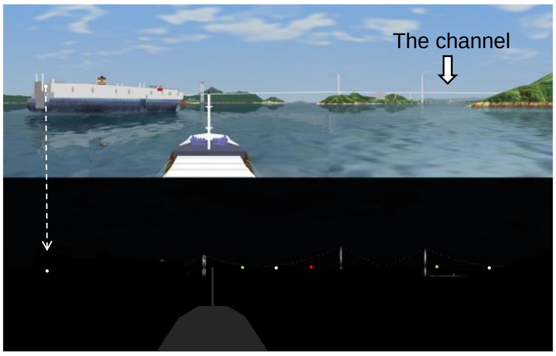

Figure 4: Ro-Ro on the way of altering her course seen from the general cargo ship

14.2 Difficulties in Controlling Vessel Position during Disturbance and Significance of Information Provision

Figure 5 and Figure 6 show the congestion status of vessels that occurred within a controlled traffic route after a typhoon passed in a certain morning. The east wind of 10～12m/s was still blowing. The VTS operators were divided into two groups: one group handles Pure Car Carrier (PCC) indicated by yellow and another one provides information required for the PCC from the operators' room by VHF radiotelephone.

Furthermore, the speed of the PCC at the dead slow ahead was 5.9 knots. Additionally, when wind speed reaches four times of the PCC speed, she would become out of control. As overtaking is prohibited at the narrowest part of the channel, vessel traffic would be increasingly congested and the situation continues where vessels should navigate by decelerating to around 3 knots consequently, as they approach the channel. In this aspect, it is extremely challenging for PCC to secure a safe distance between vessels and control her heading and positioning.

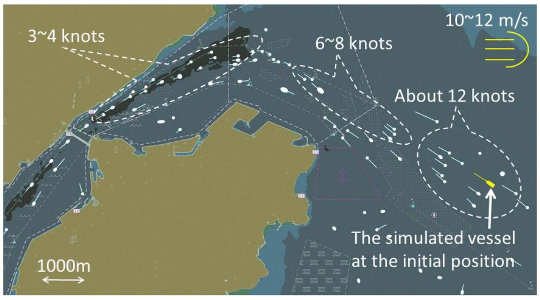

Figure 5: Congestion status after a typhoon passed

Figure 6: Congestion status seen form the simulated vessel

Such ship-handling experience will enable VTS operators to understand:

- It is impossible to grasp the situations where vessels must navigate at an extreme low speed from the sea area where vessels were navigating at 12 knots.
- It is necessary for VTS operators to provide information on the situations within the sea area where the vessels can turn around and make their captains determine whether vessels can safely pass through the channel.
- Vessels are facing difficulties in the situations where they must navigate at a low speed in strong wind, as they cannot control their course or vessel positioning without frequently maneuvering and boosting main engine.
- When caught in vessel traffic congestion, the duties within the bridge become complicated as they must repeat speed adjustment frequently while continuously measuring the distance from surrounding vessels in order to prevent collision.
- In the bridges where the duties of navigation officers become complicated, response to unnecessary radio communication may be more burden on them.

15 CONCLUSIONS

By performing interviews on inappropriate behavior observed in inexperienced VTS operators to VTS supervisors etc., we have classified the results of such interviews for each module indicated in V-103/1. This means that the competence required for VTS operators could be obtained if inappropriate behavior described in this article is corrected. Authors et.al suggests to the instructors in OJT that they can efficiently improve the competence of such inexperienced VTS operators by implementing VTS simulator training specialized in improvement of their behavior, utilizing inappropriate behavior indicated in each table as a guideline.

However, Module 4: Nautical Knowledge includes the matters that are difficult to make VTS operators understand by VTS simulator training. Because of this, the methods for education and training using ship-handling simulator have been adopted to education for VTS operators. By implementing education and training using ship-handling simulator, it has become possible to make VTS operators understand the necessity for information provision from the viewpoint of ship handlers.

16 ACKNOWLEDGEMENTS

For this article, we have obtained lots of advice from Mr. Tatsuya KAWASHIMA, Deputy Chief of Kurushima Kaikyo Vessel Traffic Service Center upon planning ship-handling training for VTS operators.

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S9.5 VTS English Communication Proficiency Criteria Based on G1132 VTS VHF Voice Communication (047)

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ABSTRACT

IALA Guideline 1132: VTS Voice Communications and Phraseology is designed to assist authorities in implementing the practices outlined in *IALA Recommendation 1012: VTS Communications*, with the goal of harmonizing VTS communications through the use of standard message structure and phraseology. IALA Guideline 1132, it is recommended that VTS Authorities put adequate procedures in place to ensure its consistent and correct implementation for the actual VTS operation, which could naturally encourage the adoption of a VTS-specific language testing system that includes specified language testing evaluation criteria for the quality assurance and sustainable maintenance of VTS communications. For this reason, the Republic of Korea made a test-bed for this during the course of the last two years. In this paper, therefore, VTS English communication proficiency test, in accordance with IALA G1132, will be proposed as the foundation for improving VTSOs' communication capabilities throughout their career lifecycle in terms of training, accreditation, and revalidation. With the aim of facilitating the discussion, a range of suggestions to be considered in the development of testing system and/or IALA guideline on the VTS English competency test will be made.

KEYWORDS: VTS English Proficiency, VTS-specific language testing system, evaluation guideline and criteria

1 INTRODUCTION

Since the successful completion of IALA Guideline G 1132, the next step can be to apply this into the actual VTS language training and gauge its effectiveness, and it is an issue to be carefully dealt with. Specifically, the development of a VTS-specific English language test reflecting the updated guideline has been requested for provision in the national training context in order to precisely gauge the trainees' levels of English from their entry to the completion of IALA model courses at different levels. Considering the fact that the VTS English test has not yet been developed for this purpose in the international context, and is in the very early stages of discussion within the IALA VTS Committee, special emphasis must first be paid to the establishment of Guidelines on VTS English competency test in order to provide a suitable guidance on testing - competent authorities, VTSOs, and training institutions. For this purpose, this paper will suggest a variety of elements that should be taken into account when developing the Guideline in compliance with IALA G 1132.

2 DISCUSSION

VTS English communication encompasses a variety of specific characteristics in terms of VHF phraseology, plain language, procedures, and message delivery techniques. Additionally, in the domain of language testing, a variety of factors should be considered, including validity, reliability, and practicality, as well as delivery mode and associated administrative procedures. In terms of developing the guideline in this regard, the following factors needs to be carefully considered.

2.1 The General Framework of the Test

The general framework of the test needs to be specified. This may include the duration of the test, the number of questions, the subject matter of the questions, the period of revalidation, the test mode, and the testing environment. The following recommendations can be made based on the results of the VTS English Competency Test administered in the Republic of Korea for the last two consecutive years and targeting all Korean VTSOs (VTS51-3.2.4).

- The duration of the test is recommended to be no more than 30 minutes, taking into account the human attention span, and the number of test questions should not exceed 10 with increasing in difficulty and complexity;
- A CBT-based test is required that permits immediate collection and electronic storage of testing data;
- The subjects of the questions must be limited to situations in which the IMO SMCP and IALA Phraseology can be applied, with a particular emphasis on evaluating for harmonized VTS communications via the usage of standard message structure and phrases.
- An expiration date for language testing should be specified, taking into account the entire career lifecycle of VTSOs in terms of training, accreditation, and revalidation, not exceeding 5 years when the washback effect is taken into account;
- Minimum standards for language testing administration should be stated, including soundproofing recording room, technical requirements/support, security, invigilation, and oversight.

2.2 Language Evaluation

With the aim of enhancing validity, reliability, and practicality, the pre-requisites for language evaluation should be established, ranging from rating scales, evaluation elements (e.g., use of standard phraseology, delivery techniques), and descriptions of each element at each level, to the qualifications of test designers and assessors. For this, the following suggestions can be made according to IMO Maritime English Model Course 3.17 and IALA Guideline 1132 – VTS Voice Communications and Phraseology:

- The rating scale can be comprised of six levels. IMO Model course suggests seven levels, beginning with 'beginner', followed by 'false beginner', 'elementary', 'lower intermediate', 'intermediate', 'upper intermediate', and 'advanced'. Given that the entrance level for VTS Model Course V103/1 is scheduled to be revised in a way to ensure an appropriate professional level of English language capabilities, the two low levels (i.e., beginner and false beginner) can be consolidated into a single 'beginner' level;
- The detailed evaluation elements must be in accordance with IALA G1132 in order to ensure consistency of standards across IALA documentation and its implementation worldwide. The major elements that can be reflected in the evaluation criteria are as follows;

Evaluation Factors	Details
Standard VTS Procedures	- Message structures (p.9) - Message markers (p.10)
Standard Phraseology	- Phonetic alphabet (p.12) - Phonetic numbers (p.12) - Position, bearings, course, distance, speed, time, geographical names (p.13-14) - Standard phrases (p.20-31)
Plain language	- General rules for construction and content of messages (p.9) - Ambiguous terminology (p.16)
Delivery techniques	- Tone and volume (p.14) - Emphasis on keywords (p.15) - Word grouping and pausing (p.15)
Interpretation and monitoring	- Questioning techniques (p.15-16) - Response (p.16)

	- Corrections (p.17) - Repetition (p.17) - How to interpret a message (p.17)

- Test designers and assessors should be comprised of a team of specialists in VTS, navigation, English training, and linguistics (English for Specific Purposes) domains, considering that VTS English training requires a high level of specialised knowledge both in language teaching and VTS operation but specialised expertise in both fields;
- In addition, the establishment of a comprehensive and complete set of VTS language testing development and assessment course needs to be developed and provided by IALA in order to achieve the highest possible standardisation of communicative output globally via testing.

3 CONCLUSION

This paper proposed that the considerations to be taken into account when the guideline on VTS English language competency test is developed on the basis of IALA Guideline G 1132, as summarized below:

First, the overall structure of the test should be clearly identified. This comprises the duration of the test, the number of questions, the subject matter of the questions, the period of revalidation, the test mode, and the testing environment.

Second, language evaluation criteria must be defined, including but not limited to rating scales, evaluation elements, as well as the qualifications of test designers and evaluators, in order to increase validity, reliability, and practicality. In terms of evaluation elements, for example, five categories can be recognized in accordance with IALA G1132: standard VTS procedures, standard phraseology, plain language, delivery techniques, interpreting and monitoring. If adopted as-is, the detailed scale and associated criteria per scale must be added to the work scope of the guideline's working group in the future.

In conclusion, for IALA Recommendation 1012 VTS Communications to be implemented in a more effective and field-oriented manner, the English communication capability of VTSOs must first be harmonized so that our service recipients, primarily seafarers navigating the globe, can exchange navigational communication in a clear, effective and timely manner. It is expected that the information contained in this paper, which focuses on the direction of the development of the VTS English competency test, would be of assistance in facilitating this process.

4 ACKNOWLEDGEMENTS

Sincere appreciation is extended to the more than 400 Korean vessel traffic operators who, with the strong backing of the Korean Coast Guard, have shown a strong commitment to implementing IALA Guideline 1132 on VTS VHF Voice Communication in their actual working environments over the past two years. Their efforts to improve the VHF Voice Communication by participating in a variety of voluntary trials, such as speaking test data, learning records, and a machine learning trial for AI-based automatic scoring, should be clearly acknowledged as having the potential to significantly advance the development of more harmonized and effective VTS communication on a global scale.

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SESSIONS 10 AND 110 – VTS TECHNOLOGIES

S10.1 Innovation decision support tools VTS operator (143)

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ABSTRACT

There is an increasing pace of technological advancement within the maritime industry that will impact the Vessel Traffic Service (VTS) operation. The possibility of supporting the VTS operator in their tasks changes with time due to advances in data sharing and more intelligent algorithms. Each opportunity to support the operator with automation or provide the operator with new or different information may seem beneficial; however, a proper assessment and system implementation is vital for a successful introduction.Several human factors issues are upon the introduction of new functionalities and information and relate to situational awareness, decision-making and workload.

In this study, the impact of several support tools on situational awareness and the VTS operator's decision-making process is scrutinized. Based on studies performed at VTS centers for two ports within the Netherlands, involving on-site observations, cognitive tasks analysis and workshops with operators, operator wishes for supportive tools are gathered, analyzed, and linked to the cognitive information processing stages of VTS tasks. The research indicates which support of situational awareness in detecting information, understanding information, and forecasting future traffic states could benefit. Furthermore, the study indicates the sensitive balance in providing the correct type of information and the proper amount of information to the operator to prevent overload. The research offers ground for assessing decision support tools for the VTS operator and the impact on situational awareness and decision-making process.

1 INTRODUCTION

Digitalization and automation have revolutionized the maritime industry, providing vessel traffic operators (VTOs) with powerful tools to manage vessel movements more safely and efficiently. Among these tools are advanced decision support systems that use real-time data from various sources to provide VTOs with actionable insights to make informed decisions and prevent potential unsafe and undesired situations. With the increasing availability of data and technology, decision support systems are becoming more sophisticated, enabling VTOs to access more accurate and comprehensive information to make better decisions.

Decision support systems could provide VTOs help in analysing complex data and visualize vessel movements, helping them to identify potential conflicts or provide VTOs with alerts and notifications for critical events, enabling them to take action promptly. However, plainly providing the VTSO with more information, cues or alarms does not simply results in better VTS task performance by the operator. The design of DSS should prioritize the operator's cognitive abilities, workload, and roles and responsibilities to provide the right information at the right time. For example, information provided should not be so complex that it becomes difficult to interpret. The system should provide easy-to-understand and actionable insights that can support the VTOs' decision-making process. Additionally, the format of data presentation should be designed to minimize cognitive load, enabling VTOs to process information quickly and accurately. Human factors and ergonomics should be considered to create an optimal workload and enhance situational awareness of VTSO's.

1.1 VTS tasks

Previous studies have examined the work of VTS operators, as evidenced by the works of Wiersma [1] and Praetorius [2], Brodje et al [3], Moreno et al [4] and the Vries [5] shedding light on the daily performance of VTSOs. Wiersma [1] emphasizes task performance, stating that "In order to perform effectively, operators must not only communicate the appropriate matters to vessels, but also do so at the appropriate moment." This underscores the significance of understanding the optimal timing for delivering specific information to vessels. The underlying cognitive processes in timely providing assistance can be describe with the conceptual model of situational awareness by Endsley [6], which is widely used and adopted in the human factors domain and in the maritime sector.

This paper highlights the need for a comprehensive understanding of how VTSOs carry out their work in order to explore the possibilities of supporting or modifying VTS tasks through new technology. With the aim of assisting in the support of VTS operators, this paper employs Endsley's (1995) model of situational awareness to describe the various VTS tasks. Additionally, it presents the design of a basic tool that aids situational awareness, based on the identified user requirements that have undergone thorough examination.

Insights on the desired support for VTS tasks were gathered with the research that involved conducting interviews with VTSOs and conducting a questionnaire. The questionnaire aimed to determine the types of support, such as cues, alarms, information, or automation, that would facilitate the performance of VTS tasks. All suggested support measures were then aligned with the situational awareness model of Endsley [6], indicating the specific level of situational awareness or decision-making step that would be bolstered.

2 METHOD

The research primarily focused on exploring how VTS tasks can be supported from a human-centered perspective. To gain a deeper understanding of the cognitive processes involved, a cognitive task analysis approach was employed to examine the various cognitive steps undertaken by operators. To gather data on VTS work practices, multiple visits were made to three VTS centers located in two major ports in the Netherlands. These visits involved observing multiple teams and spending multiple days on-site. VTSOs were engaged in discussions and interviews both during and outside their working hours to gain insights into their job performance. Additionally, a questionnaire was developed and distributed among a larger group of VTSOs to gather feedback on the usability of the current VTS operational system and gather suggestions for improvement. From the numerous suggestions received, three were selected for further exploration and to create a concept design. Initial sketches were created on paper and discussed in a design workshop involving VTSOs. Their input was utilized to define the features of the information-support tool, including determining when and which information should be displayed in the interface. This input was also used to redesign the interface itself. In collaboration with VTS system provider Tidalis, the designs were implemented in the latest VTS software suite and presented to VTSOs as a functioning tool, allowing for further refinement of the design and functional specifications.

3 VTS TASKS

Based on the cognitive task analysis, the VTS tasks were deconstructed and aligned with the situational awareness model proposed by Endsley [6], as depicted in Figure 1. Each phase of the model is briefly outlined. The primary VTS task, as identified in this study, involves providing timely and relevant information to the maritime traffic environment. This task is further broken down into five sub-tasks, which are summarized in Figure 1. Notably, Step 3 is highlighted with a red outline to underscore its significance as the most complex cognitive task in establishing situational awareness (SA). This step involves predicting or projecting future traffic situations, placing higher demands on working memory as various information sets, such as the prediction of ship intersections, need to be integrated by the VTSO.

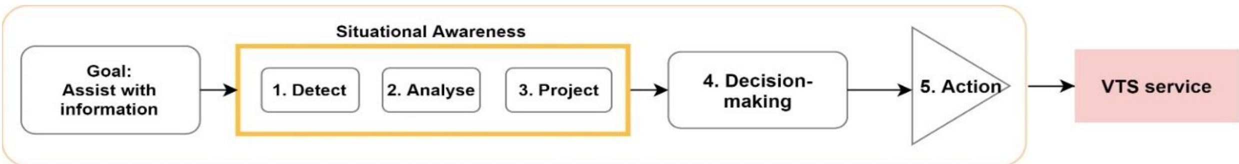

Figure 7

The detailed process of information utilization for establishing situational awareness (SA) is further expounded upon in Table 1. The table is structured into three distinct sections: 1) detection of information, 2) comprehension of the situation, and 3) projection of the traffic situation. By sequentially traversing these three steps in SA development, a cognitive representation of the current traffic scenario and anticipated relevant situations is formed. Notably, these steps may often occur in a nearly simultaneous manner; for instance, upon observing a vessel's position, speed, and course within a waterway, an expectation regarding its projected route and future location can instantaneously emerge based on prior experience. The principal activities associated with each step are delineated as follows:

1. Detection of ships in the designated area (detection)
2. Detection and monitoring of ship movements (comprehension of current situation)
3. Analysis of interactions between ships and their environment (projection of future situation)
4. Communication with ships – or other relevant parties (task execution)

Table 4 Information sets for three stages of situational awareness

Detection of situation	Understanding of the situation	Projection into the future
Ships in motion • Name/ID • Location in the sector • Speed • Course • Type of ship and associated properties • Destination Planned ships • Name/ID • Location in the sector • Type of ship • Schedule (time + destination) • Hydro and weather conditions • Work and other particulars	• Traffic intensity/crowdedness • Interpretation of positions on the waterway and in relation to the environment: traffic, reference points in the sector, and existing particularities (such as work activities) • Interpretation of current course and therefore direction of travel in relation to the environment • Interpretation of current speed (appropriate for the ship and route) • Interpretation of the available space around the ship • Interpretation of the current manoeuvre being used in relation to the environment • Interpretation of hydro & weather information on traffic situation • Interpretation of whether the vessel movement poses a direct danger/relevance to the ship or environment	• Expected travel route • Expected positions on the route (time) • Expected interactions, such as crossings and passages with ships on the route and in time • Expected passages of particularities such as diving activities • Evaluation and prediction of potential (nautical) danger to the ship or environment • Evaluation and prediction of potentially relevant interactions between actors (such as two ships crossing within a certain distance of each other), • including assessment of how ships cross or pass each other, taking into account: ship type/category, dimensions, risk profile, manoeuvrability, traffic intensity, hydro and weather conditions.

3.1 Decision-making process

Which action(s) the VTSO must take is based on the built-up SA. In the build-up of the SA, it is determined which traffic situations are or become relevant, but sometimes not all information is available to make a good assessment to determine whether assistance is useful. Depending on the certainty of the built-up SA, including the predicted traffic handling, an operator can first decide to gather more information, such as using available system tools (for example, CPA tool), or contact a vessel to get more information. For a relevant situation, a VTSO must decide whether and what action should be taken. An action means providing assistance, along with two main questions: what assistance for whom and when the assistance should be provided – which is in line what Wiersma [1] stated about VTSO performance: communicate the right issues at the right moment. Figure 2 schematically shows the main cognitive decision steps for providing assistance as a result of the cognitive task analysis.

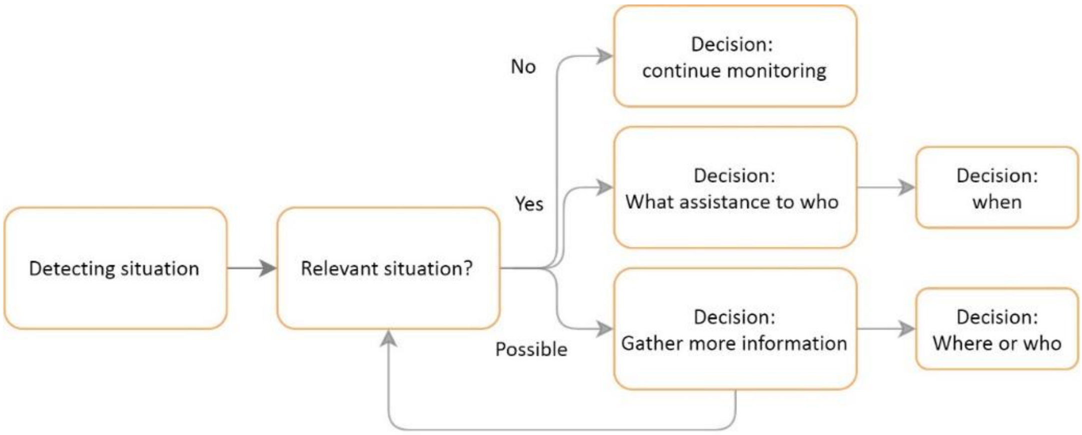

Figure 8 Decision-making steps

3.2 Planning and Time

During the decision-making phase, a VTSO develops a plan regarding the specific assistance to be provided to individuals and the appropriate timing, based on the situation awareness (SA) acquired, which relies on the use of local knowledge and anticipation to integrate information from different sources as stated by de Vries [6]. The process of formulating and implementing the plan typically involves multiple cognitive steps. The detailed specification of the plan, including the specific assistance required and the content of the provided support (e.g., information with precise distances), may be deferred and addressed at a later stage. This temporal delay depends on the assessment of when and where such information needs to be conveyed. Although the creation and execution of the plan can occur seamlessly, there may also be a time lapse between these two stages which places a cognitive demand in holding the intention to convey information at the right time and place.

3.3 Supporting VTS tasks

The cognitive task analysis is utilized to determine how VTSO's can be supported in their work through the operational system. Table 2 covers examples of such support: the left side describes on a cognitive based level how the VTSO may be supported, the right side contains examples of informational support. To provide an illustration, VTSOs are required to retain various types of information in their short-term memory during their work, such as vessel names, destinations, and sailing intentions, which need to be communicated at the appropriate time. However, there may be a delay of several minutes between gathering the information and the actual communication. In situations where VTSOs are distracted by other traffic events or engaged in communication with other vessels, there is a higher likelihood of forgetting the correct information or the intention to communicate it.

One strategy to address this challenge is to minimize the number of concurrent tasks or reduce intervening tasks that impede the completion of the initial task. Another strategy, as outlined in the right section of Table 2, involves incorporating user-friendly memory aids into the VTS operational display.

The emphasis is on the current task requirements and aims to determine the information that is valuable for operators in terms of gathering, processing, and making decisions, as well as taking actions. This serves as a foundation for selecting appropriate support formats and identifying potential information support or tools to fulfill those requirements.

Table 5

Support explained on a cognitive level	Support examples to the VTSO
Reducing the amount of information that needs to be held in working memory, which decreases cognitive load and reduces the likelihood of forgetting formed intentions, such as informing a skipper about ongoing work activities.	Providing memory aids through indications and information, such as indicating a vessels approach towards an no-go or maintenance area.
Increasing problem-driven attention and reducing heightened vigilance for changes and relevant events, which reduces cognitive load and mitigates the risk of cognitive tunneling when focusing on a single area/ship.	Providing information about relevant deviations by increasing the salience of events, such as temporarily assigning new ships a different designation.
Reducing cognitive energy when assessing situations and directing attention towards relevant events	Providing information that simplifies the interpretation of immediate safety in relation to the environment (traffic, objects, and waterway), such as using a safety zone around a ship.
Reducing the complexity of assessing future safety and enabling greater control over workload through preparatory work.	Providing information about future situations, such as predicted routes and the location and time of ships, for analyzing predicted congested intersections.

4 SUPPORT TOOLING

The results of the questionnaire and interviews with VTSO's reveals a common picture about the user-wishes of VTSO's regarding system 'support tools'. The most named types of support are listed here below:

- Collision avoidance: attention to ships on a collision course
- Grounding avoidance: marking a ship approaching shallow water with the risk of running aground
- Route deviation alert: attention to deviation from predicted or shared route
- Prediction traffic conflicts: Marks ships at risk of collision and provides advice on speed and timing at the waypoint of a critical point on the route
- Automatic critical CPA: attention to ships approaching each other (interacting) with automatic Closest Point of Approach (CPA)
- Ship alerts: attention to ships newly entering the sector, departing vessels
- Speed alert: attention to ships with speed changes (too low or too high for certain areas and sudden speed fluctuations)
- Communication alert: attention to a transmitting ship or incoming call
- Ship destination tool: a tool to easily view and adjust ship destinations

Each tool provided offers support for one or more levels of situational awareness. The suggested tools have been translated and associated with the corresponding SA levels, as depicted in Figure 3. This framework serves as a foundation for understanding how to effectively support VTSOs. For instance, several suggested tools can be linked to level one, "detection," such as tools for detecting departing vessels or directly determining the location of a vessel in communication via VHF. These aids facilitate the monitoring task of vessel movements, as outlined in Table 1. Moreover, they reduce the cognitive load and time required to locate vessels when contacted via VHF, thereby enhancing task performance.

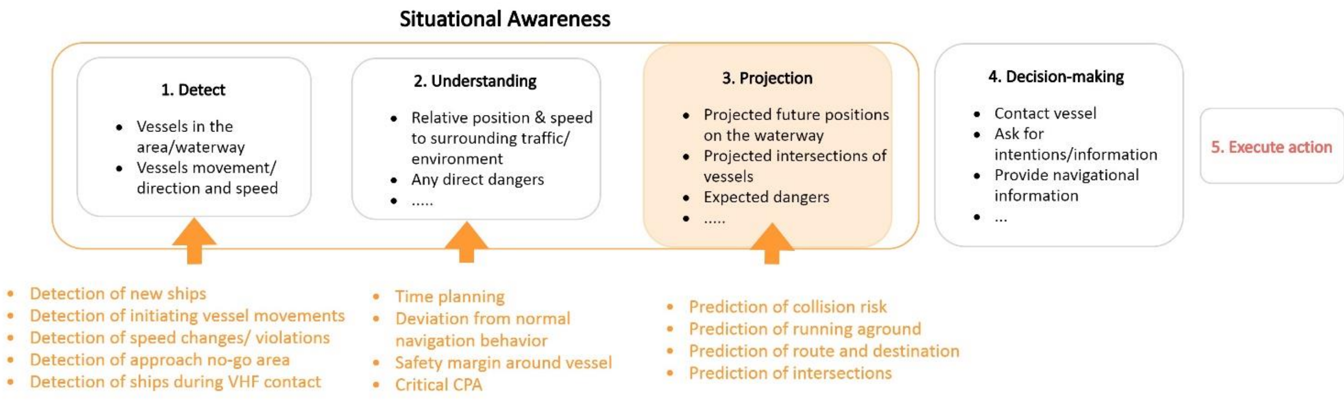

Figure 9

5 EXAMPLE CASE DESIGN OF SUPPORT TOOL: ALERT ON APPROACHING MAINTENANCE AREA

Based on the results, three suggestions for information-support were taken up for further design, one of these suggestions – an alert on approaching or speeding traffic towards a maintenance area – is explained in more detail as example case. Vessels are currently actively informed by the VTSO about on-going maintenance or restrictions in the area; there is no automatic message service that informs vessels. Based on the on-site observations, it was found that VTSOs occasionally fail to notify vessels approaching restricted or maintenance areas to adjust their speed and maintain a safe distance.

This lack of communication can lead to hazardous situations for workers, particularly when divers are involved in underwater construction or other activities. It is crucial for vessels to modify their speed and maintain an appropriate distance from these areas, with the specific requirements varying depending on the size and draught of the vessel. The responsibility for assessing the required distance and determining the appropriate speed lies – in the end – with the ship's captain or pilot.

Special circumstances or work activities need to be reported in a timely manner, such as timely reporting of diving operations. If an operator detects a ship with the expectation that it will pass by the work activities but is still far away, the operator must hold a future communication intention in memory. This is a task that burdens the operator and is not a strong suit for humans; forgetting a planned action is also one of the most common human errors. Information support indicating which ship should be informed about specific details at the right time may reduce cognitive workload and decreases the likelihood of forgetting to provide information.

To specify the user-requirements in more details, several questions were used such as which memory support is most important, how the borders of the maintenance area are defined or when the vessels speed is judged too high by the VTSO. Hereafter, the basic concept was outlined consisting of rules that defines the area/ safety zone, when a vessel forms a danger based on the type of vessel (such size, draught and so on), speed, distance to the area and course. All relevant rules were inventoried on which three alarms levels were set up, next to the basis situation of displaying the maintenance area or activities in the operational screen. The three alarming levels are:

1. Vessel is speeding near the maintenance
2. Vessel is approaching or the maintenance area
3. Vessel is hitting the maintenance area

An initial design concept for situations where a vessel approaches a maintenance area is presented in Figure 4. Discussions were held with VTSOs to determine the most practical concept and establish the necessary business rules for creating a reliable and consistent alarm. VTSOs emphasized the importance of a clear interface, which guided the design decisions. For instance, during certain maintenance activities, it was agreed upon by the VTSOs not to display the area borders unless diving activities were taking place, as this helped reduce visual clutter on the screen.

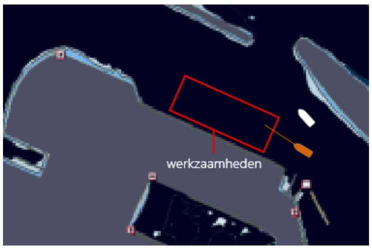

Figure 10 First mock-up design of alarm 2

The design was refined based on feedback from VTSOs and implemented as a functional design. The presentation of the design to VTSOs received positive feedback. VTSOs emphasized the importance of effective alerting and tooling, with minimal occurrence of false positive warnings that could be distracting instead of helpful in identifying the correct events and situations. Moreover, it was highlighted that the information should be presented in a simple manner, favoring the use of symbols over text to reduce reading time and screen space.

Although not all conceptual and information display issues were immediately resolved, some required more time and consideration. One such issue pertained to determining which vessels should be notified and which should not. VTSOs indicated that vessels should be informed at the "right" moment, based on factors such as their distance, course, speed, and expected route towards the maintenance area. Additionally, the relevance of the vessels varied based on their known characteristics. Since not all information is always available, certain business rules may not always be applicable or valid, necessitating additional validation by the VTSO.

The reliance on reliable data and information concerning maintenance activities and vessel characteristics influenced the ability to provide intelligence to the alerts. While some alerts could be fully automated when reliable data was available, it was suggested to establish different levels of automation for the alerting system, allowing VTSOs varying degrees of control in setting the alerts themselves.

6 CONCLUDING

The situational awareness model developed by Endsley [6] offers a valuable framework for designing decision-support tools for the VTSO. This model assists in identifying the specific cognitive steps in VTS tasks that can be supported, taking into account the available information and how it is presented to VTSOs.

The concept designs for alerting vessels approaching or speeding towards a maintenance area incorporate a range of variations in information provision and visualization, with a strong emphasis on meeting specific user requirements. These requirements were carefully considered and incorporated throughout the design process to ensure acceptance and trust among VTSOs. The workshops conducted with VTSOs played a vital role in identifying various dependencies, including the necessary number of business rules and the importance of reliable data.

VTSOs recognize the advantages of utilizing decision-support tools, however, there are also apprehensions regarding their implementation, with concerns raised about potential negative consequences such as visual overload and the generation of non-relevant alerts or alarms. These concerns are well-founded, as even minor visual alterations in the VTS operational screen can significantly affect the process of developing situational awareness.

To enhance the refinement of the support tool designs, it is advisable to carry out simulations incorporating realistic real-time scenarios. This approach will yield a deeper understanding of VTSOs' experience, situational awareness, and workload. Ongoing research on decision-support tools targeted at enhancing situational awareness and optimizing workload will contribute to a more comprehensive understanding of optimal design principles for supporting VTS tasks.

AUTHOR BIOGRAPHY

I am a Human Factor specialist at MARIN, involved with Human-Machine teaming/ interaction and human performance research. I have a background in cognitive psychology, which focuses on human information processing as a framework to guide and explain human behaviour. I have experience with defining and delivering Human Factor work in technology development projects and in designing and testing new decision-support tools. My most profound interest is how human work can be enriched and improved by using the latest or upcoming technology, from a human-central perspective considering human possibilities and restrictions, and sense-making. In the past five years, I have investigated human performance in complex systems concerning topics such as measuring workload and situational awareness, cognitive task design, training optimisation and mapping operational behaviour. For the largest ports in the Kingdom of the Netherlands, I have been involved with VTS research on the workload of VTS operators and investigating how VTS operators can be helped in their tasks through automation, such as with decision-support tools.

S10.2 The challenge of implementing digital VHF radio in the maritime domain (164)

Jeffrey Van Gils, Senior-Advisor, Ministry of Infrastructure and Water management, The Netherlands

ABSTRACT

The voice radio telephony service in the VHF maritime mobile band is still the most important communication system for shipping. The congestion in the VHF maritime mobile band has become a serious problem not only in The Netherlands but also other countries and is continuing to grow. As a consequence of the implementation of DSC, AIS and VDES the number of available voice channels in the VHF maritime mobile band has been reduced rapidly.

To mitigate this problem, the use of digital VHF radio in the mobile band which significantly improves spectral efficiency could be a way forward. This process will involve both the ship and shore infrastructure to migrate from a complete analogue voice to an environment where digital and analogue voice will operate seamlessly next to each other. During this process, steps should be taken carefully to ensure the continued use of the exiting channels without compromising safety. These steps must be in accordance with all organisations involved.

KEYWORDS: Digital VHF voice radio communication

1 HISTORY

In the past 25 years “new” technology was introduced to the maritime domain operating in the VHF band (ITU RR Appendix 18). These technologies used some of the existing voice bandwidth from this spectrum. The introduction of DSC, AIS and VDES on the maritime mobile band took space away from analog voice channels. Although the introduction of e-Navigation expected that VHF voice communications would be reduced, up until now, this has not reduced the VHF voice communication or the use of analog VHF voice channels. Due to the increase of shipping in some area’s, the use of analog VHF voice communication has even expanded and resulted in more VHF voice channels needed.

Within Europe ECC decision (19)03 from 8th of March 2019 [1] based on the IMO MSC.1/Circ.1460/Rev.2 [2] and taken before the WRC-2019 resulted in freeing the Global VDES before the 1st of January 2023. Due to the IMO circular, decision of ECC and WRC-2019 it is not clear which VHF channel plan should be used in the analog VHF voice radios.

2 CHALLENGES FOR THE NETHERLANDS

In the South of the Netherlands, near to the Belgium border, The Netherlands and Belgium administrations have to coordinate the use of VHF voice channels. Due to the high useage by VTS, Ports, locks and bridges there are no analog VHF channels left. Therefore, the VHF voice channel 1028 will be used for the new lock at Terneuzen, the entrance to the canal from Gent to Terneuzen.

The figure [Figure 1: The Scheldt] on the next page shows the area of this lock. In this area there are multiple users of the analog VHF radio from shore perspective. The whole Scheldt is a VTS area and within a few months the Canal Gent – Terneuzen will also become a VTS area. Next to this in Flushing, Terneuzen, Hansweert and Antwerp there are locks with multiple chambers that can contain Sea going vessels. Along the Scheldt, the Port of Antwerp-Bruges and North Sea Ports are also using VHF voice frequencies. In this picture there is a big and busy Inland lock with two chambers and just outside this picture there are two big inland locks with multiple chambers. Next to this, the port of Zeebrugge is also within reception range of this area. This all makes this area the busiest VHF voice (channel) area within Europe.

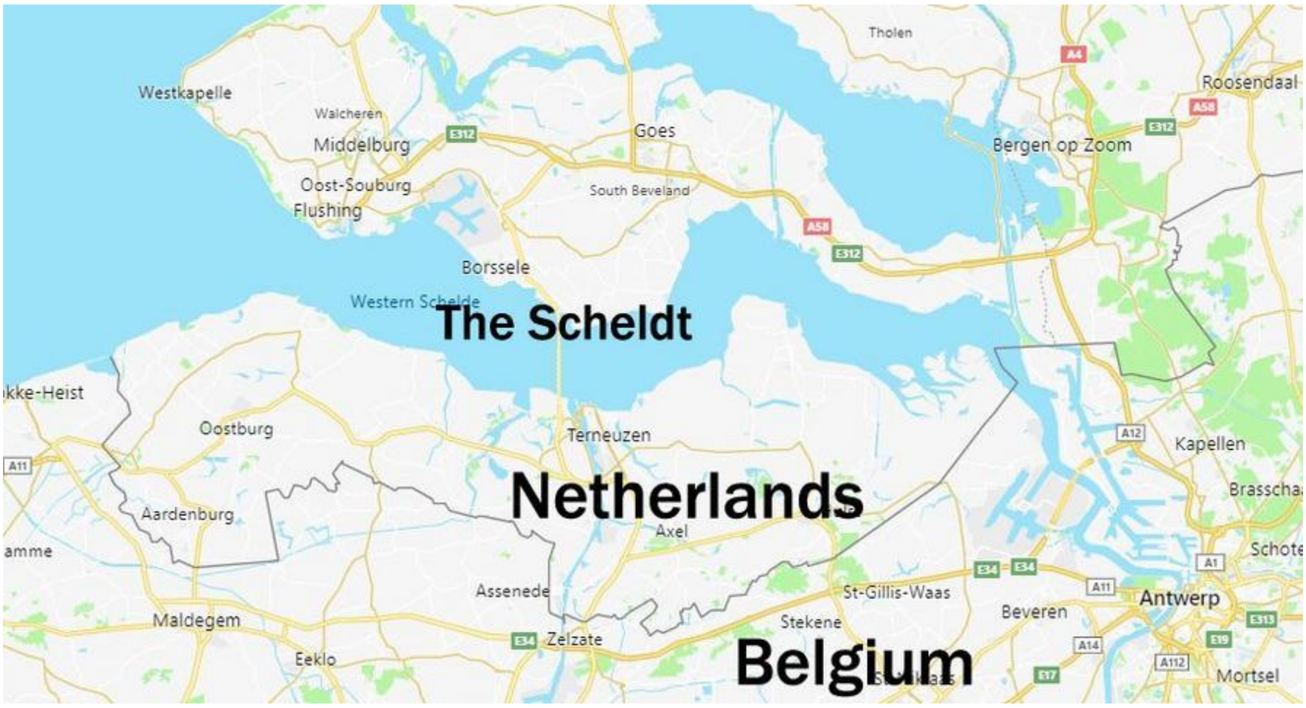

Figure 11: The Scheldt

Due to slow implementation of e-Navigation, VHF voice channels are still heavily used and the demand for VHF voice channels is growing along with the increased demands from the wind and solar farms off shore (supporting the transition to new sustainable clean energy) but nearby the coast.

In the VHF band there are also channels used for GMDSS. These channels should be “quiet” in normal operations so that they are available for emergency and safety, so even these channels may seem to be available, they cannot be used operationally and must be always be available for GMDSS.

3 ORGANISATIONS INVOLVED

Before digital VHF voice communications can take place several organisations must understand the need of digitisation of VHF voice communications and the new opportunities it will bring and compare them to the challenges poses. Some of the opportunities are the more efficient use of the existing spectrum (more VHF voice channels available), supporting e-Navigation by sharing additional information through the digital VHF voice channels and more real-time information from the transmitting stations.

The migration of some of the analogue VHF channels to digital VHF voice channels will take some time and equipment has to be changed on both shore and ship side. During the transition/migration and beyond analogue VHF communication should be available preferably by the same “box”. For the users on ship and shore it should operate and react in the same way that the current analogue VHF voice equipment does.

In the upcoming years IMO could provide new performance standards for (digital) VHF voice. IALA could provide guidelines and recommendations about the use of VHF voice. Within such a exercise new information could be added for safer sailing and increased situational awareness.

ITU could be asked to provide the technical constrains for digital VHF voice whereby IEC could provide the test standards to test if the digital/analog VHF voice apparatus complies to the performance standards, technical constrains of ITU and guidelines/recommendations from IALA.

4 INTERNATIONAL CHALLENGES

One of the biggest challenges is to align and inform, in the right way and the right level, the different International Organisations in their areas of competence.

Another challenge is to align with ship owners and cargo handlers that equipping their ships with a new VHF radio and the gains / advantages they will get with it. It may become mandatory when using some waterways or infrastructure in the future that a new radio is needed to use all the assets, otherwise only limited assets will be supported by the old analogue VHF voice radio.

For Waterway authorities, it will be a question when to upgrade their systems to support both analogue and digital VHF voice. Authorities need to inform themselves what is the current state of innovation of VHF voice and what benefits or improvements they could have by upgrading their system. Next to this they need to take part in international discussions to ensure that the new innovations and performance standards help to support their task.

What functionality that is already present in land mobile systems could be used for maritime? Some examples:

1. Is information about the location of the radio an asset for their situational awareness? Using this information together with radar and AIS can confirm which ship is now talking?
2. Do they want to control the radios of the ships in their area of responsibility more than at the moment? Like giving priority to radios for ships in difficult situations? Stop a radio transmitting for a short while so other ships radio's have time to communicate with the authorities?
3. Digital VHF voice radio can be repeated without loss of quality. Analog VHF voice radio doesn't: how will the authorities implement this? This allows all ships operating in an area covered by a duplex coast station to hear ALL radio communications, not just the VTS transmissions as at present.
4. Do they want to cooperate with other authorities by sharing VHF radio stations?
5. Will it be allowed to have encrypted VHF voice on the channels for special purposes?
6. Will they only accept open standards for connecting the radios and VTS/bridge/lock?

5 WAY FORWARD

IMO *Resolutions RESOLUTION MSC.511(105) Performance Standards for Shipborne VHF Radio Installations Capable of Voice Communication and Digital Selective Calling - (adopted on 28 April 2022)* [3], and IMO *Resolution A.803(19) – Performance Standards for Shipborne VHF Radio Installations Capable of Voice Communication and Digital Selective Calling – (Adopted on 23 November 1995*) [4] are the base for the functionality and performance a VHF voice radio should comply to. This standard is for ships and shore installations have to connect to this standard. Part of the standard. These standards should be analysed and probably revised to enable digital VHF voice communication next to analog VHF voice communication.

The ITU Radio Regulations [5] should be looked at and especially Appendix 18 and possibly Appendix 15. ITU Recommendations like Recommendation *ITU-R M.489-2 Technical Characteristics of VHF Radiotelephone Equipment Operating in the Maritime Mobile Service Channels Spaced by 25 kHz* [6] and Recommendation describes characteristics of VHF radio systems and equipment used for the exchange of data and electronic mail in the maritime mobile service RR Appendix 18 channels. Next to this Recommendation of ITU the DSC *Recommendation ITU-R M.493: Digital selective-calling system for use in the maritime mobile service* [7]. At this moment ITU WP5B has a correspondence group working on this matter.

IALA Standards, Guidelines and Recommendations should be checked if new functionality for digital VHF voice radio could help the authorities to enhance their tasks, safety and procedures.

In Europe CEPT FM58 has made a report ECC Report 329 - *Implementation of digital voice radio telephony in the VHF maritime mobile band (approved 08 October 2021)* [8] where they analyse the performance standards of IMO, ITU recommendations, available digital VHF voice systems and VOice CODEder. In this report also test done by Estonia and The Netherlands are included. The test in The Netherlands did not zoom in on the technology but more on the functionality and user experience from a Mariner and a VTS operator.

ETSI has standards for land mobile digital VHF voice technology that could be used for digital VHF voice radio but all of them would need to be revised for Maritime use. At this moment a report is available *ETSI TR 103 784 V1.1.1 (2022-06) Digital VHF Maritime Radio Air interface for voice and data services using FDMA in 6,25 KHz bandwidth* [9] showing how the existing dPMR standards can be adapted for Maritime use. If it is decided by IMO and ITU to use the land mobile dPMR standard as the basis of the way forward, then this will need further development.

IEC test standards should be revised to accommodate the new digital VHF voice radio. The standard IEC 62238 Maritime navigation and radiocommunication equipment and systems – VHF radiotelephone equipment incorporating Class "D" Digital Selective Calling (DSC) – Methods of testing and required test results (2003-03) [10] need to be amended to accommodate the digital VHF voice technology according with DSC.

From shore perspective the operating of the shore based radio's requires that additional meta data needs to be exchanged alongside the voice communication. Technologies from Aeronautical environment could be used, amended or been used as an example. Most analog VHF voice radios support already the *ED-137 Interoperability Standards for VoIP ATM Components*" [11]. The question is if the ED-137 standard "Interoperability Standards for VoIP ATM Components" prepared by EUROCAE could add specific Maritime functionality, if needed, or should IALA develop their own standard for this purpose?

The above text only gives an impression of the organisations and standards involved that need to be "synchronised" during the process more might arise.

6 CONCLUSION

To have digital VHF voice operational in the future a concrete planning should be made with milestones and effect if these milestones are not met. IALA members that has the most to gain with the new functionality and efficient use of spectrum, that is also a goal of ITU, could be the organisation to coordinate this. Through their members/delegates who are also member/delegates of other International Governmental Organisations like IMO and ITU could help the other delegates in these organisations to define their standards enabling digital/analog VHF voice communication.

Some of the milestones could be reached at the ITU World Radio Conference of 2023 by getting a agenda item on the next ITU World Radio Conference of 2027. Another milestone is the IMO Maritime Safety Committee meeting in spring 2024 and get there a work item agreed for revising the performance standards for VHF voice radio.

If those milestones are reached IALA's members could start with doing tests with users on ship and shore side and change and define the Standards, Guidelines and Recommendations needed to migrate to and implement digital / analog VHF voice communications in their operational work.

7 REFERENCES (STYLE HEADER)

[1] ECC decision (19)03 from 8th of March 2019

[2] IMO MSC.1/Circ.1460/Rev.2

[3] RESOLUTION MSC.511(105) Performance Standards for Shipborne VHF Radio Installations Capable of Voice Communication and Digital Selective Calling - (adopted on 28 April 2022)

[4] Resolution A.803(19) – Performance Standards for Shipborne VHF Radio Installations Capable of Voice Communication and Digital Selective Calling – (Adopted on 23 November 1995)

[5] ITU Radio Regulations

[6] ITU-R M.489-2 Technical Characteristics of VHF Radiotelephone Equipment Operating in the Maritime Mobile Service Channels Spaced by 25 kHz

[7] Recommendation ITU-R M.493: Digital selective-calling system for use in the maritime mobile service

[8] ECC Report 329 - Implementation of digital voice radio telephony in the VHF maritime mobile band

[9] ETSI TR 103 784 V1.1.1 (2022-06) Digital VHF Maritime Radio Air interface for voice and data services using FDMA in 6,25 KHz bandwidth

[10] IEC 62238 Maritime navigation and radiocommunication equipment and systems – VHF radiotelephone equipment incorporating Class "D" Digital Selective Calling (DSC) – Methods of testing and required test results (2003-03)

[11] ED-137 Interoperability Standards for VoIP ATM Components (Volume 1 -Radio, Volume 2 – Telephone, Volume 4- Recording and Volume 5 - Supervision

AUTHOR BIOGRAPHY

Jeffrey has a longstanding experience in maritime and nautical IT matters. He started his career within the Ministry of Infrastructure and Water management at an operational site in the Southern part of the Netherlands and acted as conceptual and technical project manager. He was involved with and responsible for the development the Inland Tracking System for Inland Waters. As from the beginning Jeffrey was engaged in the domestic and regional development of AIS, the last 15 years also on international level. During the last decade he acts as a Senior Advisor for maritime communications and other technical e-Navigation related aspects, both again on national and international level.

Since 2008 he is a member of IALA e-Navigation Committee, where he started in the Architecture working group and later on joined the COMMS working groups and is also a member of the Engineering Committee. Jeffrey is also the custodian of the IALA related website www.e-navigation.nl The last four years he promoted the digitisation of VHF radio as a way forward for e-Navigation and to accomplish a better voice quality and resilient of VHF voice. Since 2022 he is chair of the committee that handles the use of VHF radio in the Scheldt area, a area close to Belgium with a huge demand of VHF voice communications, that since the implementation of the ITU regulations has been challenging for finding proper implementation.

S10.3 Artificial Intelligence in Radar Subsystems for Vessel Traffic Service (123)

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ABSTRACT

Artificial Intelligence (AI) and machine learning (ML) concepts have in recent years attracted increased attention also in the domain of VTS systems, using operational input data at scales not previously feasible in classic methods, to augment and improve the overall situational awareness of the VTS operator.

The advantages of these techniques apply not only to streams of data aggregated and analysed at the top VTS system level but are also highly relevant in the local data processing undertaken by subsystems.

This article sets focus on the application of the techniques in data processing components of VTS radar sensor subsystems and how these enrich the conventional radar data streams provided to the overarching system. Autonomous target classification is presented as one important example of this, including an architectural overview and a discussion of radar sensor properties and performance parameters impacting classification performance. Furthermore, the benefits and challenges, as seen from a VTS system level perspective, resulting from the close integration of radar sensor, target tracking and classification components in the radar subsystem are covered. Operational and practical considerations on the important topic of data collection, annotation and training of AI components are also discussed.

Concluding the discussion, thoughts are given to future uses of AI of benefit to VTS within the radar subsystem.

KEYWORDS: AI, radar, VTS, edge computing, machine learning

RESUMEN DEL ARTICULO

Los conceptos de Inteligencia Artificial (AI) y Aprendizaje Automático (ML) han atraído una atención creciente en los últimos años también en el dominio de los sistemas VTS, utilizando datos de entrada operativos a escalas que anteriormente no eran factibles en los métodos clásicos, para aumentar y mejorar la conciencia situacional general del operador VTS.

Las ventajas de estas técnicas se aplican no solo a flujos de datos agregados y analizados a nivel del sistema VTS superior, sino que también son altamente relevantes en el procesamiento de datos local realizado por los subsistemas.

Este artículo se centra en la aplicación de técnicas en componentes de procesamiento de datos de los subsistemas de sensores radar VTS y cómo enriquecen los flujos de datos de radar convencionales proporcionados al sistema general. La clasificación autónoma de objetivos se presenta como un ejemplo importante de esto, incluyendo una descripción general de la arquitectura y una discusión de las propiedades y parámetros de rendimiento del sensor radar que afectan al rendimiento de clasificación. Además, se abordan los beneficios y desafíos, resultantes de la estrecha integración de los componentes de sensor radar, seguimiento de objetivos y clasificación en el subsistema de radar vistos desde una perspectiva de nivel de sistema VTS, es discutido. También se discuten consideraciones operativas y prácticas sobre el importante tema de la recopilación, anotación y entrenamiento de componentes de inteligencia artificial.

Para concluir la discusión, se exponen reflexiones sobre los futuros usos de la inteligencia artificial que beneficiarán a VTS dentro del subsistema de radar.

PALABRAS CLAVE: IA, radar, VTS, informática perimetral, aprendizaje automático

RESUME DE L'ARTICLE

Les concepts d'Intelligence Artificielle (IA) et d'apprentissage automatique (ML) ont attiré ces dernières années une attention augmentée également dans le domaine des systèmes VTS, en utilisant des données d'entrée opérationnelles à des échelles auparavant impossibles avec les méthodes classiques, afin d'améliorer la conscience situationnelle globale de l'opérateur VTS.

Les avantages de ces techniques s'appliquent non seulement aux flux de données agrégés et analysés au niveau supérieur du système VTS, mais sont également très pertinents dans le traitement local des données entrepris par les sous-systèmes.

Cet article met l'accent sur l'application des techniques dans les composants de traitement de données des sous-systèmes de capteurs radar VTS et sur la manière dont ceux-ci enrichissent les flux de données radar conventionnels fournis au système global. La classification autonome de cibles est présentée comme un exemple important de cela, y compris une vue d'ensemble de l'architecture et une discussion des propriétés des capteurs radar et des paramètres de performance ayant un effet sur les performances de classification. En outre, les avantages et les défis, vus du point de vue du système VTS, résultant de l'intégration étroite du capteur radar, des composants de poursuite et de classification des cibles dans le sous-système radar sont couverts. Des considérations opérationnelles et pratiques sur le sujet important de la collecte de données, de l'annotation et de la formation des composants de l'IA sont également abordées.

En conclusion de la discussion, des réflexions sont données sur les utilisations futures de l'IA au bénéfice du VTS au sein du sous-système radar.

MOTS CLÉS : IA, radar, VTS, informatique de pointe, apprentissage automatique

1 INTRODUCTION

A key aspect of a VTS system is the ability to provide decision support to VTS operators. In addition to directly relaying and presenting data from the various sensors of the system, this entails collation, filtering, and analysis of data to aid the human mind deduct the right course of action in matters of safety, shipping efficiency and environmental protection.

Recent years have seen the rise of several new trends with varying impact on maritime traffic patterns and security in VTS areas: The establishment of large offshore wind turbine farms, giving rise to traffic management and wild-life protection considerations, a huge increase in drone traffic – increasing the needs for situational awareness, the onset of autonomous ships. The same timeline has, however, also seen increased focus and tension around geopolitics and security.

In parallel, technological evolutions in the areas of sensors and system architectures are being adopted, systems integrated on increasingly larger scales. The combined effects these parallel evolutions of operations, technology and politics in turn leads to increased complexity, blurred system boundaries, and added responsibilities of (sub)systems. As large- and small-scale examples of the latter, consider the establishment of global VTS systems and the hybrid use of a VTS radar for maritime surveillance, protection against hostile measures (e.g., surface or airborne drones) and detection of bird migration around an offshore windfarm.

The potential volume of data at the disposal of a VTS systems integrator to build a maritime awareness picture that forms the backbone of decision support is larger than ever, multi-dimensional and expanding. The evolution of data processing paradigms to handle this scaling of data and adaption to new trends is thus of high importance.

This paper explores the implications on VTS radar subsystems of two such technological paradigms: Edge computing and AI based data processing. The basic concepts are defined and then elaborated in the context of an example case. This is followed by a discussion of practical and operational considerations. Before concluding, a view is made to the future potential of these approaches.

While much of the discussion here is focused on the radar subsystem of the VTS system, many of the considerations and points made are generic in nature and are expected to apply, to a large extent, to other subsystems as well.

2 EDGE COMPUTING

Edge computing can be described as a subset of distributed computing architectures that focuses on data processing and storage close to the data source(s), the primary objectives being to reduce the amount of data to be moved between nodes of a system and hence improve response times and conserve network bandwidth. The basic concept is illustrated in Figure 12, comparing an edge computing system to a purely data centre based, architecture.

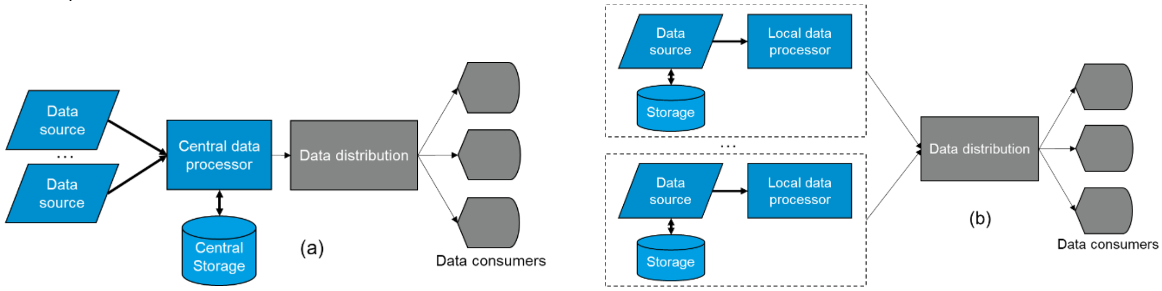

Figure 12: Centralized data processing architecture (a) compared to edge computing architecture (b)

Originating in the realm of IT systems serving multimedia content to end users, the concept has over the past 5-8 years gained more widespread use, including commercial applications (e.g., Internet of Things (IoT) [1]) as well as military use cases [2].

Exemplifying the conceptual architectures of Figure 12 to the integration of radar subsystem(s) in a VTS system, the situation in Figure 12(a) can be taken to depict the architecture of a system where raw radar video from a number of radar stations is transmitted over a communications link to a data centre where all subsequent processing (which could include steps such as clutter suppression, plot extraction, target tracking and track fusion) is then carried out. The combined traffic image is then made available to VTS operators (the data consumers) through relevant distribution channels. A setup like this would typically depend on a high-speed, low-latency communications network for data transmission between the radar stations and data centre due to the amount of real-time data transmitted.

An alternative architecture addressing the same operational needs is shown in Figure 12(b). In this case, each radar station carries out as much of the computation of the full traffic image as possible from local computational resources applied to locally available data (the raw radar signal plus possibly auxiliary sensor information), including clutter and video processing, plot extraction and target tracking. The condensed and enriched data streams are then transmitted to the data centre for further processing including fusion of data from multiple radars into the overall traffic image.

The interface between the radar sensor and the system is in either case defined by the data formats and the properties of the communications link. Also, the architectural differences between the systems concern the back end only, while the presentation tier remains the same.

Key properties of the two architectures are summarized in Table 6.

The architectures should be viewed as idealized models of systems and can as such be regarded as representing the extremes: In practice, several factors are considered when deciding on the optimal "responsibility split" applied in a given system to obtain an attractive cost/performance trade-off (for one view on this, see [5]). These factors are further discussed in section 5.

Table 6: Key properties of the centralized architecture vs. the edge computing architecture

Centralized processing	**Edge computing**
Raw data transmitted from sensors to data centre for processing	Raw data processed (and potentially stored) locally. Condensed and/or enriched data streams transmitted to data centre

High-bandwidth, low latency requirements to infrastructure	Less taxing requirements to infrastructure. Thinnest possible interface.
Sensor complexity low, single responsibility	Sensor subsystem complexity high, additional layers of responsibility besides core task.
System level complexity high. Complexity of sensor specifics handled at system level.	System level complexity reduced. Complexity of sensor implementation delegated to subsystems.

3 AI BASED DATA PROCESSING

The edge computing paradigm described in the previous section provides a practical platform for architecting the trade-off between centralized versus local computational capabilities, network capacity and response time. As such, it dictates no specific methodology for implementing actual data processing algorithms.

A large class of interesting problems in present day (radar) systems evolve around the need for discovering trends and predicting outcomes based on the large quantities of data governed by complex relations. Radar sensor data are stochastic in nature and while the rules governing propagation and detection are dictated by physics, relations are complex, changing with the environment and the range of scenarios vast. While traditional methods of building explicit logic and rules to process such data can be successful, the pre-conditions under which they can be expected to work needs careful consideration.

Artificial Intelligence (AI) covers a broad spectrum of methodologies that aims to mimic a human cognition approach to solving complex tasks including “learning” from doing so.

An important subset of AI is the field of Machine Learning (ML), which is a computational paradigm concerned with building statistical models based on a previously gathered dataset. Based on specific properties – features – the models identify, or learns, patterns in the data of interest to the solution of a given problem. When subsequently applied to new data, the models can be used to predict similar patterns. This stands in contrast to traditional approaches to building algorithms where logic and rules are explicitly devised for processing a piece of input data to produce an output.

The terms AI and ML are often seen used interchangeably although AI should be thought as the broader concept of mimicking and ML is a specific application. In this paper, the broader term “AI based data processing” is used when a specific methodology is not inferred. Much of the discussion and examples will, however, assume the application of Machine Learning approach.

By moving the focus of problem solving away from explicitly constructing logic and rules to the data and data features representing the domain of the problem, intuitively the challenges faced will change to focus on the data. Indeed, as discussed in later sections, access to relevant data in large quantities may be one of the major obstacles to applying these techniques. Likewise, proving intended behavior and validating operational requirements is a challenge that, while not necessarily prohibitive to the successful application of an AI based algorithm, will require additional considerations compared to traditional methods.

4 AUTOMATIC TARGET CLASSIFICATION

Automatic (radar) target classification refers to the ability to determine, for a given detected radar target, the target type, or *class*, selected from a fixed – usually small – set of classes. Examples of target classes could be *surface vessel, aircraft, bird, drone*. Operationally, this can provide useful extra information directly to aid an operator as well as a means of filtering data in automated processing systems.

Target classification differs from the related concept of automatic target identification in that the purpose is to obtain the target type – not to ascertain the unique identity of the target.

Figure 13 shows an example of a radar video augmented with tracks and target classes.

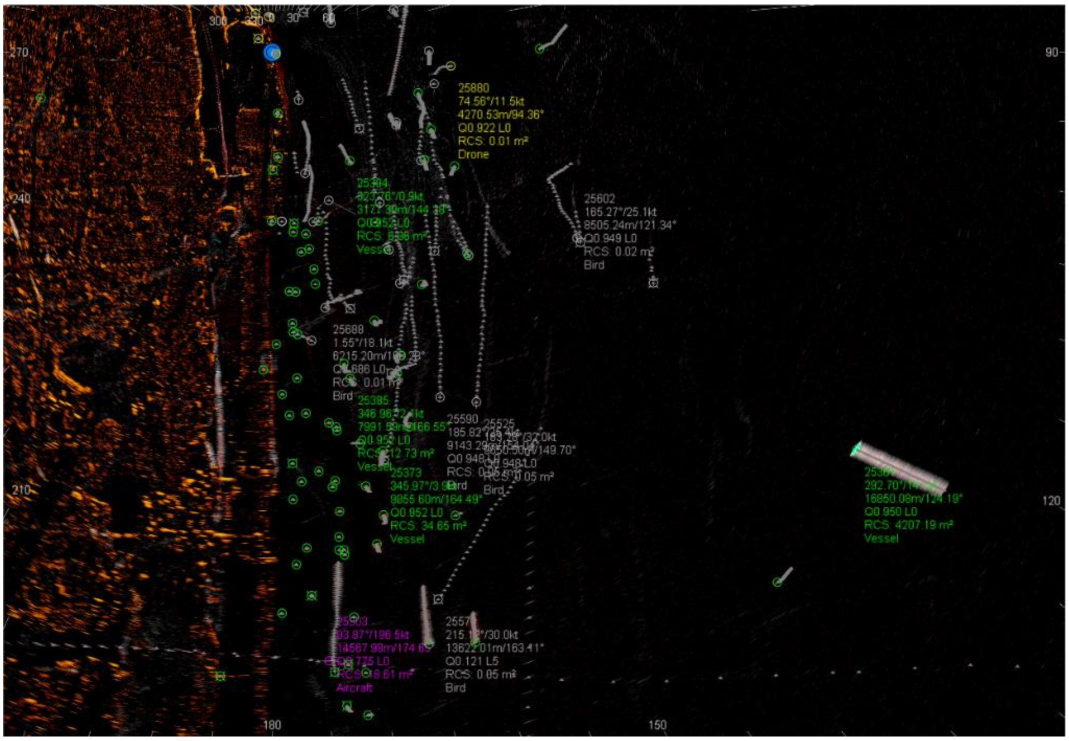

Figure 13: Radar video overlayed with detailed track information and target class. Target tracks are colored according to class as an example of using this information to enhance presentation.

Examples of practical applications of target classification include detection of drones and detection of birds, the latter either for suppression in presentation or for detection in the monitoring of wildlife around e.g. wind farms.

4.1 Cooperative and non-cooperative targets

In a multi-sensor system, a target classification capability can be implemented in several ways. One simple approach would be to combine – correlate – radar tracks with secondary sensor data such as AIS to obtain not only a target type, but also other key properties as well as the actual target identity. The major limitation of this approach is that it depends on targets being *cooperative*, i.e., it fails to deliver a result for targets for which secondary sensor data is not available (e.g., because targets are not equipped with the required transponders) and will provide erroneous information in cases where the secondary data is, by intention or not, incorrect. As such, the cooperative approach thus precludes application of the target classifier for use cases such as filtering of bird targets or as an aid to detecting asymmetrical threats.

An implementation able to provide classification based on the assumption that all targets are *non-cooperative* will resolve these deficiencies yet is also, intuitively, a broader and less tangible problem to solve: Given real-time radar surveillance data from an operational area of interest, relevant target characteristics – features – must be monitored and logically combined to obtain a (timely) decision on class membership.

4.2 A VTS radar system with target classification capability

The architecture of a VTS radar system capable of providing radar video for presentation as well as a radar track data stream augmented with target class information is shown in Figure 14.

The system leverages the two concepts introduced earlier:

- An *edge computing* architecture is employed, providing a local processing capability with sufficient computational power to process the real-time high-resolution raw radar data into data streams for presentation and classification purposes, respectively. The processing steps undertaken includes pre-processing and clutter filtering of the radar data, plot extraction and target tracking. Besides a video stream for presentation purposes, the output of the processing steps comprises the features that form the input for the classifier.

- A *machine learning* algorithm is used as the backbone of a classifier of non-cooperative radar targets, operating on the features extracted from the processed radar sensor data. Several methodologies for constructing this exist, including Random Forests, where classification is obtained by constructing and combining a large number of decision trees, or artificial neural network approaches such a Long Short-Term Memory (LSTM) that include inherent properties making them attractive for processing sequences of data. A detailed discussion of these methodologies is outside the scope of this paper – for further information, see for instance [3] and [4].

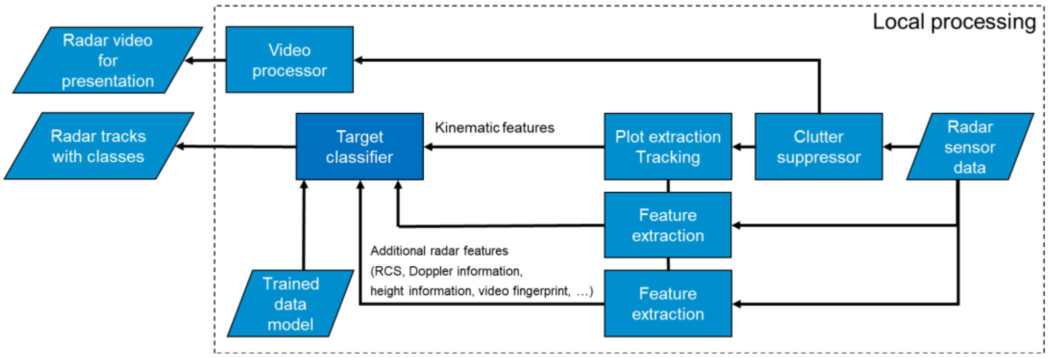

Figure 14: An example architecture of a radar system with a target classification capability

The selection of targets of interest for classification in this system is given by the set of targets tracked. For each target track, the classifier maintains a probability vector that a given track belongs to each of the defined classes. The most probable class is reported as the result with each track update output from the system. In general, the classification result becomes more robust the longer a track has been maintained. The system may include additional filtering functionality to control the threshold and other properties of class publication.

4.3 Features

Features should ideally be selected such that they, individually or in some weighted combination, represent a partition of data corresponding to the set of target classes desired.

When selecting features, target properties due to behavior as well as radar detection should be considered. Examples of features include:

- Kinematic features (target behavior including estimated target speed, acceleration, turn rate etc.)
- Radar Cross Section (RCS) estimate
- Doppler information
- Target height information
- Radar video fingerprint

The ability of a given feature to decorrelate target classes is an important property. An example of this is shown in Figure 15: The distribution of targets compared to measured average main lobe RCS is plotted for a set of targets of known classes. In this particular data set, it appears that average main lobe RCS would provide information to distinguish targets of e.g., the Bird class from the Aircraft or Vessel classes, whereas this feature would provide no de-correlation of the Bird and Drone classes.

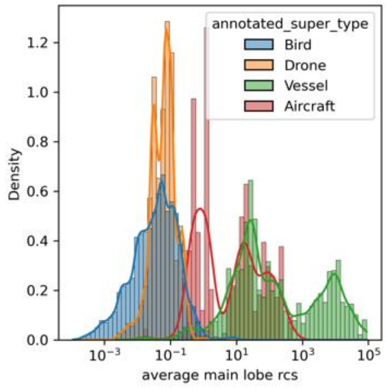

Figure 15: Distribution according to RCS of a set of targets of known class

Analytic methods, such as Principal Component Analysis, are often used to identify the most significant features for a given data set.

The coupling between intrinsic properties of the radar transceiver and the sophistication and quality of the extracted features should also be observed. Key properties of impact include:

- Range and angular resolution
- Dynamic range
- Coherent operation
- Target dwell time (scan rate and update rate)

Besides the selection of features and the availability of adequate training data, a number of other considerations and trade-offs are involved in a real-world implementation and deployment of a target classification capability. These are discussed in section 5.

4.4 Training

The central part of building the statistical model of the target classifier is called training and involves the application of many samples of data where the correct class is known a priori. The data should represent as closely as possible the diversity of targets expected to be encountered in the given operational setup. Collecting and annotating data can be a laborious process that often faces practical challenges (see section 5.1).

The exact training process varies with the machine learning algorithm used but is usually computationally intensive. Depending on the level of sophistication of the system, the operator interface may provide the possibility of manually specifying the target class for incorrectly classified targets. The classifier may be capable of being retrained in-situ to incorporate the amended data or require retraining to be done offline – or even off site – due to the computational effort involved.

4.5 Performance evaluation and validation

The target classifier is a statistical model designed to provide the optimal fit of the training data to the set of classes based on the selected features. Classifier performance is evaluated by running the trained model on a known test data set not used as part of training. The result can be summarized in terms of a confusion matrix, a simplified example of which is shown in Figure 16. The matrix compares actual classification to predicted classification expressing for each class the rates of:

- *true positives (TP)*, the probability of correctly classifying a radar track update representing a target belonging to that class.
- *true negatives (TN)*, correct classifications to other classes
- false positives (FP), incorrect classification

- false negatives (FN), incorrect classifications to other classes

The term confusion matrix stems from the fact that it provides insight into the expected rate of the classifier confusing a target belonging to a particular class for belonging to the other classes of the set.

Multiclass Confusion Matrix		Predicted S_1	Predicted S_2	Predicted S_3
Actual	S_1	TP	FN	FN
Actual	S_2	FP	TN	TN
Actual	S_3	FP	TN	TN

Actual \ Estimated	Small Slow Vessels	Small Fast Vessel	Medium and Large Vessels	Static targets	Aircraft and helicopters	Unknown	Penalty	#Samples
Small Slow Vessels	**0.931**	0.000	0.054	0.011	0.000	0.004	0.069	25631
Small Fast Vessel	0.047	**0.403**	0.327	0.004	0.086	0.133	0.597	11716
Medium and Large Vessels	0.221	0.005	**0.744**	0.025	0.000	0.004	0.256	31812
Static targets	0.011	0.000	0.006	**0.978**	0.000	0.004	0.022	29365
Aircraft and helicopters	0.004	0.002	0.001	0.002	**0.940**	0.051	0.060	12046
Unknown	0.018	0.001	0.016	0.175	0.023	**0.767**	0.233	7454
F1 score	0.829	0.568	0.776	0.949	0.921	0.729	0.795	
Precision	0.747	0.959	0.811	0.921	0.904	0.694	-	
False Alarm Rate	0.253	0.041	0.189	0.079	0.096	0.306	-	

Mean recall: **0.794**, precision: 0.839, penalty: **0.206**, false alarm rate: **0.161**

Figure 16: (left) Conceptual confusion matrix, showing entries representing TP, TN, FP and FN when focusing on class S_1 (left) and (right) actual example of confusion matrix for a classifier with 6 classes.

While the confusion matrix provides insight into the *expected* performance of the underlying classifier model, it cannot be used to directly draw conclusions on the performance obtained in an actual operational setting.

As the entries in the confusion matrix represent expected values of random variables, the direct way to validate the performance of the classifier calls for recording and evaluating many actual classifications to establish the statistical sample distribution of each of the variables. In practice, this is a very time consuming, and maybe even operationally infeasible approach (e.g., if obtaining large quantities of known-good target tracks of a given class is hard or expensive.). As an alternative, given a small, or varying number of collected classifications, a simple binomial test can be carried out to test the true positive figures (the diagonal of the confusion matrix).

5 PRACTICAL CONSIDERATIONS

As the discussion on building a target classification capability above shows, the application of machine learning techniques gives rise to several considerations, some of which are related to the problem itself while others are generic in nature. The following sections elaborate on the major areas that needs practical consideration when AI based processing is applied.

5.1 Data governance

The data used for the training of ML models is crucial to the performance obtained when these are ultimately deployed operationally.

Key points to consider include:

- Availability and quantity: Enough data needs to be gathered to cover all corner cases of the problem of interest. What are the primary data sources? In the target classifier example above, one should aim for roughly the same amount of data samples for each class which may in practice be surprisingly hard to attain as some target types are inherently harder to “capture”. Data to create both a training set and a test set (for performance evaluation) should be collected.
- Applicability: Will data exhibit strong dependency on the environment and conditions (e.g. weather) under which they are collected or can models built on these data be expected to more generically applicable?

- Validity: The performance of the constructed model depends strongly on the quality of the manually annotated training data. Errors in data and annotation will propagate to the trained model.
- Robust data management: A structured approach to data collection, annotation, formatting, storage and backup should be established at the outset. The more data collected, the more cumbersome retrofitting mitigating actions for flawed data management is likely to become. Furthermore, having relevant tools in place for data collection, annotation, browsing and analysis will save time and create transparency.
- Value: Collection and cultivation of data at a large scale can be expected to be costly. As such, the data ends up representing real value both financially and in terms of intellectual property and should thus be treated as an asset (and depending on the situation as a commodity).
- Confidentiality: If a system is built on data that are sensitive or originating from sensitive sources, any applicable regulations and laws should be considered and may severely limit the general applicability of the resulting system.
- Commercial rights: If data are obtained from a 3rd party (or a customer), who will retain the rights to data model developed based on the data?

5.2 Performance evaluation and validation

Operational validation of a functionality based on a ML model can be expected to be quite different from the validation of a conventional system parameter.

End user requirements for specific capabilities are often not phrased with a statistical model in mind. Work is therefore likely required in the tender, development, and commissioning phases of a project to bridge operational requirements and verification methods.

In some cases, the right choice of terminology may be of help to overcome this challenge. For radar systems, the stochastic behavior of core radar performance is generally acknowledged when specifying requirements and is reflected in well-established, well-known terminology in requirements (e.g., probability of detection, false alarm rate etc.). In the case of the target classifier discussed above, translating the properties expressed by the confusion matrix into this familiar terminology may present a straighter way of stating the requirements and reasoning about success criteria for a radar domain audience.

As also exemplified by the discussion on performance evaluation of the target classifier, practical approaches to verification also needs to be devised and agreed upon to keep cost and effort at a manageable level.

5.3 Product lifecycle

Capabilities based on ML models come with the inherent flexibility that given an improved set of training data, a model may be “re-trained” for improved performance. For applications where changes to the statistical properties of the data (with respect to the features considered) can be expected over time, such re-training may even be mandatory.

For these reasons, in-field update cycles different from traditional system components should thus be considered. As a vendor of ML based capabilities, the concept of supporting in-field updates should be considered as part of product design. As customer or integrator, data model upgrades should be expected and planned for from budgetary as well as an operational point of view.

6 LOOKING AHEAD

As mentioned in the introduction, recent years have seen the need for increased situational awareness and to manage new types of traffic and operational scenarios of increasing complexity.

The perspectives of incorporating AI methodologies to VTS system design and decision support are the subject of research in both industry and other parties, searching to answers for questions from how AI can be used to improve prediction and simulation of vessel manoeuvring (building digital twin models), over the design of VTS operator HMIs to AI based functionality to the legal impacts of enrolling AI “in the loop”.

As these questions, and more, are answered, the delegation of responsibility (or not) to the various subsystems of a VTS system becomes an important topic. The edge computing and AI based processing concepts presented in the previous sections are generic concepts that provide great flexibility in the construction of data processing subsystems to aid architecture and design processes. Computational power available at the edge nodes of networks can be expected to continue to increase, increasing flexibility even further. As improved sensors and new types of data become available, the potential and need for data models exploiting these will of course also, in turn, increase.

7 CONCLUSION

The volume of data to be managed by present day VTS systems and potentially acted on by operators is larger than ever and growing.

Edge computing and AI based data processing are technological paradigms providing frameworks to tackle some of the challenges related to distribution of data, computational power and the construction of operational decision support systems based on data.

The discussion in this paper has exemplified this by studying the problem of target classification in radar systems and providing an overview of practical considerations implementing the two schemes.

In summary:

- Edge computing provides practical platform for architecting the trade-off between centralized versus local computational capabilities, network capacity and response time.
- While machine learning methodologies provide a solid framework for implementing statistical models, significant domain insight is required to select features of relevance and tackle the challenges associated with governance of data.
- AI based data processing capabilities introduce a new level of flexibility, allowing systems to resolve decisions they were not explicitly programmed for. This imposes challenges on the validation of performance of such systems, requiring considerations and alignment not only as part of systems development, but also in planning and commissioning phases of systems.

Current development trends suggest that radar subsystems closely integrating the radar sensor with AI and ML based advanced data processing capabilities are gaining momentum and that the advantages greatly outweigh the challenges in doing so. The added complexity also means that more demanding and complex requirements for these systems can be expected, going forward.

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AUTHOR BIOGRAPHY

Mads Ulrik Kristoffersen holds a position as Senior Product Manager within Terma's Radar Product Management team. His main areas of responsibility include the product strategy for radar sensors targeting the Vessel Traffic Services (VTS) and Costal Surveillance (CS) markets as well as the associated product portfolio: the SCANTER 5000 and 6000 Series radar systems, target tracking and classification products and software technology platforms.

During his more than 17 years of combined experience with the radar markets, radar systems and radar product development, he has been influential in the development of Terma's current radar product lines, having prior to his current position served as Director of Radar Software development within Terma R&D for a period of 5 years and, prior to that, as Software Architect for 7 years. Terma is a long time Industrial Member of IALA and participant in the VTS committee. Mads has since 2021 joined this work as a Terma representative. Mads holds an MSc in Computer Science from Aarhus University, Denmark.

S10.4 The Application of a VTS Decision Support Tool based on Artificial Intelligence (078)

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ABSTRACT

China MSA has begun to fully apply artificial intelligence, big data and other technologies to develop an autonomous monitoring system for abnormal ship behavior based on AI technology through data analysis and modelling of ship navigation patterns, and promoted it as a new VTS decision support tool in VTS center. The input of this system has improved the accuracy and timeliness of identifying and predicting the unsafe behaviors of vessels in the VTS area, and provided intelligent decision support for VTS personnel to respond in time and intervene in advance for possible accident risks.

KEYWORDS: VTS,DST,AI,abnormal ship behavior

1 CURRENT STATUS OF VTS SYSTEM ALARM RULES

The setting of alarm rules in current VTS system is usually knowledge-driven, that is, navigation rules are set according to laws and regulations, experience accumulation and demand of emergency events, such as speed limit, course alteration, anchor prohibition, navigation restrictions, etc. This may lead to the set rules not fitting effectively with the navigation rules of vessels in the VTS area. If the rules are too stringent, excessive alarms will be generated in the VTS system. On the other hand, if the rules are too loose, the alarms will be reduced substantially, resulting in the loss of proper function of alerting. For example, the VTS system deployed in 2017 in Weihai VTS Center, provides alarm rule settings for vessel speed reduction, speed increase, sudden course alteration, etc. However, the set rules are for the whole VTS area, if the speed reduction alarm rule is set, the alarm will be triggered when a vessel approaches her berth or anchorage in the VTS area, such alarm is not required by VTS, and is therefore meaningless .

In addition, the combination of knowledge-based alarm rules is limited, either based on vessel type or specific area such as precautionary area or anchorage. Moreover, these rules will not be automatically adjusted with the change in vessel type and navigation behavior in the area.

2 CONCEPT OF ABNORMAL SHIP BEHAVIOR

How to make the VTS alarm rules more intelligent, better reflect the navigation characteristics of different types of ships and different regions, and realize differentiated management, it is necessary to introduce the concept of abnormal ship behavior. The so-called abnormal ship behavior refers to the behavior that the ship's track, speed, navigation area or AIS equipment status under specific conditions is different from the usual performance of similar ships in the same region, which may be a sign of potential risks or a concrete manifestation of violation. For example, a significant decrease of ship speed within a short period of time is categorized as abnormal speed behavior, which may be caused by breakdown of main engine or navigation incident such as collision or grounding.

For the identification of abnormal ship behavior, China MSA together with the 28th RESEARCH INSTITUTE OF CHINA ELECTRONICS TECHNOLOGY GROUP CORPORATION has adopted a data-driven approach, that is, using big data mining technology to calculate ship activity rules by analysing historical data of ships navigating in a specific area, and then using AI technology to train, generate and automatically update ship navigation rules, so as to develop an autonomous monitoring system of abnormal ship behavior based on AI technology, and gradually promoted as a new type of VTS decision support tool in VTS center.

3 INTRODUCTION OF THE AUTONOMOUS DETECTION SYSTEM FOR ABNORMAL SHIP BEHAVIOURS

3.1 Functions of the system

3.1.1 Analysis of ship historical navigation data and generation of ship navigation model training

Through machine learning and big data technology, a large amount of ship navigation history data in VTS area can be mined and analyzed to discover the normal navigation, anchoring and operation rules of ships, generate effective ship navigation rule models, and provide training models for further abnormal behavior monitoring. The specific technologies include distributed computing technology, track data pre-processing technology, unsupervised machine learning technology, data mining technology, etc.

In addition, the VTS watchkeepers can also manually intervene in the abnormal ship behavior detected by the system, and then make corrections to the navigation rule model, thus further improve the accuracy rate of abnormal behavior judgment.

3.1.2 Real-time automatic monitoring of ship navigation behavior.

The system has the capability of real-time training of ship navigation behavior, and it can detect the real-time AIS track data intelligently and generate warning information. In addition, the system also supports the generation of warning information based on rule settings. The generated warning information is managed in a unified manner and sent to each operation terminal to display. The types of warning generated by real-time ship monitoring include abnormal position, abnormal speed, abnormal course, abnormal AIS signal, suspected imitation of other ships, deviation alarm, speed limit alarm, proceeding in the opposite traffic lane, dragging anchor.

3.1.3 Traffic situation display

The traffic situation display function is to provide system users with rich human-machine interaction and warning information display. Specific functions include:

1) Loading, displaying and convenient operation of electronic nautical charts in compliance with S57 standard format, with map scaling supporting the specified scale entered by the user in real-time operation; providing navigation environment and ship target situation display.
2) The system is capable of displaying the detected potential ship navigation rules on the electronic chart;.
3) It can display on the chart the ship that triggers the alarm and the reason and level of the alarm;
4) It can display the alarm event records and details about the alarm and response process in the form of text descriptions and charts;
5) It can confirm or deny the alarm according to the staff response and feedback the corresponding operation to the system, so as to adjust the navigation rules of the ship.

3.2 System Architecture

The system adopts server-client architecture mode, including basic operating environment, data training layer, automatic monitoring layer and human-computer interaction layer, and its system architecture is shown in Figure 1.

Among them, the data training layer corresponds to the ship navigation model training center, which governs and trains the massive historical ship track data to generate ship type models and ship navigation models.

The automatic monitoring layer corresponds to the automatic monitoring center of ship navigation behavior, which automatically monitors the accessed real-time ship navigation data and generates early warning information based on the trained model.

The human-computer interaction layer corresponds to the traffic situation display station, which provides functions such as chart display and operation, navigation environment display and control, information query on charts, measurement calculation on charts, ship target display, ship target operation, rule display, event display, alarm display and alarm setting.

The system application layer includes user business applications, third-party system applications, etc.

system application layer

user business applications	third-party system applications	Etc.

human-computer interaction layer

chart display and operation	navigation environment display and control	information query on charts	measurement calculation on charts	ship target display
ship target operation	rule display	event display	alarm display	alarm setting

automatic monitoring layer

Track fusion	Model loading	Rule generation	Anomaly detection	Anomaly analysis	Warning generation

data training layer

Cargo ship navigation model	Passenger ship navigation model	Fishing ship navigation model	Dangerous goods ship navigation model		
Speed model	Position model	Course model	Navigation feature model	AIS Signal Model	
Data Storage	Data Governance	Supervised Learning	Unsupervised Learning	Streaming Computing	Batch Computing

Basic operating environment

Operating System	Database system	Electronic chart display platform	Information exchange service

Figure 1 System Architecture

3.3 Workflow of the system

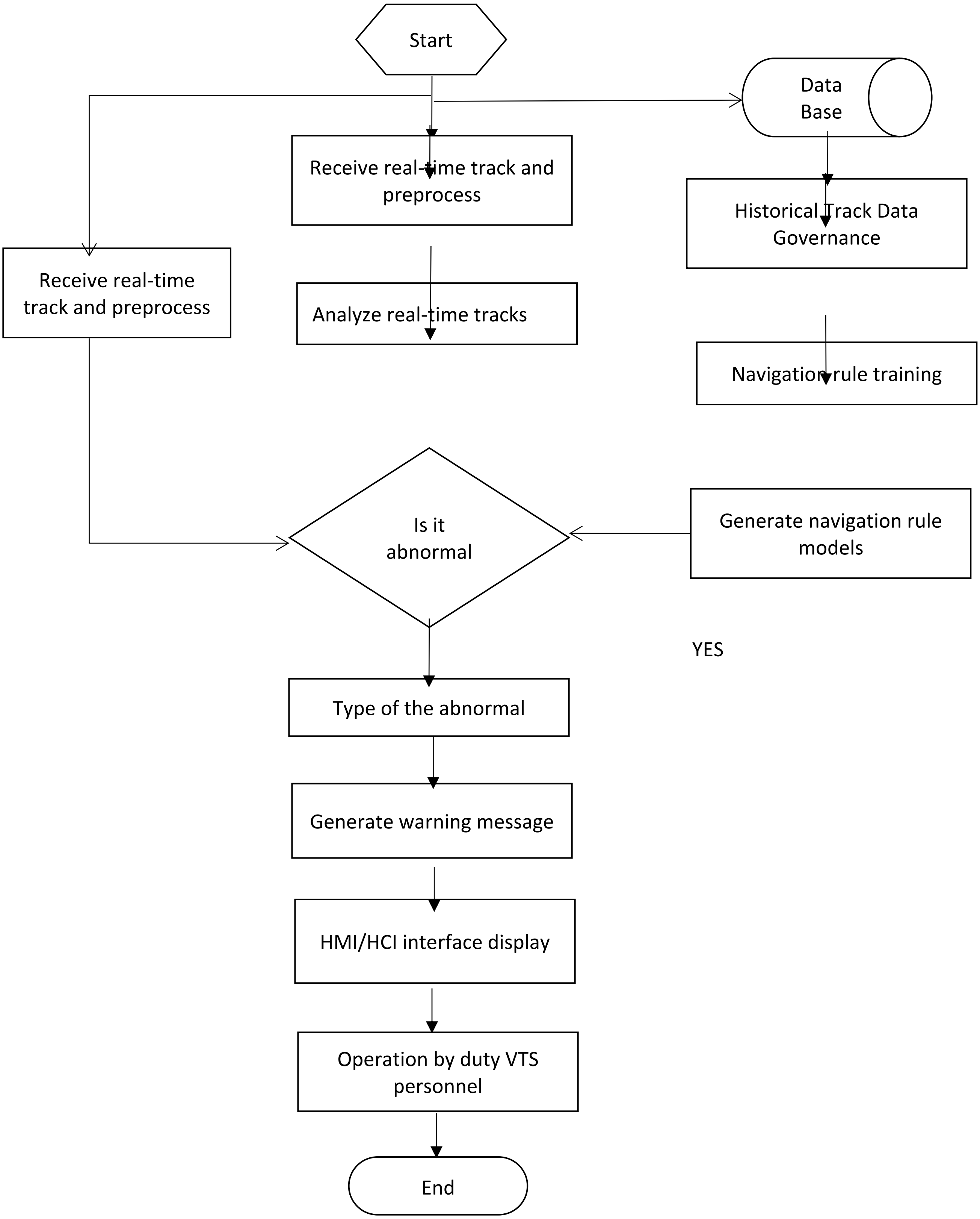

Figure 2 Workflow of the system

3.4 System Features

The autonomous detection system for abnormal ship behaviours provides intelligent support for VTS decision-making, enabling VTS personnel to detect abnormal ships earlier and more accurately, thereby responding to unsafe conditions in development in a timely manner, improving the effectiveness and pertinence of VTS service and reducing the risk of accidents. Compared with traditional VTS decision support tools, it has the following characteristics:

1) There are more types of abnormal ship behaviour warning. Through data mining and AI technology, abnormalities such as abnormal course, abnormal speed, entering unconventional areas, abnormal AIS equipment, anchoring in unconventional areas, near miss, and violation of navigation rules can be detected.

2) The recognition of ships’ abnormal behaviour is smarter. Taking entering an abnormal area as an example（The flow chart is shown in Figure 3）, the traditional VTS decision support tool needs to set the prohibited area in advance, but the autonomous detection system can autonomously judge that the ship has entered an area that others usually does not enter through data mining, and provide support for VTS personnel to discover ships’ abnormal behaviour in time. As shown in Figure 4, the ship "Ocean Glory" entered an area that ships would not normally enter. The system generated an alarm. After verification by the VTS personnel, the ship was out of control due to the main engine failure.

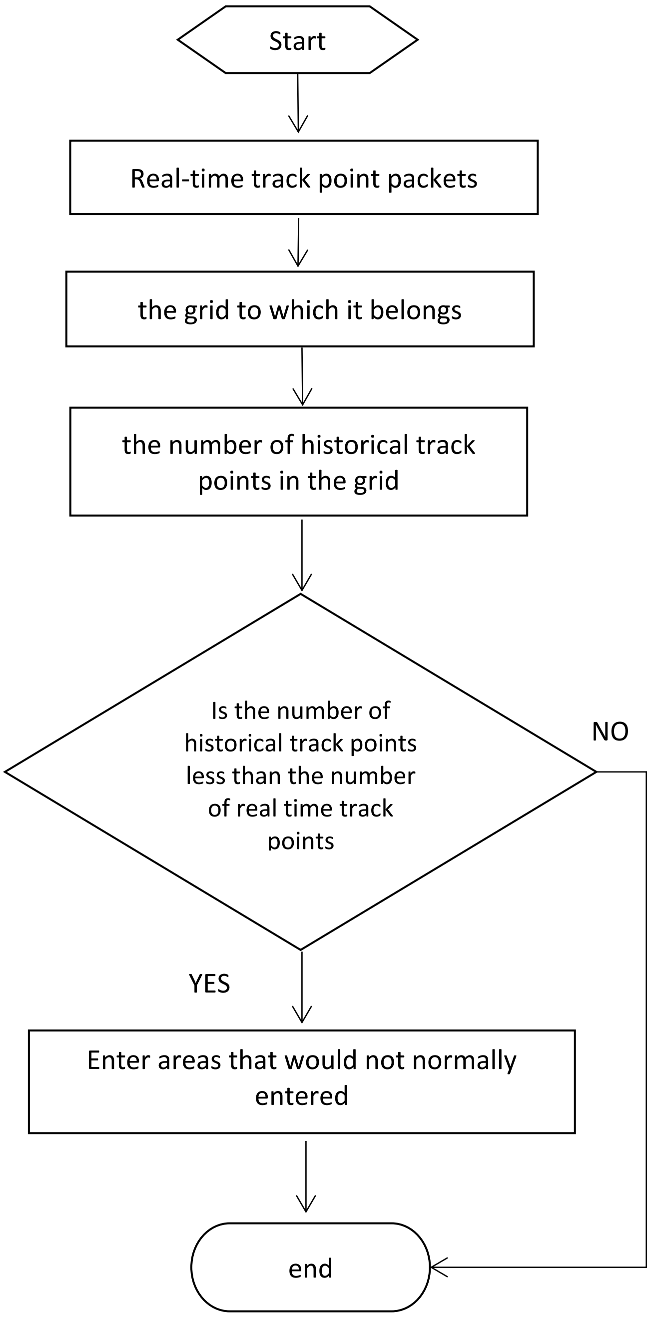

Figure 3 Flowchart of position anomaly detection

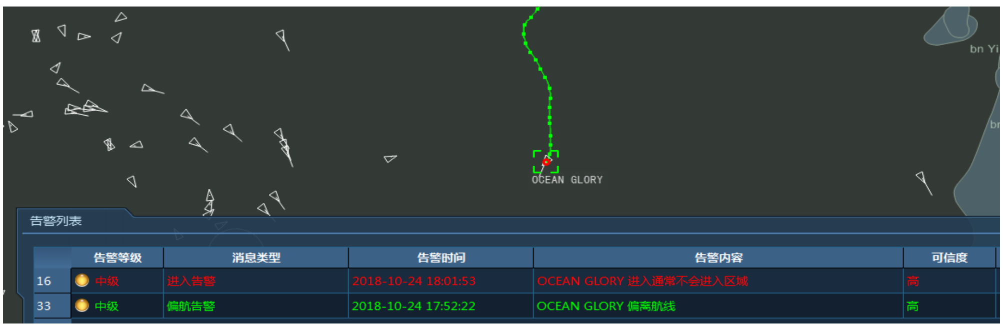

Figure 4 Alarm of “ocean glory” entering an area that ships usually does not enter

3) The rules of ships' abnormal behaviours can be optimized independently. The system can continuously monitor and analyse the ship traffic situation in the VTS area, and independently learn according to the processing results (processing or ignoring) of the alarm by VTS personnel, and continuously modify or adjust the abnormal behaviours recognition rules to conform to the VTS regional vessel traffic characteristics and VTS management service requirements.

4) Higher alarm accuracy rate. Traditional rule alerting relies on expert experience to design alerting rules for key waters. The rules are complicated to set and difficult to update in time. With the change of hydrographic conditions and ship navigation status, the accuracy of warning will be significantly reduced. This system will be able to integrate the real-time ship navigation data into the training of current ship navigation rules.From data accumulation, rule training to anomaly monitoring, the system completes automatically, saves time and effort, and the ship navigation rules are more in line with the current ship navigation conditions, and the warning accuracy is high. According to data from the practical vessel experiments and more than half year's trial operation, we got the result that the recognition ratio of the vessel's abnormal behaviors is over 95%, the false alarm ratio is close to zero and the system alarm is 0.5-2 hours ahead of the manual identification.

3.5 Deficiencies of the system

The deficiency of the system is that the system is developed based on AIS data, and its judgment of abnormal ship behavior is also based on ship AIS information, which has the possibility of inaccurate input and tampering, and the AIS equipment also has the possibility of malfunctioning or even being shut down. Therefore, when the AIS information is inaccurate or lost, the function of the system will not be performed, while the VTS system can also rely on radar to provide support for VTS personnel's decision making.

4 TYPICAL APPLICATION

1. Provide support for decision-making of VTS personnel. The autonomous detection system for ships' abnormal behaviours is a new VTS decision support tool based on big data technology and AI technology. Compared with the alarm function of traditional VTS decision support tools, it can provide better decision support for VTS personnel to respond to unsafe behaviours in development, so as to better contribute to safety of life at sea, safety and efficiency of navigation and the protection of the environment within the VTS area.

   Begun at the end of 2018, the trial operation verified the validity of the system by some real cases. E.g. At 13:45, March 17, 2019, at 1345, the system shows that the vessel named "Hongsui" has three alarms: abnormal heading, abnormal anchoring, and steering against traffic. After verification by the VTS operator, we confirmed that vessel "Hongsui" was under emergency reparation due to host failure.

2. Provide support for the formulation of vessel traffic regulations. The autonomous detection system for ships' abnormal behaviours can generate data products such as analysis reports on ships' navigation rules, distribution statistics of ships' abnormal behaviours for different vessels, different time periods and different regions, and can provide data support for formulating and adjusting traffic rules (such as introducing ships' routeing system), maritime planning, predicting high-risk areas, and discovering high-risk ships for VTS and stakeholders.

3. Realize the autonomous management of ship traffic safety in the whole area. The system can be deployed in a wider sea area, that is, outside the VTS area, and the system can be combined with E navigation technology, such as route exchange technology (MonaLisa 2.0), to realize automatic pushing of abnormal navigation information of ships and improve the navigation safety of ships.

AUTHOR BIOGRAPHY

LI Yuanhang has been engaged in the vessel traffic management and vessel traffic services in the waters of Chengshan Jiao Promontory since 2010 and has extensive practical experience in the ship's routing system and the mandatory ship reporting system. 2020 Mr. Li was qualified as a VTS training instructor in compliance with IALA R0103 standard.

S10.5 Next generation VTS development incorporating maritime AI and big data intelligence (127)

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ABSTRACT

Maritime traffic safety is paramount for maritime activities. Maritime traffic monitoring and other intelligence services-based development are becoming increasingly important for vessel traffic safety management, which also serves as an indispensable element in autonomous ship technologies. Expectation on such advanced development challenges the current Vessel Traffic Services (VTS) systems which are mostly passive information systems and lack of desired system intelligence and automation. Decision support features that are able to reduce human labours and avoid human errors are highly crucial to the development of next generation VTS systems.

In this study, based on the maritime AI and big data intelligence research conducted with the support of MPA Singapore, we will highlight the strategic role of maritime AI and big data intelligence technologies as key functions of next generation VTS systems, as well as their functional features within an inclusive framework design for proactive vessel traffic safety management.

KEYWORDS: Vessel traffic information systems, vessel traffic safety management, system intelligence, decision support

1 INTRODUCTION

To safeguard maritime traffic, Vessel Traffic Services (VTS) systems are implemented by an assemblage of information technologies that aid in the gathering, storing, processing, and presenting vessel traffic data as an inclusive system solution.

However, the present VTS systems work as “passive” systems, of which the main purpose is to visualize and observe vessel traffic dynamics with limited smart decision supporting features. Those systems require a lot of human labours, largely relying on domain experience and expertise. The industries have higher expectation on decision support features to enhance VTS intelligence and the advanced paradigm of practice.

In this paper, we focus on maritime AI and big data intelligence technologies, emphasizing the key functional features within an inclusive framework of VTS systems on maritime traffic safety management. The primary contents cover the following topics:

i. Maritime AI technologies advancing the counterpart risk warning functionalities implemented in existing commercial VTS systems: a) Upgrading the current linear model - Constant Velocity Model (CVM) to a multi-time scale multi-modal hybrid linear & non-linear model for better collision alert performance; b) Performance enhancement on achieving early alert and reducing false alert etc.

ii. Essential features that allow for better situation awareness, more proactive traffic safety management and identification of the critical vessels/situations to be tracked/monitored: a) traffic hotspot forecasting with vessels cutting cross traffic flows; b) multi-vessel encountering situation awareness. Especially, these situations focus on overtaking vessel detection & risk assessment, in/out port vessels detection & risk assessment and detection and highlighting the vessels at manoeuvring states (manoeuvring vessels are worthy for more attention as navigating states are attached with intentions that might lead to traffic disturbance).

iii. Leveraging on maritime big data intelligence to establish an incremental knowledge base that aligns with evolvement of maritime traffic patterns and is flexible to be generically adapted to international ports: a) Knowledge base extraction framework that automatically transforms the vessel traffic data to useful traffic patterns & knowledge base; b) Knowledge base addressing and storage solution to allow for efficient and effective knowledge query, retrieval and operations; c) Introducing the model interpretability and explainability in order to reach common domain understandability.

This paper focuses on VTS software-stack, especially on situation awareness related features, while collaborative coordination and mitigation strategies (after detecting and issuing alerts) that this solution will consider but not covered in depth should be further explored in future to better meet the requirements for vessel traffic safety management.

This information paper is summarized based on our industrial projects and research collaborating with domain experts, providing the inputs and key research findings in terms of intelligent Vessel Traffic Service (VTS) framework design, technologies, and the essential functional components to transfer the existing VTS systems towards more intelligent and proactive systems.

2 NEXT GENERGATION VTS – FROM “PASSIVE” TO “PROACTIVE”

2.1 The key components of VTS

VTS system is comprised of various information systems, which are seamlessly integrated and work together. A broad definition of VTS systems consists of both hardware infrastructure and software-stack systems:

i. VTS Hardware infrastructure, which collects the traffic data from multi-sources such as Automatic Identification System (AIS) [1], [2], coastal Radar systems, Long-Range Identification and Tracking (LRIT) [3] and SAR satellite [4] and so on, to remotely monitor vessel traffic.

ii. VTS software-stack system, which essentially receives the streaming traffic data from multiple sources and visualizes the vessel traffic dynamics for real-time traffic observations. The key decision-making functionalities and features serves as the core of VTS software-stack, and the ones implemented in commercial VTS information system include: a) Data sink and information visualizer for traffic dynamics and supporting components like Electronic Navigational Charts (ENC), Traffic Separation Scheme (TSS) etc.; b) Communication channel to coordinate between ship and control centre (Some systems incorporate the voice communication system through VHF); c) Vessel tracking feature for active monitoring; d) Collision risk assessment & alert feature based on traffic prediction; d) Other traffic and operation related features like route planning and service scheduling etc.

2.2 Limitations of the existing VTS systems

Among all these VTS features, collision risk assessment and vessel tracking are critical for vessel traffic safety management. Currently, there are still limitations for those functionalities in commercial system products:

a) First, most of the commercial VTS systems primarily use the CVM for vessel movement prediction followed by collision risk assessment. For navigating in straight track, CVM can perform very well [3]. However, when a vessel starts manoeuvring (changing its course or speed), CVM becomes inaccurate.

b) Second, the thresholds for alert, such as the closest point of approach (DCPA) and the time to reach this point (TCPA), are often manually decided. In many systems, a consistent set of alert thresholds applies by default without considering the water zones and traffic properties. This often leads to overwhelming alerts during busy hours and becoming not practically usable in these situations.

c) Moreover, other critical features like management of overtaking vessels, handling vessels towards pilot boarding station and vessels sailing in/out port are missing. There are absence of dedicated models to support these features, leading to the issues like alert miss, or lag in alert/alert at the last minute etc.

To accommodate these domain demands, we propose the VTS framework and key technologies to enhance the existing VTS systems to support operators' traffic monitoring duties for proactive traffic safety management and traffic situation awareness, redefined as intelligent VTS decision support system.

2.3 Transition towards Next Generation VTS

This section will elaborate the essential design considerations and critical components transforming the existing VTS software stack systems towards more intelligent, proactive, and preventive systems, so as to positively change from the existing practice with a large portion of human judgement towards computational judgement and intelligent decision support.

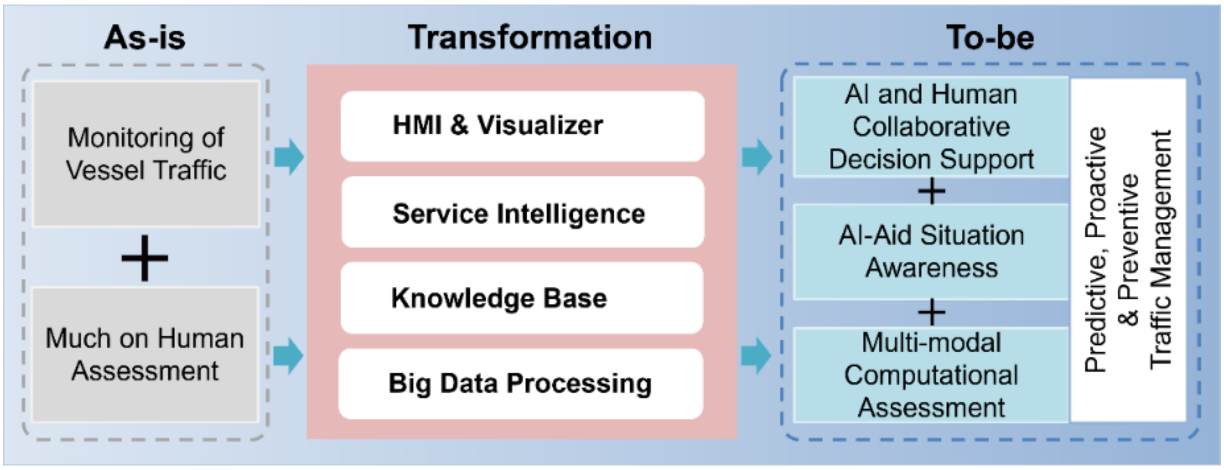

Figure 1: VTS from "passive" to "proactive" system

Figure 1 provides a high-level overview of essential components to transform the VTS from "passive" to "proactive". Those key components include data processing module, knowledge base, service intelligence through Artificial Intelligence (AI) models and human-machine interface (HMI) and operation visualizer. These layered components form a closely associate processing flow from data handling, domain-specific information extraction, AI modelling for decision support services delivering essential information and results to end-users.

3 DISCUSSION ON NEXT GENERGATION VTS

3.1 Big Data Processing

Vessel traffic data processing is the first and critical step after data being collected from the hardware infrastructure. In general, vessel traffic data processing approaches are categorized as batch and stream processing, to be explained in the following:

- Batch processing is applied for historical maritime traffic dataset. Such batch processing aims to extract the traffic patterns and knowledge base such as waterway and waypoint, traffic network and graphics, and traffic safety related situations like near miss cases and vessel close-encounter situations, and other traffic statistical insights. Maritime traffic pattern and knowledge base can be incrementally established when the latest traffic data are incorporated.
- Stream processing normally serves for real-time decision-making features that require timely response and insight generation like for on-the-fly traffic monitoring, fleet management, vessel movement prediction, traffic hotspot forecasting, collision alert, and collision avoidance and mitigation actions etc.

Although VTS systems are normally equipped with data archiving feature, most of the existing VTS systems mainly focus on stream processing. Nevertheless, off-line batch processing for traffic pattern and knowledge base extraction can bring in system intelligence and is valuable to support the real-time decision-making features. Regular traffic patterns can be applied for anomaly detection and vessel traffic long term prediction[5], [6].

3.2 Knowledge Base

Knowledge base is a higher level of functionality-driven and domain specific information cluster. The availability of big maritime traffic data foster the recent progresses on maritime traffic pattern extraction, knowledge mining as well as maritime traffic pattern analytics.

3.2.1 Waterway pattern

Waterway pattern is a type of fundamental knowledge bases. In maritime traffic sector, waterway pattern is extracted based on vessels' navigating routines that follow the basic regulation and shipping operations, hydrographical features of sea ways, down to vessels' manoeuvrability and behaviours. Waterway pattern represents the realistic sea routes extracted from numerous real-world navigation instances.

3.2.2 Knowledge base of near miss cases

High risk near-miss cases contain valuable information for researchers, port authorities and relevant stakeholders to develop preventive strategies to enhance vessel traffic safety. Near miss cases are manually reported based on personal judgement from port operators. To automatically detect near miss through AI models is beneficial to establish a knowledge base of near miss and collision cases for training and study purpose.

3.2.3 Knowledge base of multiple vessel encounter situations and hotspots

Besides the near miss cases between pairwise vessels, more complicated multiple vessels encounter situations are worthy for study to support traffic safety management. Besides, traffic congestion or traffic dense hotpot are often correlated with both traffic safety and efficiency. The detailed definitions of multi-vessel encounter situation and traffic dense hotspot scenarios will be discussed in the next section. These specific traffic situations deserve establishing a knowledge base for assessment and analytics. The historical multi-vessel encounter situation cases and traffic dense hotspots detected are supportive to build the proactive traffic safety management framework and Standard Operating Procedures (SOPs).

3.3 Service Intelligence through AI Models

3.3.1 Advancing the safety management features in existing VTS systems

Collision alert is the fundamental function of VTS systems for traffic safety management. The classic collision risk metrics such as DCPA and TCPA [7] can be directly determined using the constant velocity model for vessel movement prediction [8], i.e., assuming vessels should navigate in a straight track with a constant course and velocity in the near future. However, vessels may change its course or speed in real-world situation, CVM becomes unreliable if a vessel is changing its speed or turning its course.

Nowadays, most of the VTS systems use the CVM to predict vessel movement trajectory, since it is simple, fast, and easy-to-operate. However, when a vessel starts manoeuvring, the non-linear forecasting approaches exert much better performance through allowing earlier detection of turning intention and potential collision risk, as illustrated in Figure 2. The earlier collision risk alert issuing will bring more time for both ship masters and operators to communicate and mitigate the risk situation.

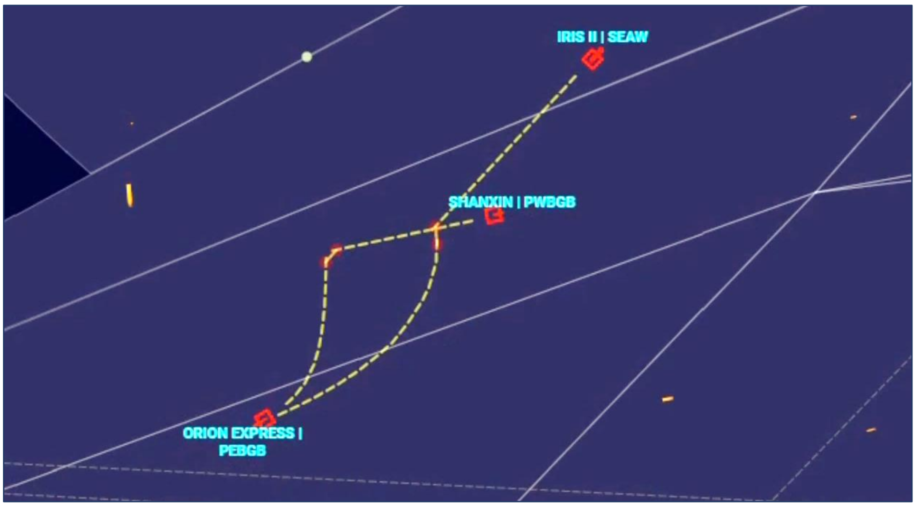

Figure 2: Non-linear forecasting versus conventional CVM based warning approach

3.3.2 Add-on features

a) Multiple Vessel Encounter Situation

Pairwise vessels' encounter and regulations are governed by Convention on the International Regulations for Preventing Collisions at Sea (COLREGS), however, more complex multi-vessel encounters that potentially occur are not clarified and regulated by COLREGS. Studies reveal that in multi-vessel encounter situations, undesirable manoeuvre actions by one vessel potentially bring more difficulties to other vessels to avoid collision. The Multiple Vessel Encounter Situation (MuVES) situation evaluation will facilitate the early alert supporting model & tool design and development for predicting multi-vessel encounter situation. MuVES is a dynamic traffic situation involving more than 3 vessels, and the set of vessels may approach closer and eventually lead to an encounter in the same area with potential complex interaction. Like pairwise vessels' encounter situation alert, MuVES is suggested to target at up to 10 to 15 min earlier situation awareness.

MuVES doesn't always cause high risk, but active and close monitoring is required since it may evolve into complex encounter or even risk situation if one (or more) vessels violate COLREGs or there is poor communication among the engaged vessels. Such progression in busy waters of complex intersections may occur more. Effective and proactive management will help prevent MuVES from evolving into high risk situation. To visualize a MuVES, the water area and vessels involved will be highlighted and CPA metrics along with other navigating states of each vessel can be retrieved, as illustrated in Figure 3.

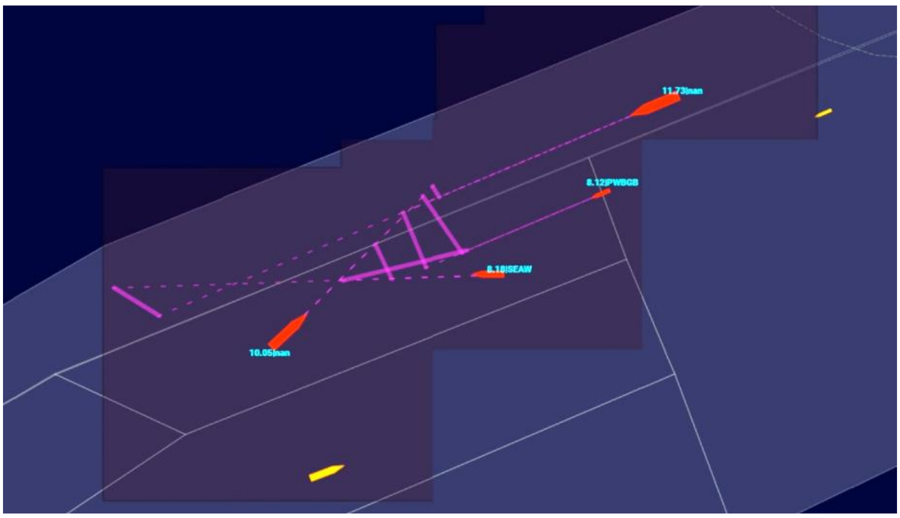

Figure 3: An example visualization of a MuVES hotspot

b) Traffic-dense hotspot

Traffic-Dense hotspot is a high dense water area where its traffic density is obviously greater than the surrounding areas, which may often decrease the navigational water traffic capacity and potentially increase the ship collision risk. Traffic-Dense hotspot is related to traffic congestion situation awareness and is suggested to target at up to 20 to 30 min earlier situation awareness in advance. Some facts about Traffic-dense hotspot are provided as follows:

- Traffic-dense hotspot may evolve into Multiple Vessel Encounter Situation (MuVES) or near miss cases or keep as congested traffic;
- The vessels enter into the traffic-dense hotspot from other traffic flow such as those navigating in/out of the port may lead it into complex encounter or near miss cases and increase risk;
- Forecasting in advance of the traffic-dense hotspot (location, duration and vessels involved) could enhance longer term visibility of future traffic situation for more proactive traffic safety management;
- From the risk aspect, it requires especially focusing on the vessels sailing in or out of port waters, navigating towards pilot boarding stations and all other crossing encounter situations.

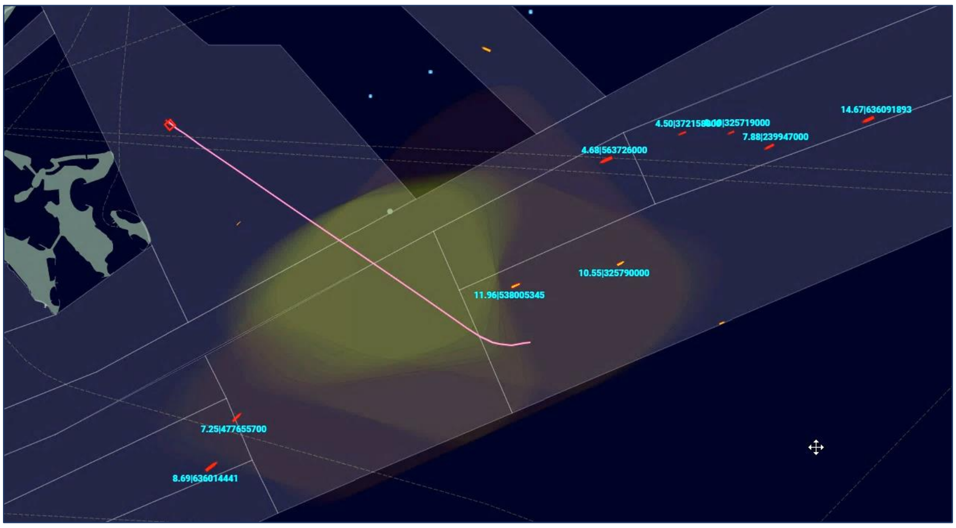

Figure 4: An example visualization for traffic-dense hotspot forecasting

An example of visualization for predicted traffic-dense hotspot is illustrated in Figure 4, the visualization indicates the trajectory of the crossing vessel sailing out from port that has potentially encounter with both the strait traffic flows and the potential encounter area (hotspot area).

It should be noted that traffic dense hotspot, MuVES and pairwise vessel collision risk forecasting altogether forms a multi-time scale proactive traffic situation awareness and management framework, which covers decision making support from up to 30 min and down to near 10 min in the future, while the forecasted results serve as input for further mitigation strategies formulation. In the meantime, in all these scenarios, the vessels involved and especially those maneuvering vessels are supposed to be highlighted and prioritized as more critical info to be presented to operators.

3.3.3 HMI & Visualizer

The decision support services and insights created through AI models need to be delivered to operators through well-designed human-machine visualizer interface. The visualization design is critical for VTS systems, which should highlight the critical information with priority, clarity, and domain understandability to system operators.

Advanced data visualization techniques can help operators to have better insights into vessel traffic situation and visually access to essential information, eventually serving as a useful tool for operational decision support. Aligned with VTS features, dynamic traffic movement visualisation, vessel trajectories and spatiotemporal traffic density distribution, collision alert and hotspot alert for monitoring, environment data and Electronic Navigational Chart (ENC) visualization among the most required elements. Visualization can be designed as for “basic information visualization”, “functionality/service-based visualization”, and “operation-driven interactive visualization” to support better understand maritime traffic situation and proactive traffic safety management in practical applications.

4 CONCLUSION

This paper is a summary of our design practice, functional module implementation, testbed and the critical research findings that are dedicated to Vessel Traffic Services (VTS) systems (specifically, we focus on vessel traffic safety management). The key design considerations on transforming the current “passive” VTS systems towards next generation “proactive” VTS systems have been discussed from the aspects of data and knowledge, AI model and service intelligence, and service delivery through user-friendly HMI. The main contents described in the paper are formed by consistent efforts and series of strongly relevant works across several industrial projects that span over a couple of years. Targeting at the real-world industrial problem statements, the challenges of common interests and solutions will be inspiring and appealing thoughts for advances to improve the existing VTS features and practice.

5 ACKNOWLEDGEMENTS

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S110.1 Cloud based Vessel Traffic Service (VTS) and Local Port Service (LPS) systems (166)

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ABSTRACT

Maritime system-of-systems or Maritime Information Systems can benefit from the significant advantages that cloud native technologies offers now and in the short, medium, and long term. These advantages include cost effective, rapid deployment of standards-based, multi-tenant solutions that are continually updated as technology, specifications and customers' requirements change.

Cloud based Maritime Information Systems assist all, from coastal authorities through to ports and smaller systems in marinas to reduce their carbon footprint while benefiting from access to a standards compliant, high performance, high availability and feature rich me Information Systems. This improves the safety, efficiency, security of ports and coastlines and is key to the protection of the natural maritime environment for all in a cost-effective manner.

KEYWORDS: Cloud, Multi-tenant, System of Systems, Maritime Information System.

RESUMEN DEL ARTÍCULO

El sistema de sistemas marítimos o sistemas de información marítima puede beneficiarse de las ventajas significativas que ofrecen las tecnologías nativas de la nube ahora y a corto, mediano y largo plazo. Estas ventajas incluyen la implementación rápida y rentable de soluciones multiusuario basadas en estándares que se actualizan continuamente a medida que cambian la tecnología, las especificaciones y los requisitos de los clientes.

Los sistemas de información marítima basados en la nube ayudan a todos, desde las autoridades costeras hasta los puertos y los sistemas más pequeños en los puertos deportivos, a reducir su huella de carbono al tiempo que se benefician del acceso a sistemas de información compatibles con los estándares, de alto rendimiento, alta disponibilidad y ricos en funciones. Esto mejora la seguridad, la eficiencia y la seguridad de los puertos y las costas y es clave para la protección del medio ambiente marítimo natural para todos de una manera rentable.

PALABRAS CLAVE: Cloud, Multi-tenant, Sistema de Sistemas, Sistema de Información Marítima.

RESUME DE L'ARTICLE

Les systèmes de systèmes maritimes ou les systèmes d'information maritime peuvent bénéficier des avantages significatifs que les technologies cloud natives offrent maintenant et à court, moyen et long terme. Ces avantages comprennent le déploiement rapide et rentable de solutions multi-locataires basées sur des normes qui sont continuellement mises à jour à mesure que la technologie, les spécifications et les exigences des clients changent.

Les systèmes d'information maritime basés sur le cloud aident tous, des autorités côtières aux ports et aux petits systèmes dans les marinas, à réduire leur empreinte carbone tout en bénéficiant d'un accès à des systèmes d'information conformes aux normes, performants, à haute disponibilité et riches en fonctionnalités. Cela améliore la sûreté, l'efficacité et la sûreté des ports et des côtes et est essentiel à la protection de l'environnement maritime naturel pour tous de manière rentable.

MOTS CLÉS : Cloud, Multi-locataire, Système de Systèmes, Système d'Information Maritime.

1 INTRODUCTION

The maritime domain is subject to the significant advances in the Information Technology (IT) domain that drives down costs through economies of scale and improved performance. This stems from new software and hardware technologies that are released almost daily.

Cloud-based maritime focused solutions deliver advantages to Operators and the wider maritime community. This gives all countries with a coastline, Aids to Navigation (AtoN) authorities, small and large commercial ports, fishing ports and even marinas access to the same systems and features available in large and expensive systems with little, and sometimes no capital investment.

When considering cloud-based maritime systems, the evaluation should include comparing cloud-based systems to discrete, on-site, or on-premises solutions and looking at attributes that include:

1.1 Carbon footprint

Cloud based data centres have significant carbon footprints but, on per application basis, each application uses a small portion of a cloud platform. When sharing loud infrastructure, each cloud-based application has a carbon footprint that is reduced by between 50% and up to 90% depending on the software application when compared to a legacy implementation of the application [1].

1.2 Life cycle costs

The life cycle costs of maintaining an on-premises bespoke maritime system are high. These costs cover monitoring, maintenance, support, ongoing technical training, regular upgrades, software and data backups, software failures and subsequent system and service recovery.

1.3 Performance

Cloud solutions are scalable and can be configured to either have a significant amount of bandwidth, processing, and storage headroom or be dynamically scaled so that as the load increases, for whatever reason (i.e., a localised incident), the software application scales to cater for the additional load. When this load reduces, the system scales down.

1.4 Availability

System availability is determined by many factors. Cloud based solutions are design to operate on a 24/7 basis with very high levels of availability that tend to approach 99.999% (the five 9s goal). Public Cloud Service Providers (PCSP) such as Microsoft Azure, Amazon Web services and Google Cloud have large data centres with high levels of hardware, connectivity and power redundancy which supports high availability levels.

1.5 Flexible topologies

System topologies using cloud native technologies are flexible. This allows for distribution between the PCSP and an on-premises cloud solution in a manner that satisfies the performance, cost profile, availability, and data storage requirements of the customer.

1.6 Cyber security

Protecting IT systems while at the same time making them more accessible to many more end users to promote safety, security, environmental protection and support the economic growth in the maritime domain is a balancing act. PCSP have a significant focus on ensuring that their systems and users are secure while accessible to end users. This is matched by the cyber security of cloud hosted applications.

2 CLOUD BASED SOLUTIONS

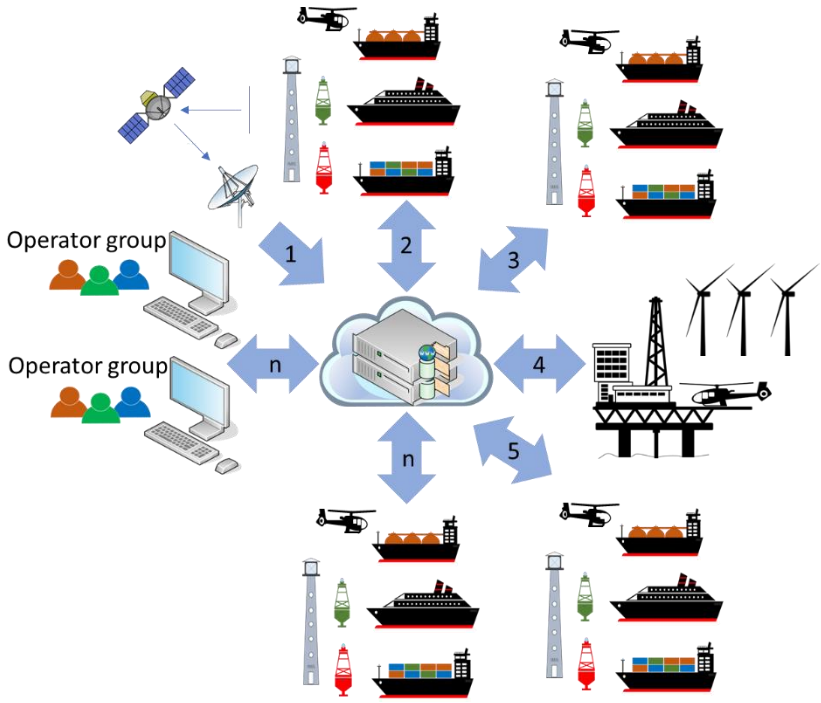
Maritime IT applications consist primarily of three components: Human Machine Interface (HMI), the Compute or processing component and the Data Storage component. The maritime application collects data from the connected sensors and processes and stores the data enabling its display and distribution.

On the HMI side, the capability of modern Internet browsers has enabled the large-scale adoption of the Internet browser as a highly capable Graphical User Interface (GUI) with an encrypted connection. This has enabled computer browser games implemented with the standard web technologies including HTML, CSS, JavaScript, and WebGL.

The HMI has been supported by an ever more powerful back-end solutions that collects large volumes of maritime centric data from a variety of sensors and connected systems and then processes, stores, displays and shares this data. This enables shore side Maritime Domain Awareness (MDA), Vessel Traffic Services (VTS), Local Port Services (LPS), AtoN systems and Shore Based Pilotage (SBP) systems. MDA, VTS, LPS, AtoN and SBP systems can be combined into a single, standards based, high performance, multi-tenant maritime system-of-systems or Maritime Information System (MIS).

MISs use 'cloud native' [2] technologies with micro-services in software containers [3], container orchestration and performance monitoring. Together these form a platform from which feature rich services to multiple logically isolated tenants or user groups is provided while ensuring logical data isolation and protection.

The MIS described above can be shown as illustrated alongside.



2.1 Benefits of cloud based MIS

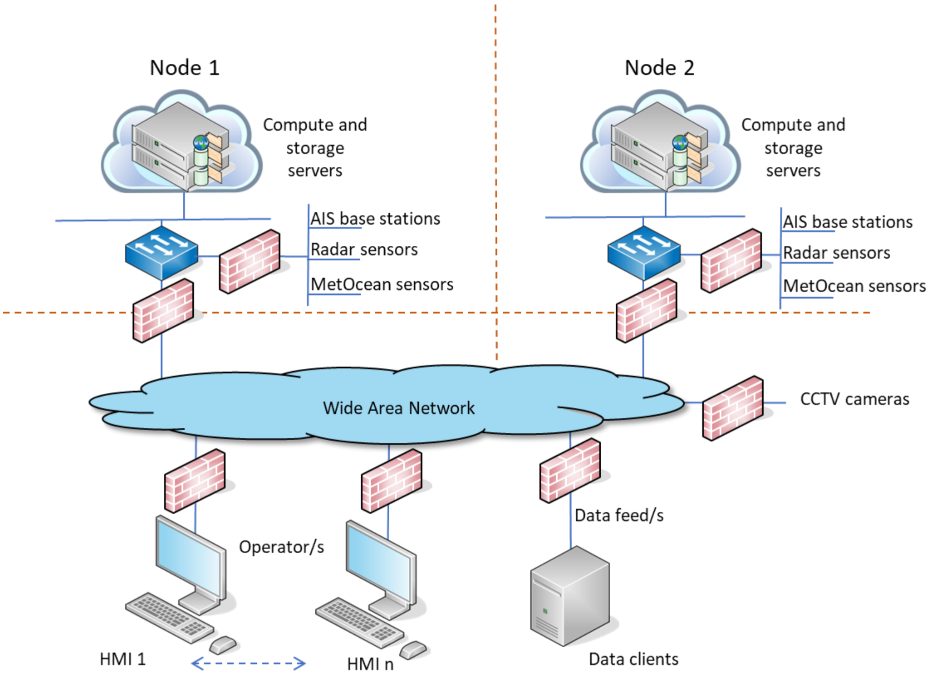
The cloud-based solution is scalable in terms of data sources and data processed, stored, displayed, and shared. Importantly the Operator Groups are isolated from each other and the activity of any one group is unknown to any other group. They are effectively unaware of the existence of each other. This required isolation is achieved by data segmentation and a finely granulated permissions system that ensures that each operator only gains access to the features, sensors, and data that they are configured or entitled to.

The number of operators and / or operator groups is only limited by the resources that are allocated within the cloud environment.

The benefits of a cloud-based MIS are linked to the resources within a cloud environment that are significantly larger than any one customer group would require. This enables the cloud environment to be shared by many customer groups and any one customer group can expand and shrink dynamically according to operational requirements with little or no effect on the performance or reliability of the MIS.

The MIS using cloud native technologies, while compliant to all applicable standards, allows features to be upgraded, new features to be added and software bugs to be rapidly resolved to the benefit of all users of the MIS.

The availability of cloud native systems provided by PSCP is very high and a single instance of an MIS in the cloud has been proven to consistently achieve >99.95%. This can be increased to > 99.99% and closer to 99.999% by allowing two cloud-based MIS, a multi-cloud deployment, to operate in an Active – Active mode so that when one node fails the other node, which is established in a different geographic and logical location, continues to operate. The result is the maintaining of the service, meeting the Service Level Objectives (SLO) and thus satisfying the Service Level Agreement (SLA).



The Active – Active multi-cloud configuration allows for several different options to connect to the sensors (AIS, Radar, MetOcean sensors and the like) so that the sensors can connect using physically and logically redundant data links, if required.

3 CLOUD DEPLOYMENT STRATEGIES

PCSP do not have to be used. Cloud services can be provided by any suitable entity and ranges from the PSCP, government and / or authority provided cloud environments through to user provided, on premises cloud solutions. Hybrid solutions with part of the system being in a PCSP environment and part being in a private, on premises cloud, is possible.

These flexible deployment strategies [4] do not prevent the vendor supplying a cloud-based solution from managing, monitoring, and supporting these flexible architectures.

Cloud deployment strategies:

- Public cloud
- Private cloud
- Hybrid cloud
- Community cloud
- Multi - cloud

4 EXTERNAL PRESSURES

While costs, carbon footprint ambitions, system availability, features, scalability, and continuous improvement drives the initial consideration of cloud-based MIS there are external pressures. External pressures such as system availability and carbon footprint reduction increase the complexity of MIS. These external pressures include:

4.1 Efficiency

Ships and ports are always looking for efficiency gains which often have the twin benefits of reducing the carbon footprint and reducing life cycle costs in the long term and operating costs in the short term. The Port Call Optimisation efforts play a significant part in achieving this.

4.2 Security

The protection of MIS from external Cyber Security threats is near the top of most authorities' agendas. The need to share detailed and real time information far more widely in the port community requires that the MIS be protected using systems that are continually being improved and adapted to deal with the latest threats.

Small ports and marinas can now easily gain access to secure systems and features that were the sole preserve of large MDA, VTS and LPS systems. This also increases the physical security of these same environments.

4.3 New technologies and standards

New technologies and associated features are becoming available almost daily. To benefit from these technologies requires access to systems that are being continually upgraded. This requires the MSI to be regularly upgraded, not with a technology refresh every 5 to 10 years but on a far more regular basis such as quarterly or even monthly.

The IMT2020 advanced (5G and then mooted 6G) technologies enable significant opportunities within ports promising GNSS independent precise positioning and >1Gb/s bandwidth connects between 5G devices including shore and ship.

The S-100 series of standards [5] are maturing and will not only have an impact on Electronic Navigation Chart Systems (ENCS) but also the sharing of information to enhance port operations (S-211), Aids to Navigation (S-201) and the connection of peripherals (S-210) amongst others.

4.4 Safety

The sharing of information in the maritime community (port and coastal) allows many more eyes to be monitoring the Common Operating Picture (COP) and with the support of Decision Support Tools (DST), normally the domain of VTS and LPS environments, many more persons and connected systems become aware of the real time operational environment. The increasing use of Machine learning (ML) in these DST allows for instance, ETA of vessels at selected points (i.e., port arrival, anchorage area, waypoints, berths, and locks) to be more accurately predicted leading to more accurate planning and supporting more efficient and safe operations.

4.5 Protection of the natural maritime environment

The protection of the natural maritime environment is under pressure from climate change and increased human activity. The maritime sector is under growing pressure to reduce its impact on the natural maritime environment.

Actions include:

1. Protecting selected areas from human activity.
2. Not allowing anchorage in selected areas.
3. Virtualising Aids to Navigation (using Virtual AtoN).
4. Increasing the efficiency of the maritime sector and so reduce the carbon footprint.
5. Monitoring shipping to ensure safety and reducing harmful incidents.
6. Integrating systems into systems of systems solutions that empower all with information.

5 CONCLUSION

MDA, VTS, LPS, AtoN and SBP MIS can benefit from the significant advantages that an MIS using cloud native technologies offers now and in the short, medium, and long term. These advantages include rapid deployment of standards-based solutions that are continually updated as technology, specifications and customers' requirements change.

Cloud based MIS assist all, from coastal authorities through to ports and smaller systems in marinas to reduce their carbon footprint while benefiting from access to a standards compliant, high performance, high availability and feature rich MIS. This will improve the safety, efficiency, security, and protection of the natural maritime environment for all in a cost-effective manner.

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AUTHOR BIOGRAPHY

Ernest started his career in telecommunications and train radio control systems and then moved into the ship and shore maritime electronics domain. Ernest has also attended the University of South Africa and Oxford Brookes focusing on business management studies. Ernest has been attending IALA meetings in Paris since the late 1990s during the early days of AIS and continues to play an active role in IALA.

Ernest is one of the two founding members of IMIS Global that, for the last 22 years, has focused on Maritime Information Systems and lately their migration to the cloud. Ernest serves as the Technical Director in IMIS Global and is the original architect of the IMIS flag ship product, MariWeb.

S110.2 Presentation of an innovative information system deployed by France for the benefit of VTS in terms of maritime navigation surveillance and risk management: the “EGIDE” module (104)

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ABSTRACT

Decision support and maritime surveillance tools are becoming essential to combine the increase in human activities at sea and the piling up of regulatory provisions with the strengthening of controls and the reduction of resources allocated to maritime public policies. In France, the field "maritime traffic monitoring" is a regulatory prerogative of the French MRCC as Regional operation Center for surveillance and rescue (CROSS). The central positioning of CROSS within the monitoring model by detecting weak signals will facilitate actions to safeguard the interests of the coastal State and and will support the concepts of VTS and VTM. Digital holds a key place in the surveillance ecosystem. The sharing of data and the system-to-system exchange between administrations and coastal States is fundamental. The purpose of the paper is to introduce the EGIDE module project as an early warning system (EWS) developed by Naval Group and funded by the General directorate for maritime affairs, fishery and aquaculture (DGAMPA).

KEYWORDS: Weak signals – Early warnings – Watch – CROSS – Risks – Decision support.

RESUMEN DEL ARTICULO

En este documento, se describen los requisitos de formato para la 20ª Conferencia de la IALA. Revise este documento para obtener información sobre el formato del texto, los títulos de las tablas, las referencias y el método para incluir la información de indexación. Las actas de la conferencia se publicarán en formato electrónico. El trabajo completo en archivo MS Word se redactará de conformidad con estas instrucciones. En una etapa posterior, se convertirá a formato de documento portátil (PDF).

Un resumen de no más de 250 palabras debe aparecer en la parte superior de la primera página, después del título del trabajo en una sección titulada "RESUMEN" (sin número de sección), después de los nombres de los autores.

PALABRAS CLAVE: Señales débiles – Alertas tempranas – Vigilar – CRUZ – Riesgos – Apoyo a la toma de decisiones.

RESUME DE L’ARTICLE

Les outils d’aide à la décision et de surveillance maritime deviennent indispensables pour conjuguer, la hausse des activités humaines en mer et l’empilement des dispositions réglementaires avec le renforcement des contrôles et la compression des moyens alloués aux politiques publiques maritimes. Le domaine « surveillance de la navigation maritime » est une prérogative réglementaire des CROSS français (Centres Régional Opérationnel de Surveillance et de Sauvetage). Le positionnement central des CROSS au sein du modèle de surveillance par la détection de signaux faibles facilitera les actions de préservations des intérêts de l’État côtier et supportera les concepts de STM(VTS) et de StM (VTM). Le numérique tient une place clé dans l’écosystème de surveillance. Le partage des données et l’interopérabilité des systèmes d’information entre administrations et États côtiers sont fondamentales. L'objet de cet article est de présenter le projet de module EGIDE en tant que système d'alerte précoce développé par Naval Group et financé par la Direction générale des affaires maritimes, de la pêche et de l'aquaculture (DGAMPA).

MOTS CLÉS : Signaux faibles – Alertes précoces – Veille – CROSS – Risques – Aide à la décision.

1 INTRODUCTION

The maritime world is entering a period of massive transformation. Climate, biodiversity, safety and security issues, the COVID-19 health crisis, geopolitical conflicts, potential shortages of qualified seafarers are affecting and posing new challenges to the sector. But also for coastal States, with risks of undermining sovereignty in French CROSS (MRCC / VTS / VTM) areas of competence (loss of human life at sea, grounding, collision, respect for the right of innocent passage, non-compliance with the regulations in force , cybercrime at sea, malicious acts against critical infrastructure at sea, etc.). Maritime data is the key not only to follow trends, but also to establish a culture of monitoring and fill gaps of all kinds by providing innovative technologies (decision support tools, artificial intelligence, deployments of new maritime surveillance censors relating to the land, maritime and space segments and the interoperability of systems, etc.). They will consolidate knowledge of the maritime situation in the French areas of interest for the benefit of the actors of the coastguard function.

The French CROSS are positioned within the surveillance ecosystem as a multi-mission center responsible for rescue at sea, navigation, pollution, fishing, dissemination of information and protection (security). Due to their geographical positions, their operational and organic supervision, and the strong links forged with the various actors who intervene at sea, they occupy a place of choice. Once the crisis has occurred, it is difficult to absorb it if there is a lack of anticipation and preparation. Detecting weak signals helps anticipate or prevent risks. This strategic watch is an opportunity to strengthen the "maritime navigation surveillance" field, the regulatory prerogative of the CROSS bringing together the components of vessel traffic monitoring (VTM), vessel traffic services (VTS) and maritime assistance service (MAS). It must promote the detection of weak signals through an intelligent combination of technological tools and business experts. Once processed, these signals contribute to the development of an operational and information feedback strategy in order to inform decision-making. Their processing is part of the stages of crisis management characterized by a first phase of prevention, which consists of monitoring potential risks.

The detection of these signals by the CROSS can be complex, given the large volume of maritime information with which they deal. This strategic watch requires effective management, human resources and appropriate tools for its proper functioning. Weak signals are useful data, provided you know how to identify them, interpret them, contextualize them, and therefore categorize them by level of risk. The circulation and decompartmentalization of information are important axes in order to exploit these signals in an optimal way. The paper will present a picture of CROSS activity, a matrix of attacks on sovereignty, as well as a method for analyzing weak signals. The place of digital technology, in particular the development of the early warning system (ÉGIDE module) [1]. The cognitive levers favoring the interpretation of these signals Is to be taken into account but will not be detailed in this paper.

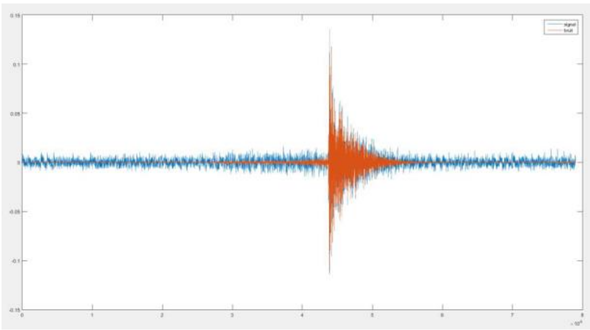


Figure 1: Signal processing analogy: ambient background noise reduction, internet source

2 SUMMARY PRESENTATION OF THE CROSS ENSURING THE FUNCTIONS OF MRCC, VTS, VTM AND LEADING POLLUTION REFERENT CENTRE

Specialized services of the interregional directorates of the sea in mainland France, the directorates of the sea and the maritime affairs services overseas, the CROSS, MRCC and JRCC carry out permanent public service missions (24 hours a day, 7 days a week), for the benefit of seafarers, professionals and yachtsmen. The missions are conducting under the authority of the representative of the State at sea (Maritime Prefect in mainland France and government delegate for State action at sea in overseas territories), and in synergy with the chain of actors of the coast guard function. The CROSS network is made up of ten centres and covers more than 24 million km² of maritime areas under sovereignty:

- 7 regional operational surveillance and rescue centres (CROSS);
- 1 secondary centre;
- 1 maritime search and rescue coordination centre, and VTM (COSS);
- 1 maritime and aeronautical search and rescue coordination center (JRCC).

All the competence areas of the centres (SRR and EEZ) are accessible via the following link: https://data.shom.fr/donnees/contexte/shom_data_context_x1

These multi-mission centers use information and communication systems for the coordination of search and rescue missions, maritime navigation surveillance (vessel traffic monitoring, vessel traffic services, maritime assistance service) and monitoring pollution at sea. They ensure the coordination of operations and the monitoring of events at sea to avoid the development of unsafe situation. To do this, they rely on a technical radar and radio-monitoring network operated remotely (80 sites spread over the national coast in France and overseas), on a communications management ecosystem called "SGVT" and operations called " SEAMIS" and access to the integrated maritime services of the European Maritime Safety Agency (EMSA). The monitoring and processing of events are ensured by a watch team made up of a duty officer authorized as coordinator of the rescue mission, watch supervisors and watch assistants, VTS Operators, petty officers of the French Navy. The organization is specific to each CROSS and linked to the operational functions performed.

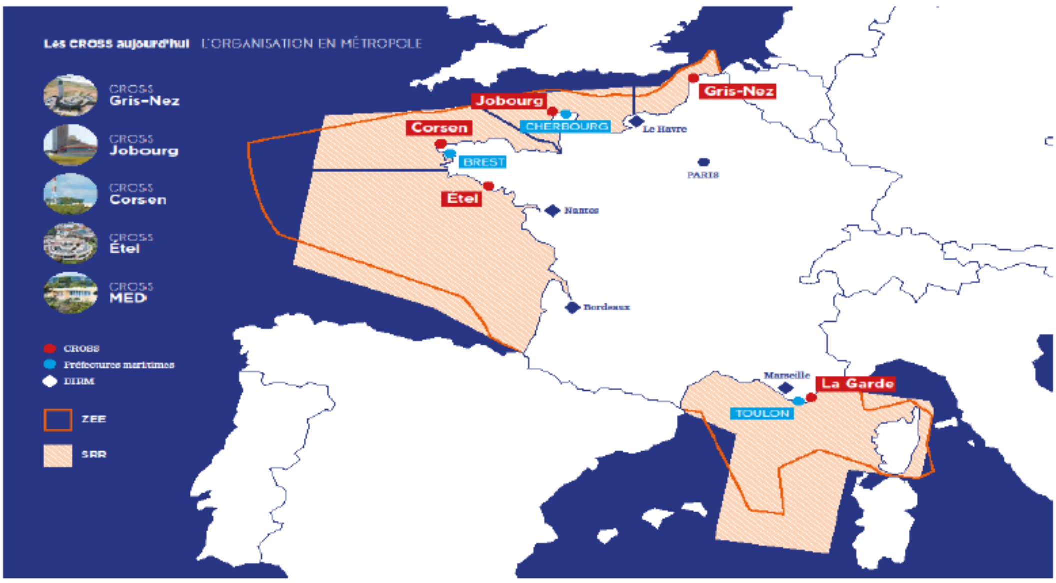


Figure 2: Location of CROSS in mainland France, source DGAMPA

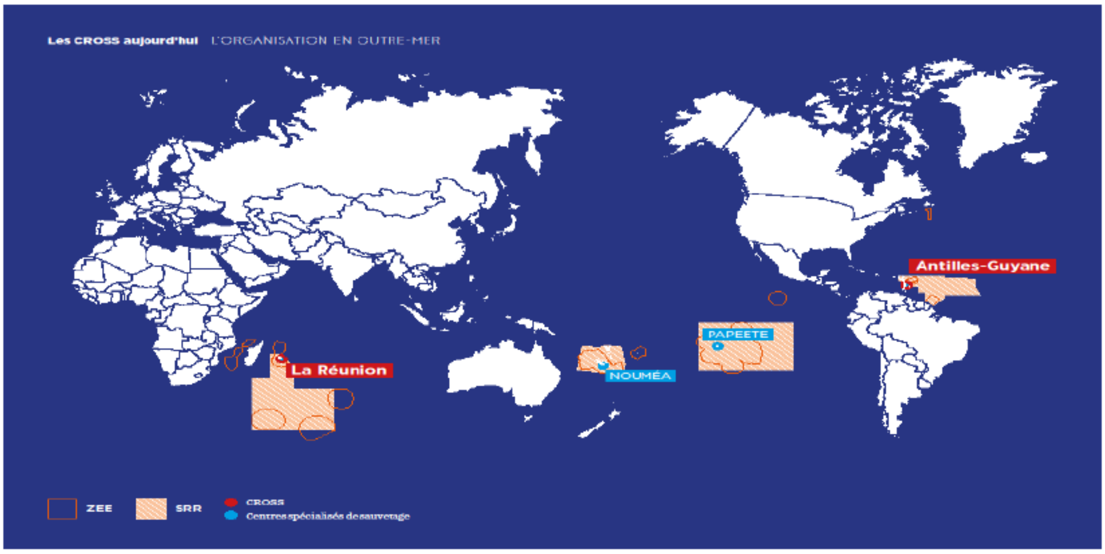


Figure 3: Location of overseas CROSS, source DGAMPA

3 MATRIX OF INCIDENTS, RISKS AND THREATS

The protean nature of threats, the contributing and aggravating factors that influence their occurrences and kinematics, the degradation of the geopolitical context raise questions about the technical capacity and organizational structure of the coastguard function to anticipate them, and to respond to them effectively and timely. The difficulty lies in the ability to anticipate these direct and indirect, immediate or latent risks (see table 1 below) through weak or early signals.

Table 7: Matrix of incident, risk and threats

Maritime Incidents (Security)	**Domain**

• Acts of piracy or maritime robbery
• Suspicious approaches
• Thefts on a vessel at dock or at anchor
• Maritime extensions of conflicts
    ○ food impact
    ○ Economic impact
    ○ Destabilization
    ○ Hybrid threats
    ○ Energy impact
• Acts of terrorism at sea
• Disruption of the operation of any communication system or any other equipment (submarine cable networks)
    ○ Jamming of VHF channels, AIS…
• Embarkation or disembarkation of goods, funds or people in contravention of the laws and regulations in force
• Maritime cybercrime
    ○ Jamming / Spoofing of the satellite positioning system (GNSS)
	• Sovereignty and protection of national interests
	    ○ Protection of maritime traffic and offshore installations
	    ○ Innocent Passage Police
	    ○ Flag policing on the high seas
	• Policing radio stations at sea
	• Maritime Security
	    ○ Fight against terrorism at sea
	    ○ Security of ships at sea
	    ○ Maintaining public order at sea
	• Customs and tax police at sea

Maritime Incidents (Security)	Domain
○ Impersonation ○ Hacking ○ Malware	
Trafficking and smuggling	**Domain**
• Alcohol • Weapon • Precious wood • Fuel • Cigarettes, tobacco • Protected species (poaching) • Narcotics (flow of heroin, cocaine, methamphetamine, etc.)	• Fight against illicit maritime activities ○ Fight against maritime smuggling of prohibited or heavily taxed goods ○ Fight against narcotics at sea ○ Fight against the trafficking at sea of arms, ammunition, explosives, weapons of mass destruction and their vectors of dual-use goods
Human exploitation at sea	**Domain**
• Illegal immigration ○ Migratory flow by sea to Mayotte ○ Migratory flow by sea to Reunion ○ Migration by sea to England • Hidden work	• Fight against illegal work at sea • Fight against illicit maritime activities ○ Fight against illegal immigration by sea
Maritime Incident (Safety)	**Domain**
• Body accident • Swim incident • Diving incident • Medical problem • Spearfishing incident • Falling into the sea • Object discovery • Discovery of bodies • Carried away by a wave • Siltation • Medical assistance at sea • Accidental pollution at sea • Illegal discharge at sea • Damage • Collisions • Sinking • Grounding • Beaching • Blast • Collide • Fire • Anchor engaged • Loss of cargo • Loss of stability • Mooring failure • Unauthorized mooring	• Sovereignty and protection of national interests ○ General surveillance of maritime approaches ○ Innocent Passage Police • Sanitary control and working conditions at sea ○ Sanitary control at sea of people and cargo • Safeguarding people and goods at sea • Maritime Safety • Environmental Protection • Management of protected areas ○ Marine protected areas ○ PSSA of the « Bouches de Bonifacio » ○ Future NW Med PSSA ○ Special areas (ECA, SECA, NECA...) • Management of the maritime public domain

Maritime Incidents (Security)	Domain
• Tailgating • Ingress of water • Ship collision with large and medium cetaceans • Non-compliance with the rules of a naval control • Research or surveys without authorizations • Failure to report an incident at sea • Lack of mandatory reporting • Non-compliance with specific traffic rules (Premars Orders) • Failure to respect the COLREGs rules	
MONITORING of fishing activity and fight against illegal fishing	**Domain**

• Illegal transhipment
• Use of flags of « convenience » or substandard ships
• Call in in ports of "convenience"
• Carriage of fraudulent documents
• Poor living conditions for the crew
• Fishing in an unauthorized area
• Violation of fishing regulations (declarative error, non-compliance with fishing effort, etc.)
	• Management of marine heritage and marine public resources
	  ○ Marine Fisheries Police
	  ○ Police hunting at sea
	  ○ Management of living marine resources

4 VULNERABILITY OF SUBMARINE CABLES

Submarine cables now allow the transit of 99% of global data exchanges and are the source of wars of influence as well as commercial and geopolitical struggles. Camille MOREL in her doctoral thesis on the state and the global network of submarine communication cables highlights the vulnerability of the global cable system (Corrosions, earthquakes, ship anchors or fishing gear) and the social and economic impacts major consequences of a cut in the submarine network [2]. Submarine cables also allow the transport of electrical energy between electrical substations at sea and onshore centers within offshore wind farms. On two counts, they represent vital interests and make these networks potential targets for States or non-state actors (sabotage, cybercrime (espionage)...).

5 "BIG DATA », A TECHNICAL KEY FOR THE PROCESSING OF WEAK SIGNALS, A DECISION SUPPORT TOOL UNDER DEVELOPMENT: THE ÉGIDE MODULE (EWS)

Monitoring is above all "giving the right information, to the right person, at the right time, to make the right decision". It therefore appears as a process of collecting information in the service of decision-making. This definition highlights two important themes of monitoring: transmission and temporality. The special status of the weak signal lies in its temporality: it is an annunciator. It is placed before the event and the strong signal, which almost certainly determines the event to come. We can define the weak signal as an element carrying information of an anticipatory nature, which makes it possible to imagine the future, to identify a threat or an opportunity. The potential of the weak signal lies in the capacity of the person receiving it to interpret it, as well as to relate it to other elements, to give it meaning.

The EWS module being developed by Naval Group is funded and supported by the DGAMPA and is based on a model capable of qualifying abnormal situations according to a scenario matrix. The principle of the system is to carry out a pre-processing of the available maritime data, to analyze them in order to produce an alert and finally to constitute a presentation report to the operator. This module must be able to process a certain number of input data from the DGAMPA environment and third-party systems. EWS will be part of the CROSS

SEAMIS environment by 2024. The first phase of the project is to create a rule engine allowing an alert to be raised based on use cases scenario filled in by the module administrator.

The second phase of the project will capitalize on the qualification of the scenarios and the analysis of the alerts reported. Indeed, the analysis phase cannot be automated today due to a lack of cases. For an artificial intelligence (AI) to develop, in the long term, in the business domain of CROSS and to integrate into a virtuous circle of automatic learning, it is first necessary to store a number of significant cases (> 10,000) allowing the design of relevant algorithms. The determination of an alert requires a prior and permanent collection of data to be processed and analyzed to bring out the salient elements, then to qualify the alert and finally to specify the result and the context of its realization.

The threat matrix and the business case study must allow the identification of weak signals (associations of referential, kinematic or algorithmic primitives). The automated processing will make it possible to highlight the "TRUE" primitives in the ambient background noise within areas of interest previously recorded in the module. The alert is pushed to the human-machine interface (HMI) of the operator if the primitives are checked or according to the weighting of certain primitives. A referential primitive must be a filter, criterion or threshold on simple referential data (Example: type of ship = oil tanker, type of flag = X), or complex (combination between different data from several tables = table of moorings, table of ships under surveillance…). A kinematic primitive calls for more elaborate calculations (algorithms = moving towards an area, drifting, close situation, outside a navigation route, etc.). The technology used is based on a rule engine allowing the construction of simple or complex scenarios. This rule engine will be manageable through a time-considered software called EWS-Manager. A scenario can only associate a maximum of 10 kinematic, algorithmic and/or referential primitives. The result of a scenario can be an input primitive of another scenario. They are the modeling of business processes, which are define by experts working within the CROSS.

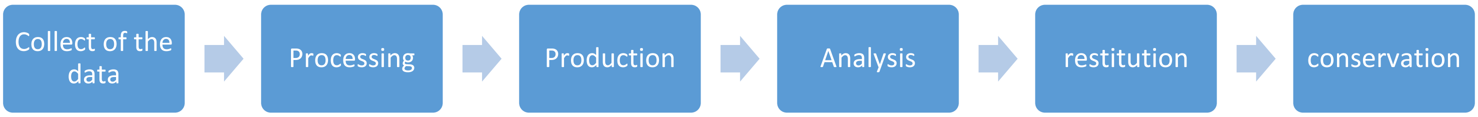


Figure 4: Block diagram of the ÉGIDE (EWS) module, source DGAMPA

Table 2: Example of one simple scenario

Raise a level 1 alert for all commercial vessels that have not completed their mandatory report (MRS) at the entrance to the TSS of Casquets (MANCHEREP) in the CROSS Jobourg area of competence. Purpose: to anticipate a failure to report.

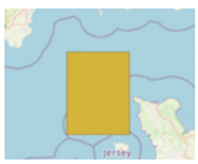
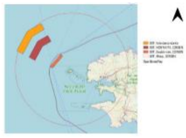
Referential primitives	**Kinematic primitives**	**Complex algorithmic primitives**	**Calculation areas / Areas of interest**	**Alert level**
Vessel type = all vessel Type of message = did not do his MRS	Algorithm = is in the area	None	SRR extended to the EEZ of CROSS Jobourg / VTS Jobourg service zone: 	1

Table 3: Example of one complex scenario

Bring up all oil tankers with low flag performance indices in close quarters with other vessels on level 2 alert in the Pas-de-Calais TSS in the CROSS Gris-Nez area of competence. Purpose: to anticipate a risk of collision between two ships.

Referential primitives	**Kinematic primitives**	**Complex algorithmic primitives**	**Calculation areas / Areas of interest**	**Alert level**
Vessel type = tankers Flag Performance = gray List or black list	None	Close situation	SRR extended to the EEZ of CROSS Gris-Nez / TSS of Pas-de-Calais (VTS service zone) 	2

6 CONCLUSION

Monitoring is above all “giving the right information, to the right person, at the right time, to make the right decision”. The EWS module as the third eye of CROSS operators will have the mission of making the weak signal management process more reliable by automating the steps. The system will pre-process the available maritime data, analyze it in order to produce an alert and finally compile a presentation report for the operator. Training through simulation in the detection of weak signals will make the operator's judgment more reliable and develop a culture of attention, distinguishing between a true alert and false positives. Note that the multiplication of points of view and expertise favors the identification of weak signals. This module will help once in production after ongoing qualification phase to enhance situational awareness, also support VTS personnel providing relevant information to respond timely to developing unsafe situations [4]. Connectionist artificial intelligence (IA) will play a key role in the automatic processing of maritime data; the DGAMPA should promote technological monitoring and investments in this area. The ability to detect better will go through the development of new censors to improve the detection of weak signals and the identification of abnormal and/or illicit behavior. The innovation of earth observation programs and the "dronization" are opportunities to ensure permanence at sea, in the air (satellites, aerial drones, surface drones and submarines) and overcome the tyranny of distances overseas.

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AUTHOR BIOGRAPHY

After 10 years at the service of the administration of maritime affairs and more than 10 years as officers on board merchant ships, I take part in the development of the framework applicable to the maritime domain at different levels, national, European and international (OMI). I currently hold the position of deputy head of the Search and Rescue and maritime traffic monitoring office at the General directorate for maritime affairs, fisheries and aquaculture.

I am graduate of the French Maritime Academy (ENSM) and of the National School of Maritime Safety and Administration (ENSAM). I served as second captain and second engineer on board French oceanographic vessels in the IFREMER’s fleet. At the Maritime Affairs, I held the positions of inspector in charge of control by the port State and the flag State, then that of deputy Head of LA REUNION MRCC in the southern maritime zone of the Indian Ocean.

Since 2019, at DGAMPA, I provide support and oversees the action of the Regional Operational Center for Surveillance and Rescue (CROSS / MRCC) in their field of expertise, including the three CROSS in the Channel, which have, among other things, the specific functions of Vessel Traffic Service (VTS).

S110.3 Implementation of the Vessel Traffic Management and Information System - VTMIS in Rio de Janeiro (049)

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ABSTRACT

The implementation projects of the Vessel Traffic Management and Information System - VTMIS of the Rio de Janeiro Port Authority (CDRJ) cover the Ports of Rio de Janeiro/Niterói and Itaguaí, where CDRJ is the Port Authority. In search of greater efficiency, the VTMIS implementation projects gained strong momentum after 2019 thanks to an agreement signed with the Brazilian Navy (MB) that will allow CDRJ to use military sites as remote stations of VTMIS, given that MB is implementing a monitoring and surveillance system of the Blue Amazon called SisGAAz. In addition, the projects were designed to present some differentials, such as: partnerships with the Academy will allow the maritime and scientific community to access meteorological and oceanographic data and climate predictions up to 7 (seven) days in real-time; in the first phase of the projects, the implementation of Local Port Services (LPS) is planned, sharing, with MB, coastal maritime surveillance radars coupled with natural light and thermal image cameras; use of Automatic Identification System (AIS) Base Stations with the new VHF Data Exchange System (VDES) technology, in order to allow the integration of CDRJ's VTMIS with the e-Navigation project, currently being developed by MB; and the implementation of a modern Environmental Monitoring System equipped with meteorological and oceanographic sensors to be installed around Guanabara Bay, which will allow the implementation of the ReDRAFT® software for calculating the Under Keel Clearance (UKC), with a view to safe transit and greater operational windows for ships with critical draft.

KEYWORDS: vessel traffic management and information system; Port of Rio de Janeiro; oceanography.

RESUMEN DEL ARTÍCULO

Los proyectos de implantación del Sistema de Información y Gestión del Tráfico Marítimo - VTMIS de la Compañía Docas do Rio de Janeiro (CDRJ) abarcan los puertos de Río de Janeiro/Niterói e Itaguaí, donde la CDRJ es la Autoridad Portuaria. En busca de una mayor eficiencia, los proyectos de despliegue de VTMIS lograron un fuerte impulso después de 2019 gracias a un Acuerdo firmado con la Marina de Brasil (MB) que permitirá al CDRJ usar los sitios militares como las estaciones remotas de VTMIS, puesto que, la MB está implementando un sistema de monitoreo y vigilancia del Amazonas Azul llamado SisGAAz. Además de los proyectos, se elaboraron para presentar algunos diferenciadores, como las alianzas establecidas con la Academia permitirán a la comunidad marítima y científica tener acceso a datos meteo- oceanográficos y a previsiones climatológicas de hasta 7 (siete) días en tiempo real; en la primera fase de los proyectos, está prevista la implantación de Local Port Services (LPS), compartiendo con el MB, radares de vigilancia marítima costera acoplados a cámaras de imagen diurna y térmica; el uso de estaciones base del Sistema de Identificación Automática (AIS) con la nueva tecnología VHF Data Exchange System (VDES), para permitir la integración del VTMIS del CDRJ con el proyecto de e-Navegation, que lo está desarrollando el MB y la implementación de un moderno Sistema de Monitoreo Ambiental con sensores meteo- oceanográficos que se instalarán alrededor de la Bahía de Guanabara, lo que permitirá la implementación del software ReDRAFT® para calcular el Espacio Libre Dinámico Bajo la Quilla (FDAQ), con el fin de permitir el tránsito seguro y en mayores ventanas de operación de los buques con calado crítico.

PALABRAS CLAVE: sistema de información y gestión del tráfico marítimo; Puerto de Rio de Janeiro; Oceanografía.

1 INTRODUCTION

The Port of Rio de Janeiro is located on the West coast of Guanabara Bay and includes the maritime areas of downtown and the neighborhoods of Gamboa, Saúde, São Cristóvão, and Caju. For planning purposes, it is part of the Port Complex of Rio de Janeiro and Niterói, which also includes the Port of Niterói and 18 Private Use Terminals (BRASIL; UFSC; LABTRANS, 2019). The Port Authority that manages the Port of Rio de Janeiro is the Rio de Janeiro Dock Company (CDRJ), which is responsible for managing the public ports of the State of Rio de Janeiro, comprising the ports of Rio de Janeiro, Itaguaí, Niterói, and Angra dos Reis. Through port administration in the organized port areas, dock companies have responsibilities as cargo depositary, port authority, and concessionaire of public services (OLIVEIRA JÚNIOR, 2015). The Organized Port area of Rio de Janeiro (Figure 1) is defined by Ordinance No. 505 of July 5, 2019, published in the Federal Official Gazette No. 129 and subsequently demarcated after the validity of Law No. 12,815/13 (BRASIL, 2019). The organized port area comprises port facilities and infrastructure for the protection and access to the port, a public asset built and equipped to meet the needs of navigation, passenger movement, or movement and storage of goods, and whose traffic and port operations are under the jurisdiction of the port authority. (BRASIL, 2019).

Figure 1 - Representation of the current polygon of the Organized Port area of Rio de Janeiro.

2 CONTEXT

The Brazilian port sector faces problems of lack of planning and coordination between infrastructure and waterway transport sectors. This is evidenced by the bidding process for the Vessel Traffic System (VTS) at the Port of Rio de Janeiro, which has been cancelled and restarted several times due to bureaucratic obstacles. The VTS is a system aimed at increasing navigation safety and improving maritime traffic efficiency. In addition, the growth of international trade and technological development has led to larger vessels and, therefore, the need to maintain safe navigation. To address these challenges, CDRJ is implementing the Vessel Traffic Management and Information System (VTMIS) Project at the Ports of Rio de Janeiro/Niterói and Itaguaí.

2.1 Intervention

With the aim of creating improvements and solutions for the water transportation of ports, joint actions are being developed between CDRJ, the Port Authority (AP) of the ports of Rio de Janeiro and Niterói, and MB, the national Maritime Authority (AM), through a convention signed on December 18, 2019, with the purpose of implementing, in the Port of Rio de Janeiro, the Vessel Traffic Management Information System (VTMIS), within the scope of the AP, integrated with the Pilot Project of the Blue Amazon Management System (PP-SISGAAz), currently being developed within the AM, through the sharing of sensors, images, data links and information. The VTMIS is an electronic navigation aid tool, capable of providing active monitoring of water traffic in real-time, with the purpose of: a) providing navigation safety; b) safeguarding human life at sea; c) increasing the efficiency of water traffic; d) assisting in the prevention of water pollution; e) protecting communities and port infrastructures; f) monitoring environmental, meteorological and hydrological conditions; and g) enforcing international maritime standards, within its area of responsibility.

The purpose of implementing the VTMIS is to provide the ports of Rio de Janeiro/Niterói and Itaguaí with a system capable of effectively controlling the flow of vessels that use the water infrastructure of these port units, aiming to increase navigation safety in access channels, maneuvering areas, anchorages and other component spaces, through active and continuous monitoring of the entire maritime area of these ports. Once implemented, the VTMIS system will allow managing situations involving high traffic density, traffic of hazardous cargoes, adverse environmental conditions, possible damage to the environment, interference of vessel traffic with other aquatic activities, and vessel traffic near restricted areas. It will also allow sharing of traffic information with allied services and integration with other port management systems, as well as systems dedicated to port security, support and management of Pilotage, cargo management systems and property management in general, berthing planning, port fee billing systems, quarantine control, customs control and support for Maritime Police operations.

To this end, VTMIS is equipped with radars; medium and long-range cameras, with night-time target identification capability; automatic identification systems (AIS) for vessels; meteorological and hydrological sensors; VHF communication equipment; radiogoniometers for detection of electromagnetic emissions in the VHF range; radio links and/or fiber optic cables for data transmission; and a data center and an Operational Control Center (CCO), to which all information captured by remote sensors will converge. For maneuvers in restricted areas, it is necessary to obtain meteo-oceanographic parameters, measured in real-time, in order to allow ships to pass safely and with greater operating windows, despite the increase in transported cargo volume, thus benefiting the local economy with a reduction in the risk of environmental damage. Through a Technical Cooperation Agreement (ACT) signed by CDRJ on December 14, 2020, with the Federal Universities of Rio Grande (FURG) and Rio de Janeiro (UFRJ), it was possible to obtain meteo-oceanographic data collected by the RJ-3 and RJ4 buoys of the Brazilian Coast Monitoring System (SIMCosta), anchored at the entrance of Guanabara Bay, with the purpose of allowing the use of software for real-time calculation of Dynamic Under Keel Clearance (DUKC)[1]. The recommendations and norms applicable to the implementation of VTS and VTMIS are established by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), which is a non-profit organization.

2.2 Implementation of Vtmis in the Ports of Rio De Janeiro/Niterói and Itaguaí

The implementation of Vessel Traffic Management Information System (VTMIS) in the Ports of Rio de Janeiro/Niterói and Itaguaí was divided into three stages, as provided for in the 4th revision of the Maritime Authority Regulation (NORMAM), which regulates Vessel Traffic Services, NORMAM-26 of the Hydrography and Navigation Directorate (DHN), as follows: a) 1st Phase: activation of Local Port Services (LPS) – in progress; b) 2nd Phase: activation of Vessel Traffic Services (VTS); and c) 3rd Phase: activation of VTMIS.

2.3 First PHASE: ACTIVATION OF A LOCAL PORT SERVICE (LPS):

- Control Center (already operational) and VHF Transceiver (installed and operational);
- Transceiver antenna for the Automatic Identification System (AIS) (already operational);
- Data Management and Presentation System (using the software "Aquaviary Traffic System" - STAq, from the company CASH Computadores). In LPS, radars, CCTV cameras, and environmental sensors (meteorological and hydrological) are optional.

[1] Keel Clearance (KC) or Raw KC - Distance between the lowest point of the keel and the seabed. It represents the safety margin to prevent grounding or collision with the underwater relief or submerged objects; and Dynamic Keel Clearance (DKC) - It is the KC when determined in real-time, based on prediction models and monitoring that constantly update the water level, ship, and relative bottoms (BRAZIL, 2021).

2.4 Second PHASE: ACTIVATION OF VESSEL TRAFFIC SERVICES (VTS)

- Activation of the definitive CCO and installation of towers and radio links of Remote Stations;
- Installation of conventional and thermal image cameras and radars of other remote stations;
- Replacement of the VHF communication equipment by software-controlled equipment with the ability to operate with the VHF Data Exchange System (VDES);
- Acquisition, installation, and integration of mobile and fixed CCTV cameras with medium and long-range infrared and thermal imaging capabilities, with their image management system; and
- Integration of data from all subsystems into the new Data Management and Presentation System.

2.5 Third PHASE: ACTIVATION OF VTMIS:

- In the 3rd Phase, the system would be integrated with port management software such as Porto sem Papel (PSP), Supervia de Dados, SIGEP, Redraft (used to calculate the Dynamic Under-Keel Clearance - DUKC), and Port Management System (SIGPORT), all under implementation in the CDRJ scope, and other related systems. Despite LPS having optional radars, CCTV cameras, and meteo-oceanographic sensors, it was decided to add the following layers of information:
- Meteo-oceanographic sensor data, data generated and obtained by AIS base stations; images from daylight and thermal CCTV cameras; and video from the MB radar, which is already operational.

3 RESULTS OBTAINED

In the 1st phase of the project, LPS will be implemented through the completion of the following stages: a) Activation of an Operational Control Center (CCO) with a video wall, servers, and consoles for visualization, operation of equipment/systems, and coordination of actions; b) Integration of an MB radar, which is already operational, through the installation of a tower, radio link, electric motor generator group, Uninterruptible Power Supply (UPS), and other related equipment at the Navy Technological Center in Rio de Janeiro (CTMRJ); c) Provision of high-definition Pan-Til-Zoom (PTZ) CCTV camera images covering the maritime areas of terminals, maneuvering basins, access channels, and most relevant anchorages of CDRJ; d) Acquisition of 3 (three) AIS AtoN (Aids to Navigation) base stations, with 2 (two) units for the Port of Rio de Janeiro and 1 (one) unit for the Port of Itaguaí, in order to allow the generation of virtual buoys to enhance navigation safety in the access channels to the ports; e) Integration of meteorological and hydrological data transmitted by the SiMCosta buoys to environmental sensors to be acquired by CDRJ, including 6 (six) radar tide gauges, 3 (three) meteorological stations, and 1 (one) meteo-oceanographic buoy to be moored at a location yet to be defined near the Pai Island; f) Fusion of AIS, MB Radar, PTZ cameras, and meteo-oceanographic subsystem data through the use of an integrating software in a single platform; and g) Hiring of a company to operate the LPS's CCOs.

3.1 Integration of meteo-oceanographic data from SIMcosta

The information produced by the buoys of the Brazilian Coast Monitoring System (SiMCosta) feeds into the ReDRAFT software, a dynamic draft system developed by Argonáutica Engineering & Research, which determines the maximum operational draft in real time, considering the prevailing environmental conditions, in strict compliance with the main national and international regulations (ABNT, PIANC, USACE), ensuring safe traffic of large vessels in restricted areas. The RJ3 and RJ4 meteo-oceanographic buoys monitor air temperature and humidity, dew point, wind speed and direction, atmospheric pressure, solar radiation, sea surface temperature and salinity, sea state (wave height, direction and period, and directional spectrum) and ocean current profiles.

Among these parameters, the ReDRAFT system uses wind speed and direction, sea state (wave height, direction and period, and directional spectrum) and ocean current profiles. The measurements are taken continuously and the data are transmitted twice an hour. In order for this data to always be measured with high quality, periodic inspection and maintenance activities are carried out.

Currently, the ReDRAFT software is used by the Rio de Janeiro Pilots exclusively as a decision support tool ("GO"/"NO GO") for the maneuvers of larger container ships in the "North-South" Canal (also known as "Barra Grande").

At present, the responsibility for the operational maintenance of the SiMCosta buoy sensors lies with the Leased Terminals of the Port of Rio de Janeiro (ICTSI/LIBRA, MULT-RIO and TRIUNFO), with the CDRJ responsible for their structural maintenance.

3.2 Automatic Identification System (Ais) Base Stations

The purpose of AIS is to contribute to the identification and tracking of ships in a simplified way. This system allows for a more precise exchange of information with navigators and is used as one of the main components of a VTS. The introduction of AIS into the VTS system has brought significant improvements in terms of image quality and navigation information, as it allows for better tracking capacity, improved accuracy in identification and positioning, and enables the detection of vessels behind islands, bends in rivers, channels, and other obstacles that hinder visual observation. Another advance is the ability to provide a complete image of waterway traffic, providing basic navigation data and contributing to the detection of small vessels (provided they are equipped with AIS) in rough seas or during heavy rains. The acquisition of AIS base stations and the installation of AIS AtoN equipment on channel marker buoys will enable the generation of virtual buoys in channel access and increase navigation safety in the Ports of Rio de Janeiro and Niterói, respectively.

3.3 Radars and cameras

On 12/18/2019, an agreement was signed with the Brazilian Navy to develop joint projects and activities in the areas of monitoring, surveillance, and maritime security. This agreement allows for the exchange of data, including integration of the Kelvin Hughes - Sharp-Eye SBS 800-2 radar, which is already operational in CTMRJ located in Ilha do Governador, Rio de Janeiro State, with the VTMIS project.

This integration also involves the installation of radio links, towers, power generators, UPS, and other related systems at other sites located in the Superintendência de Gestão Portuária dos Portos de Rio de Janeiro e Niterói (SUPRIO) and the roof of the Edifício Barão de Ladário (EBL) of the Navy, with a view to the full operation of the system.

In addition, the CDRJ will have access to CCTV camera footage installed at various locations, including Fortaleza de Santa Cruz, Morro da Urca, Ponte Rio-Niterói, Ilha Rasa, Escola Naval, top of EBL, Base Alte. Castro e Silva (BACS), CTMRJ, and Centro de Munição da Marinha (CMM). The CDRJ will also have access to data from MB's AIS transceivers installed in the Rio de Janeiro State area.

On 11/25/2020, the CDRJ signed a contract with Hensoldt-UK to acquire three coastal maritime surveillance Kelvin Hughes radars and two sets of coupled cameras to be installed in a self-supporting tower at the CTMRJ. These radars and cameras will allow the VTMIS to detect targets without AIS transponders or with non-operational or turned off AIS.

The thermal imaging cameras installed at strategic sites will allow the CDRJ to monitor and positively identify vessels navigating even at night in access channels, port maneuvering basins, and anchorage areas. These cameras will perform tasks such as monitoring port access, monitoring vessels approaching docked or anchored ships, inspecting physical conditions of dock facilities from the sea, verifying possible improper conduct in access channels and anchorage areas, monitoring compliance with oil pollution prevention regulations, and monitoring compliance with oily waste regulations in anchorage areas.

3.4 Environmental Monitoring System (Ems)

Given that VTMIS is a service designed to improve vessel traffic safety and efficiency and aims to contribute to the protection of the environment, whose importance has grown significantly, the EMS, composed of hydrological and meteorological sensors, aims to provide environmental data of interest to navigation and monitor the marine environment, in order to enable optimization of port operational parameters and early detection of incidents and pollutants.

The implementation of a modern Environmental Monitoring System in Guanabara Bay will provide greater navigation safety, support actions in defense and preservation of the environment, as well as provide CDRJ with an important tool to improve the management of the waterway infrastructure serving the ports of Rio de Janeiro and Niterói, with a direct impact on operational efficiency.

The EMS of the Ports of Rio de Janeiro and Niterói will be composed of: a) 2 (two) meteo-oceanographic buoys (RJ-3 and RJ-4) from SiMCosta; b) 1 (one) meteo-oceanographic buoy to be anchored in a location to be defined near the Barra Grande Canal (North-South Canal); c) 3 (two) meteorological stations to be installed on Ilha Rasa, Ilha Fiscal, both belonging to the Brazilian Navy, and on Fortaleza de Santa Cruz, of the Brazilian Army (EB); d) 3 (three) Automatic Identification System (AIS) of Navigation Aids (AtoN) type 3 to identify meteo-oceanographic buoys through electronic chart navigation systems (ECD or ECDIS), in order to prevent buoy collisions; and e) 6 (six) radar tide gauges to be installed at various sites in Guanabara Bay.

3.5 Redraft

As previously mentioned, REDRAFT is a software used to calculate the FDAQ, developed since 2010 and already used by the Rio de Janeiro and São Paulo Pilots with the purpose of informing the pilots if the entry or exit manoeuvre of a ship is feasible or not, given the prevailing environmental conditions and safety parameters set by the MB.

Therefore, it is an operational and manoeuvre planning tool that is about to be employed by CDRJ and will allow for better use of tidal windows and weather and oceanographic conditions for the benefit of maximum utilization of the waterway infrastructure of the ports it manages, with a safe operation of ships with large drafts.

Initially, CDRJ envisioned the use of this software for vessels that would demand the Santa Cruz access channel ("Barra Grande" or "North-South Channel") with the purpose of providing greater safety and efficiency for the manoeuvres of ships that demand the Port of Rio de Janeiro through this channel according to dynamic rules.

However, in order for the software to be used, the use of various meteo-oceanographic sensors with equipment redundancy is required to ensure the diurnal collection of environmental and climatological data for the calculation of the FDAQ. Thus, through the use of the ReDRAFT® system, the following information can be obtained:

a) margin of response to wave effects (significant height, period and direction of waves); b) speed and course of the tidal current; c) intensity and direction of wind; d) tidal height; e) dynamic inclination and sinking of the ship due to wind and yaw; f) tidal windows and permitted times for ship entry and exit; and g) FDAQ and ship drafts for bow, midship, and stern at each control point in access/internal/approach channels, in evolution and berth basins, for each ship type.

In order to test ReDRAFT, 20 (twenty) runs were performed to validate the software, required by the Maritime Authority (AM). Through a partnership with the Numerical Tank of Tests (TPN-USP), ReDRAFT was calibrated with the dynamic modeling of container ships, operated by Terminals Leased by CDRJ. It was found, in practice, that ships navigate in Barra Grande - RJ with an FDAQ much higher than the minimum required by the AM, which will allow CDRJ to increase the maximum operational draft safely through the use of this software.

In summary, the data from the runs carried out to test the mathematical modeling of ReDRAFT proved, in practice, its operational efficiency and its high accuracy rate in calculating the FDAQ.

In the Port of Itaguaí, tests for the implementation of Dynamic Draft were completed and the results show the feasibility of using this system, allowing an increase in static draft from 17.80m to a dynamic draft of up to 18.50m, considering the tidal variation and other meteorological and oceanographic variables within a certain maneuver window. It is important to note that this possibility of gain in ship draft will increase the productivity of ore terminals, consequently generating growth in cargo movement.

4 CONCLUSION

The measures taken by CDRJ to implement the VTMIS for greater operational efficiency at the Port of Rio de Janeiro have been listed. The CDRJ's implementation project gained strong momentum after 2019 through an agreement with the Brazilian Navy, which will allow the use of military sites for the VTMIS remote stations, as the Navy is implementing a strategic monitoring and surveillance program for national defence called SisGAAz (Blue Amazon Management System). It should be noted that in the first phase of the VTMIS Project, the Local Port Service will use a Navy radar coupled with natural light and thermal image cameras for coastal maritime surveillance.

The VTMIS project for the Port of Rio de Janeiro was marked by the acquisition, installation, and integration of various high-tech equipment and real-time meteorological and oceanographic data collection in order to cover the maritime areas of the port terminals, manoeuvring basins, access channels, and relevant anchorages. It is important to note that the differentials of the Rio VTMIS project execution are: the use of AIS Base Stations with VDES technology, which will allow the integration of the CDRJ VTMIS with the E-Navigation2 project currently being developed by the Navy; and the implementation of the Environmental Monitoring System with meteorological and oceanographic sensors scattered around Guanabara Bay to allow this Port Authority to implement a dynamic draft software for calculating the FDAQ in real-time.

In summary, the purpose of the VTMIS Project is to improve operational efficiency related to maritime traffic activities. With its implementation, it will be possible, within the scope of the Port Authority's responsibilities, to coordinate various activities and services developed in the Organized Port, as well as receive and dispatch vessels with a draft greater than the static draft normally used in national ports, following navigation safety standards.

By improving efficiency, it will also be possible to predict situations involving the risk of accidents involving vessels that navigate in the Organized Port and that may cause environmental damage within its limits.

With real-time radar and visual (night-time and infrared) coverage of maritime traffic in the internal and external areas of access channels, manoeuvring basins, and anchorage areas, aiming at detecting and preventing water pollution and potential environmental damage, multiple systems can be integrated using high-level hardware and software, databases, protocols, and web services, using well-known standards and efficiency proven by the use of these current technologies.

The VTMIS system will be permanently manned and equipped to monitor, identify, and visualize maritime traffic within its area of responsibility, taking into account all the factors that influence it, in order to provide an immediate response to various occurrences that may interfere with the established navigation parameters, as well as to avoid or minimize the occurrence of undesirable situations and crises.

5 ACKNOWLEDGEMENTS

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AUTHOR BIOGRAPHY

Tatiana Briglia is an oceanographer in the Geophysical and Port Area with knowledge in the five areas of Oceanography. Experienced with work in academic, corporate and laboratory environments, with knowledge in computing and Oceanographic instrumentation. During my graduation I was an environmental coordinator at Ilha Anchieta - SP, environmental consultant at Nauta Empresa Jr. of Oceanography, intern at Núcleo de Pesquisa em Aquicultura Sustentável na UERJ and from 2020 I participated in the implementation of VTMIS in the port of Rio de Janeiro as an intern at Companhia Docas do Rio de Janeiro (CDRJ), and in late 2021 I started working with Hydrography and Geophysics, doing follow-ups and studies of Category A and Cat. B.

Currently I am a Master's student in Oceanography at the Ocean and Earth Dynamics Laboratory of the Universidade Federal Fluminense - UFF, focusing on the study of Dynamic Draft and Oceanographic Instrumentation.

S110.4 The intangibility of VTS from the perspective of the first Centre in Brazil (219)

Douglas Soares, Port of Açu, Maritime Operations Analyst, Brazil

ABSTRACT

Intangibility is the characteristic by which, because it is not tangible, palpable, the service cannot be experienced before being acquired, in other words, knowledge by the customer only occurs when the service is provided. To reduce the uncertainty associated with the service, companies seek to develop tangible strategies that show the quality of what is being offered through equipment, facilities, people, advertising materials, brand and price. These elements help the customer to have a better perception of the service offered. Service management, therefore, involves understanding this characteristic and taking it into account both in the design and development of services and in their implementation. This presentation is a brief overview of the first VTS Centre in Brazil. It brings the reasons why a VTS is an investment, not a cost.

(No paper submitted)

AUTHOR BIOGRAPHY

A majored English teacher who started his career in 2015 at Port of Açu as one of the first VTS Operators in Brazil. Since 2020, head of the Port Management Information System and member of the costumer relationship staff for the Maritime & Port Community. Point of contact for shipping agents, terminal operators, organisations, and other stakeholders during the daily use of PMIS and port related activities. Member of the staff responsible for dealing with initiatives related to nautical services, AtoN management, and international consultancy. MBA degree in Project Management, and recently started taking Port Management and Logistics college courses.

SESSION 11 SUSTAINABILITY

S11.1 Whale protection in Canada (146)

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ABSTRACT

In Canada, the federal government shares responsibility for protecting marine mammals among several departments including Fisheries and Oceans Canada, the Canadian Coast Guard (CCG), and Transport Canada. Since 2017, the Canadian government has taken significant steps to protect and support the recovery of three endangered whale species: the North Atlantic Right Whale (NARW), the Southern Resident Killer Whale (SRKW) and the St. Lawrence Estuary Beluga (SLEB), including measures to reduce the risk of whale-vessel collisions through the creation of specific protection zones. The CCG has supported federal whale protection measures by adapting the delivery of its navigation services for informing mariners of the protection zones and monitor vessel traffic within them according to established restrictions. This short brief serves as a handout for the accompanying presentation and provides more details on how the CCG is applying modern technology to protect endangered whales.

KEYWORDS: Endangered Whales, Navigation Services, Monitoring, Whale-vessel Collisions, Protection Zones

RESUME DE L'ARTICLE

Au Canada, le gouvernement fédéral partage la responsabilité de la protection des mammifères marins entre plusieurs ministères dont Pêches et Océans Canada, la Garde côtière canadienne (GCC) et Transports Canada. Depuis 2017, le gouvernement canadien a pris des mesures importantes pour protéger et appuyer le rétablissement de trois espèces de baleines en voie de disparition : l'épaulard résident du Sud, la baleine noire de l'Atlantique Nord et le beluga de l'estuaire du Saint-Laurent, y compris des mesures visant à réduire le risque de collision entre baleines et navires grâce à la création de zones de protection spécifique. La GCC a appuyé ces efforts de protection des baleines en adaptant les services de navigation qu'elle fournit pour informer les navigateurs des zones de protection et de par la surveillance du trafic maritime à l'intérieur de ces zones conformément aux restrictions établies. Ce court document accompagne l'exposé sur ce sujet et offre plus de détails sur la façon dont la GCC applique la technologie moderne pour protéger les baleines en voie de disparition.

MOTS CLÉS : Baleines en voie de disparition, services de navigation, surveillance, collision entre baleines et navires, zones de protection.

1 INTRODUCTION

In Canada, the federal government has responsibility for protecting marine mammals. Following the deaths of multiple endangered whale individuals within Canadian waters in 2017, and the 2018 Fall Report on Protecting Marine Mammals from the Commissioner of the Environment and Sustainable Development Audit[2], the Government of Canada made several investments to support the survival and recovery of the following three endangered whale species: the North Atlantic Right Whale (NARW), the Southern Resident Killer Whale (SRKW) and the St. Lawrence Estuary Beluga (SLEB). Shared among several departments including Fisheries and Oceans Canada (DFO) and Transport Canada (TC), the funding supports research and the reduction of anthropologic threats to these three whale populations, including through legal mechanisms to help address physical and acoustic disturbances, such as from vessels. TC's Interim Orders through the *Canada Shipping Act* creates specific protection zones with the goal to reduce the risk of ship-whale collisions by restricting vessel

[2] Reports of the Commissioner of the Environment and Sustainable Development to the Parliament of Canada. (Fall 2018) Report 2, Protecting Marine Mammals (Report 22561-1801)

access or restricting vessel speed. Under the DFO's *Fisheries Act*, the *Marine Mammals Regulations* sets mandatory minimum distances for approaching marine mammals including at-risk whales.

Since 2017, CCG has supported the federal whale protection measures by adapting the delivery of its navigations services to mariners while monitoring vessel traffic for compliance with mandatory measures. These additional duties have facilitated the use of modern technologies and agile processes to protect endangered whales.

2 CANADIAN COAST GUARD NAVIGATION SERVICES AND WHALES

CCG is the federal lead agency responsible for marine safety on Canadian waters, including for search and rescue operations, in addition to supporting other federal departments' efforts towards the sustainable use and protection of Canada's waterways. CCG's mandate comes from the *Oceans Act* and the *Canada Shipping Act (2001)*, for providing aids to navigation, marine communications and vessel traffic services, marine pollution response, waterways maintenance and icebreaking. Within CCG navigation programs, three are directly involved in the implementation of the protection measures for the NARW, the SRKW and the SLEB: the Marine Communications and Traffic Services (MCTS), Aids to Navigation (AtoN) and e-Navigation (see Table 1). Although all three navigation programs have distinct responsibilities and are supported by the CCG technical navigational system experts, MCTS is centre stage being the eyes and ears of marine traffic services within Canada's waters, with ten of its twelve Centres involved in the federal whale protection measures.

Table 1. Overview of CCG's Navigation Programs involved in Whale Protection

Program	**Services Provided**
Marine Communications and Traffic Services Centres (MCTS)	Provides vessel traffic services and radio safety communications through 12 MCTS Centres operating 24 hours/365 days and relying on 188 remote sites for communications and monitoring; Broadcasts marine safety information (MSI) including navigational warnings (NAVWARNs) and weather information; Monitors vessel traffic within whale protection zones.
Aids to Navigation (AtoN)	Deploys aids to navigation to ensure mariners can access information to safely navigate; Tests virtual aids to navigation to delineate various zones for the protection of endangered whales and provide mariners with real-time dynamic information. Publishes Notice to Mariners (NOTMARs), which provides updates on charts and nautical publications, including coordinates of marine protected areas and whale protection measures.
e-Navigation	Optimizes data and directly supports communication exchanges with the Coast Guard Fleet and mariners, including through the e-Navigation Portal (e.g., notices and navigational warnings related to whale protection measures).

CCG whale related activities can be divided into three broad streams (please refer to Figure 1 for more details):

1. Programming of traffic monitoring systems and tools to support compliance efforts;
2. Informing mariners and monitoring vessel traffic within whale protection zones;
3. Transmitting contravention reports to the responsible federal authorities.

CCG monitors vessel traffic through its vessel traffic monitoring and information system, referred to as INNAV, which has been programmed to create alerts based on vessel mandatory restrictions described within the TC's Interim Orders for NARW and SRKW. MCTS informs mariners of these restrictions by issuing and broadcasting navigational warnings (NAVWARNs), which have force of law for operationalizing TC's Interim Orders for the NARW and SRKW. Vessels must comply with NAVWARNS or could face penalties and fines. The AtoN program publishes notices to mariners (NOTMARs) to inform mariners of the whales protection zones, their associated speed restrictions and penalties for non-compliance. The AtoN program is also testing the use of virtual Automatic Identification System aids to navigation (Virtual AIS AtoN), used to delineate specific types of protection zone, information that is accessible through CCG's e-Navigation Portal and can be displayed on ships' navigation equipment such as Electronic Chart Display and Information System (ECDIS) and Electronic Nautical Charts (ENC), among other tools. Finally, MCTS compiles contravention reports that are sent to the responsible authorities for further action, which include AIS data from non-compliant vessels received through its INNAV system and other CCG internal sources.

ACTIVITY	BRIEF DESCRIPTION
Programming Navigation Systems and Tools (For monitoring)	- Addition of geofences to trigger alarms in the INNAV Monitoring System when vessels enter a no-go zone or exceed a mandatory speed limit; - Creation of navigational warnings issued via NAVWARN Issuing System; - Virtual AIS AtoN are created to delineate dynamic zones to mariners.
Informing Mariners & Monitoring Vessel Traffic (incl. creation of notices)	- NAVWARNs broadcasted throughout the season (subscription also available); - Special edition & monthly NOTMAR are published; - AIS Application Specific Message (AIS ASM) Area Notices are broadcast to indicate active dynamic restriction zones for NARW, which can be displayed on properly configured shipborne equipment; - Calls with every vessel transiting the affected area to inform on speed restrictions; - Calls with non-compliant vessels (speed in excess of 10 knots for more than 95 sec); - CCG E-Navigation Portal (https://e-navigation.canada.ca) is used to access updated notices and interactive maps.
Transmitting Contraventions Reports to Authorities (Every 24 hrs.)	- Compilation of AIS data for non-compliant vessels; - Production of contravention reports, which are sent to Transport Canada.

Figure 1. Main Streams of CCG Activities in Whale Protection

2.1 Southern Resident Killer Whale Measures

The CCG established a Marine Mammal Desk (MMD) within the MCTS Centre located in Victoria, British Columbia (BC), as part of the Government of Canada's commitment to offset impacts on aquatic species at risk, including the SRKW, from increased marine shipping associated with new oil and gas-related projects.

The MMD monitors vessel traffic within the protection zones created through TC's Interim Order for the SRKW to reduce underwater noise and the risk of ship strike in key areas used by the killer whale population. The MMD shares vessel traffic information, including AIS data, to support compliance efforts. CCG disseminates information on Transport Canada's mandatory restrictions to mariners through NAVWARNs, which describe two types of protected zones: i. Seasonal Slowdown Areas (or Speed Restricted Zones) where any vessel is deemed non-compliant if transiting the zones over the maximum speed of 10.0 knots; and ii. Interim Sanctuary Zones (ISZs) where vessels are generally prohibited. CCG is also testing the use of virtual aids to navigation (Virtual AIS AtoN), to delineate the Interim Sanctuary Zones, which help communicate these boundaries and requirements to vessels.

The data from the CCG MMD further informs scientific modelling to better understand threats to whales from vessels, and reports contraventions of the *Marine Mammal Regulations,* which prohibit vessels and persons operating vessels from approaching any killer whale less than 400 metres in certain areas. The MMD also reports marine mammal incidents and whale sightings/observations to authorities and whale conservation groups for all marine mammal species in the area, and in support of the Enhancing Cetacean Habitat and Observation (ECHO) Program, a Port of Vancouver initiative encouraging multistakeholder voluntary measures to protect marine mammals including the SRKW.

2.2 North Atlantic Right Whale Measures

The protection efforts implemented to reduce the risk of vessel collisions with NARW during their seasonal migration (from April to November) are based on a concerted effort from the federal government to prevent further declines to the endangered whale species. The CCG Les Escoumins MCTS Centre, located on the St. Lawrence River in the Province of Quebec, monitors vessel traffic according to mandatory speed restrictions within each category of zone created through the TC's Interim Order for the NARW. As of 2022, there were four types of zones being monitored by CCG in the Gulf of St. Lawrence, each delineated through geo-fencing, targeting vessels over 13 meters in length (unless listed as an exception). The four types of zones are:

i. Static Zone – mandatory speed limit of 10 knots for most vessels during the entire migration season;
ii. Seasonal Management Area – mandatory speed limit of 10 knots for a portion of the season (between April to June in general), with speed restrictions extended whenever a whale is detected;
iii. Restricted Area – area to be avoided by vessels unless part of the exceptions but requiring a maximum speed of 8 knots;
iv. Dynamic Shipping Zone – mandatory speed restrictions triggered upon the detection of NARW, which remains in effect for 15 days, or more if a new detection occurs within the last 7-days of the initial detection.

CCG MCTS officers communicate requirements to targeted vessels approaching and within these protection zones, monitor vessel speeds, and report any contraventions to Transport Canada. Given the large area covered by Transport Canada's Interim Order, two MCTS Centres (Sydney in the Province of Nova Scotia and Port-aux-Basques in the Province of Newfoundland and Labrador), are also involved to contact vessels within the Restricted Area zone using VHF radio frequencies.

A vessel is deemed non-compliant when it transits in the speed restriction zone for more than 95 seconds in excess of 10.0 knots (or 8.0 knots for those allowed within the Restricted Area), for which an alarm is set off in INNAV. Virtual AIS AtoN are also being tested and broadcasted for dynamic zones when a speed restriction is in effect as they can be turned on/off. CCG MCTS officers issue a contravention report for every incidence of non-compliance that is detected. A detailed contravention report is then compiled daily by MCTS and sent to Transport Canada listing infractions, the vessels' AIS position, its speed throughout the restriction zone based on information gathered via terrestrial AIS, and any special circumstances such as severe weather or emergency situations.

2.3 St. Lawrence Estuary Beluga Measures

The SLEB are generally found within the waters in and around the Saguenay–St. Lawrence Marine Park, a federal-provincial marine park that protects a portion of their habitat in the St. Lawrence River, in south-eastern portion of Canada. The Park is managed according to its Marine Activities in the Saguenay–St. Lawrence Marine Park Regulations, in addition to the *Marine Mammal Regulations*. Although CCG does not have a specific role for monitoring vessel traffic within the marine park or the estuary, it supports protection efforts for the SLEB and other whales through the dissemination of notice to mariners in its annual NOTMAR publication[3].

The annual NOTMAR makes reference to the marine park regulations, the federal *Marine Mammals Regulations* and further describes voluntary slowdown measures for vessels in waters surrounding the marine park, important feeding areas for the SLEB between May and October.

3 OPPORTUNITIES

3.1 Potential for supporting Canada's 2030 Conservation Targets

In December 2022, the federal government adopted the Kunming-Montreal Global Biodiversity Framework at the 15th meeting of the Conference of the Parties (COP15) to the United Nations Convention on Biological Diversity in Montreal. The Framework includes 23 action-oriented goals, including protecting 30% of lands, oceans and freshwater by 2030, as well as stopping human induced extinction of known threatened species and take urgent actions for their recovery. Canada currently protects 14.66% of its marine and coastal areas.

Although shipping is generally allowed within marine protected areas (MPAs) in Canada, unless it contravenes the conservation objectives for the site, there are various implications for the delivery of CCG marine navigation services if the number of MPAs is to double to meet the 2030 targets. CCG is working closely with federal authorities creating MPAs in Canada and TC to better understand these implications on shipping activities. CCG is also exploring how it could apply its approach to support the protection of endangered whales to also support expanding ocean conservation efforts in terms of the use of digital aids to navigation to delineate protected areas, draw on its implementation of the digitalization of its navigation services such as through the S-100 and e-navigation to issue notices and navigational warnings to inform mariners of protected areas in terms of access and restrictions for vessels, and monitoring speed restrictions through the use of digital tools to transmit close to real-time dynamic information.

3.2 Other Marine Conservation Domestic and International Initiatives

Canada is developing an Ocean Noise Strategy, expected in 2023, that will inform its approach on how to address underwater noise issues including vessel-related noise affecting endangered whales like the NARW, SRKW and SLEB. Canada's efforts align with various initiatives of the International Maritime Organization (IMO), including: the 2014 IMO's Marine Environment Protection Committee guidelines under review, the guidelines aiming to reduce underwater noise from commercial shipping to address adverse impacts of marine life; the IMO's series of routeing measures to protect whales from ship strike by amending traffic separation scheme (TSS), which was implemented in Canada's Bay of Fundy on the east coast, resulting in the moving of traffic from a high density area used by the NARW to a lower density area. There could be opportunities for the Canadian Coast Guard to participate in domestic and international pilot projects, including through Transport Canada's involvement as the lead federal department at IMO.

4 CONCLUSION

CCG's role in the protection of endangered whales in Canadian waters has been instrumental and well received by federal partners and external stakeholders. While CCG continues to deliver its marine navigation services mandate, it is also preparing for how to best continue supporting federal whale protection measures by being able to adapt its service delivery to be better positioned to respond to an increase in services. With the SRKW, NARW and SLEB populations remaining low and unstable, CCG expects increasing federal efforts will be

[3] Annual NOTMAR 2023. The annual NOTMAR edition provides key information mandatory and voluntary measures for many whales and other marine mammal species targeted for protection in Canadian waters, how to report incidents as well as providing coordinates for marine protected areas and their associated regulations.

needed to support these species recovery, and potentially to support additional populations, including efforts to address vessel-marine mammal related impacts.

Additionally, and in light of increasing marine conservation efforts in Canada and through international platforms such as through IMO's related initiatives, there is potential for CCG to play an increasing role in the support of marine conservation initiatives more broadly. Building from its whales protection work and its transition to the digital delivery of marine navigation services, CCG is positioning itself as a key enabler with better and faster tools for supporting Canada's marine conservation goals while ensuring the safety of mariners that will allow CCG to provide enhanced and real-time information in support of conservation compliance efforts and for communications with mariners.

AUTHOR BIOGRAPHY

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Antonella joined Coast Guard in 2000 as a Marine Communications and Traffic Services Officer and has more than 20 years public service experience. Within CCG, Antonella has held roles with increasing responsibility including acting at the executive level and in various management roles within Maritime Security; Oceans Protection Plan (OPP) Implementation Team; and, Marine Navigation Branch. Antonella has extensive policy, operational, and program implementation experience.

Antonella holds a Masters of Public Administration from Lake Superior State University and a Bachelor of Arts Sociology/Criminology form the University of Windsor; and, she completed the National Security Programme at the Canadian Forces College in Toronto, Ontario.

S11.2 US Coast Guard AtoN Programmatic Consultation on Endangered Species and Essential Fish Habitat (114)

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ABSTRACT

An Aids to Navigation (AtoN) program is focused on facilitating navigation and improving maritime safety, including protecting people and property from vessel-related harm and ensuring that maritime activity does not degrade the environment. The U.S. Coast Guard (USCG) shares responsibility with U.S. National Marine Fisheries Service (NMFS), U.S. Fish & Wildlife Service (FWS), and other U.S. federal agencies to protect and ensure the sustainability of species and their critical habitats listed under the U.S. Endangered Species legislation. As an organization responsible for both enforcing and following U.S. environmental law, the USCG implements operational directives and procedures aimed at mitigating the impacts on the environment and enhancing sustainability. Actions performed by the USCG to establish floating and minor fixed AtoN historically are viewed as not individually or cumulatively having a significant impact on the environment. However, aspects of the AtoN program may have adverse effects on a few species (e.g. coral) yet have no adverse effects on others. In order to minimize potential effects of the AtoN program on endangered species, the USCG has engaged in consultations with NMFS and FWS to develop and implement best management practices and project design criteria to mitigate its impact on endangered species and habitat. These practices are not unique to the U.S., yet their broader use could improve sustainability globally.

KEYWORDS: endangered species protection, mitigate impacts of AtoN operations

1 INTRODUCTION

The United States Coast Guard (USCG), and other United States (U.S.) federal agencies, share responsibility with National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (FWS) to protect species listed under the Endangered Species Act (ESA) and their critical habitats. Every aspect of the USCG Aids to Navigation (AtoN) program is focused on improving maritime safety, including protecting people and property from vessel-related harm, and ensuring that maritime activity does not degrade the human or natural environment. Some aspects of the AtoN program may have adverse effects on a particular species and their designated habitat (e.g., coral) and may have no adverse effects on others. To meet its obligations under U.S. law, the USCG engaged in formal programmatic consultation with NMFS and FWS and implemented operational directives and procedures aimed at minimizing the impacts on the environment.

2 FEDERAL ORGANIZATION RESPONSIBILITY AND LEGAL FRAMEWORK

The USCG is charged with enforcing all U.S. maritime law and protects the safety and security of people, the marine transportation system and infrastructure, and natural and economic resources. These interests are located in U.S. ports and inland waterways, along the coasts, and in offshore international waters.

2.1 Responsibility under National Environmental Policy Act

The National Environment Policy Act (NEPA) was signed into U.S. law in 1970, as an “umbrella law” outlining compliance procedures for other federal environmental laws.[1] NEPA is a procedural statute intended to ensure federal agencies consider the environmental impacts of their actions in the decision-making process. NEPA analysis is required when a major federal action is taken that may have impacts on the human and natural environment. Federal actions are those that require federal funding, formal approval, permits, policy decisions, facilities, equipment, or employees. For AtoN program management, nearly every maintenance activity and permitting action qualifies as a federal action under NEPA.

As a way to streamline compliance, NEPA has a series of categorical exclusions (CATEX) for recurring federal actions which have been pre-determined to not require further environmental impact analysis.[2] The USCG relies upon CATEX L38 to cover AtoN operations.

> L38: Actions performed as a part of COAST GUARD operations and the Aids to Navigation Program to carry out statutory authority in the area of establishment of floating and minor fixed aids to navigation, except electronic sound signals.

The USCG interprets this to include all operations taken to carry out our statutory authorities pertaining to AtoN, but still must determine whether there are "extraordinary circumstances" that would prevent the use of the CATEX, such as potential impacts to ESA listed species or designated critical habitat.

Figure 17: Stellar Sea Lion rests on a buoy

2.2 Responsibility under Endangered Species Act

The Endangered Species Act (ESA), of 1973, establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat they depend on. Section 7 of the ESA requires federal agencies to ensure that their actions are not likely to jeopardize the continued existence[4] of endangered or threatened species or adversely modify or destroy[5] their designated critical habitat.[3] Federal agencies must consult with NMFS and FWS when threatened or endangered species (ESA listed) or designated critical habitat may be affected. Generally speaking, NMFS supports marine (salt water) species FWS supports terrestrial and freshwater species.

2.3 Responsibility under Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson–Stevens Fishery Conservation and Management Act (MSA), passed in 1976, governs marine fisheries management in U.S. federal waters. It is intended to support the long-term biological and economic sustainability of marine fisheries by protecting and restoring Essential Fish Habitat (EFH). NMFS has used EFH to help maintain productive fisheries and rebuild depleted fish stocks in the United States.[4]

3 U.S. COAST GUARD STEPS & PROCESSES

The USCG is responsible for maintaining AtoN placed to promote the safety of maritime traffic. To fulfill its mission, the Coast Guard establishes, operates, and maintains approximately 50,000 federal navigational aids, such as buoys and beacons. AtoN play a significant role in protecting the environment from the direct harm associated with allisions, collisions, and groundings and the secondary effects of pollution resulting from vessel accidents. As such, AtoN maintenance often takes place in areas that contain endangered and threatened plants and animals, critical habitat, and managed fisheries and habitat. To assist in executing its AtoN mission in compliance with the ESA and MSA, the USCG engaged in a formal consultation process including development of a Biological Evaluation and subsequent Biological Opinion by NMFS.

3.1 Biological Evaluation

The USCG prepared a Biological Evaluation (BE) / Essential Fish Habitat Assessment (EFHA), hence forth referred to collectively as BE, to analyse effects of the proposed action on species and habitats protected by

[4] "Jeopardize the continued existence of" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of an ESA-listed species in the wild by reducing the reproduction, numbers, or distribution of that species. (50 CFR §402.02)

[5] "Destruction or adverse modification" means a direct or indirect alteration that appreciably diminishes the value of designated critical habitat for the conservation of an ESA-listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features. (50 CFR §402.02)

the ESA and the MSA. The action area included all waters of the United States that are marked by federal AtoN and Private AtoN (PAtoN), as well as land immediately adjacent to waterways where AtoN exist.[5]

Proposed Action. The BE proposed action included five components of AtoN-related activities : (1) policies and procedures for establishing new AtoN; (2) operation and maintenance of existing AtoN, including establishing temporary AtoN as needed to address discrepancies; (3) policies and procedures for discontinuance of AtoN (4) policies and procedures for permitting PAtoN; and (5) existing USCG conservation measures incorporated into the proposed action to minimize adverse effects on protected resources. The establishment and discontinuance of specific aids (in contrast to the policies and procedures pursuant to which they are established or discontinued) was not included because there was no way to determine the future locations of proposed aids or of discontinuances. Therefore, specific actions to establish new aids and discontinue existing aids will be addressed under separate site-specific consultations.

Coast Guard maintenance of federal AtoN includes, but is not limited to, the following activities: inspecting and replacing AtoN chain, sinkers, buoys, dayboards, ladders, platforms, and pilings; repairing lighting equipment, power systems (batteries and solar panels), and sound signals; responding to and repairing AtoN discrepancies; and conducting repairs to structures.

All maintenance activities[6] were evaluated in the BE. Those with the greatest potential to adversely affect species or habitats, lifting and replacing the sinker and chain assembly that anchors a buoy in place (for floating AtoN) and replacing pilings that support signals (for fixed AtoN), were analysed in greatest depth.

[6] Effects of vessel operations in the immediate vicinity of the AtoN and during transit between adjacent AtoN were evaluated in the Biological Evaluation, but transits from the homeport to the AtoN site were not included in the consultation due to their multi-mission nature.

Source of Stressor (Maintenance)	Biological Resources Potentially Affected												
	Terrestrial Plants	Seagrasses	Terrestrial /Freshwater Invertebrates	Marine Invertebrates	Coral	Inland Fishes	Marine and Anadromous Fishes	Amphibians	Terrestrial Reptiles	Sea Turtles	Birds	Terrestrial Mammals	Marine Mammals
Vessel-Related Stressors (All ATON; in water and on land)													
Physical presence of vessel/engine noise/exhaust fumes/ fuel releases	-	•	•	•	•	•	•	•	•	•	•	•	•
Increased turbidity	-	•	•	•	•	•	•	•	-	•	-	-	-
Anchor/spud	-	•	•	•	•	•	•	•	-	-	-	-	-
Floating ATON													
Removal from water	-	•	•	•	•	•	•	•	-	-	•		•
Cleaning	-	-	•	•	•	-	-	-	-	-	-	-	-
Returning buoy	-	•	•	•	•	•	•	•	•	•	•	•	•
Fixed ATON in Water													
Cleaning	-	•	•	•	•	•	•	•		•	-	-	•
Refurbishing	-	-	-	-	-	-	-	-	-	-	•	-	•
Replacing pilings	-	•	•	•	•	•	•	•	•	•	•	•	•
Removing pilings	-	•	•	•	•	•	•	•	•	•	•	•	•
Fixed ATON on Land													
Cleaning	•		•	-	-	-	-	•	•	•	•	•	•
Refurbishing	-	-	-	-	-	-	-	-	•	-	•	•	-
Approaching ATON	•	-	•	-	-	-	-	•	•	•	•	•	•
Brushing ATON	•	-	•	-	-	-	-	•	•	-	•	•	-
Removing insect nests		-	-	-	-	-	-	•	•	-	•	•	-
Replacing structure	•	-	-	-	-	-	-	•	•	•	•	•	•
Removing structure	•	-	-	-	-	-	-	•	•	•	•	•	•

• Potential overlap of stressor and biological resource

The BE analysed the effects of the presence of existing AtoN based on the number and type of AtoN that overlap with listed species and habitat in each Coast Guard district. For example, physical stressors associated with an AtoN and signal include the generation of artificial light, crushing organisms or habitat, shading, and provision of artificial structure for attachment, shelter, or other uses. While fixed AtoN would cause no additional crushing or displacement after establishment, the chain portion of floating AtoN may continue to crush and displace organisms that settle in the scour radius surrounding the sinker. Acoustic stressors include the airborne sound signals intentionally emitted by AtoN. These stressors exist regardless of any maintenance activities conducted by the Coast Guard and so were analysed as a separate component to the proposed action.

Action Area The action area includes all waters of the United States that are marked by AtoN, as well as land immediately adjacent to waterways where AtoN exist. The USCG mainly operates federal AtoN throughout the territorial sea (12 nm from the baseline or shore). This area includes the territorial sea of the entire continental United States, Puerto Rico, Virgin Islands, Hawaii, Alaska, Guam and the Marianas, Midway Islands, Samoa Islands, Rota Island, Saipan, and Tinian. It also includes the U.S. waters of the Great Lakes. The Coast Guard also maintains AtoN located in inland waters such as rivers of the central United States (called the Western Rivers), bays, harbours, ports, river mouths, interstate waters (navigable waters shared by multiple states) and the Gulf Intracoastal Waterway. Although this was a nationwide programmatic analysis, District-specific information was incorporated throughout the analysis to reflect regional activities, including conservation measures developed to minimize adverse effects on protected species.

A central component of the BE is the identification of all AtoN that may overlap geographically with species and habitat protected under the ESA or managed under the MSA. Detailed data on location and type of AtoN were obtained through queries of the USCG Aids to Navigation Information System (ATONIS) database. More than 35,000 federal AtoN and 40,000 private AtoN were identified and mapped. An additional 10,000 to 15,000 uncharted[7] AtoN in the Western Rivers were also evaluated. The number and type of AtoN, and the effort required to maintain them, vary widely among geographical areas within the nine Coast Guard districts.

Analysis The BE evaluated 462 species listed [8] as endangered, threatened, proposed, or candidate under the ESA that potentially occur in the action area. ESA designated critical habitat was found to overlap with the action area for 28 threatened and endangered species. The evaluation of effects on ESA-listed, proposed, and candidate species, designated critical habitat, and EFH was grounded in available scientific literature on the biology and ecology of each species. Behaviours such as foraging, roosting, and breeding occur within given environmental contexts that can be perturbed by various types of stressors. Each species experiences interactions with humans and the built environment in a particular way that may or may not constitute an adverse effect. Analysis of potential effects takes species-specific and life-stage-specific needs and sensitivities into consideration.

Figure 18 : Elkhorn & Staghorn Coral found in USCG District 7

[7] At the time of the Biological Evaluation, most USCG federal AtoN in the Western Rivers were uncharted. The USCG now has a method and process for tracking the positions of these aids.
[8] Number of ESA listed species at time of BE completion in 2015.

ESRI ArcGIS Desktop® software was used to evaluate the overlap of the proposed action with protected and managed species and habitat. Data layers in GIS format were retrieved from publicly available Internet sites and internal Coast Guard sources. Maps were created for each Coast Guard district illustrating the locations of federal AtoN designated by type (floating or fixed) and light characteristic (lighted or unlighted). Locations of critical habitat and essential fish habitat were overlaid on the AtoN location maps. A total of 129 GIS layers were created, downloaded, and/or processed during map production. More than 50 maps were included in the BE, illustrating the overlap of federal AtoN with critical habitat and EFH in each Coast Guard district. In cases where no geospatial data was available, spatial overlap was estimated using published accounts of species' ranges.

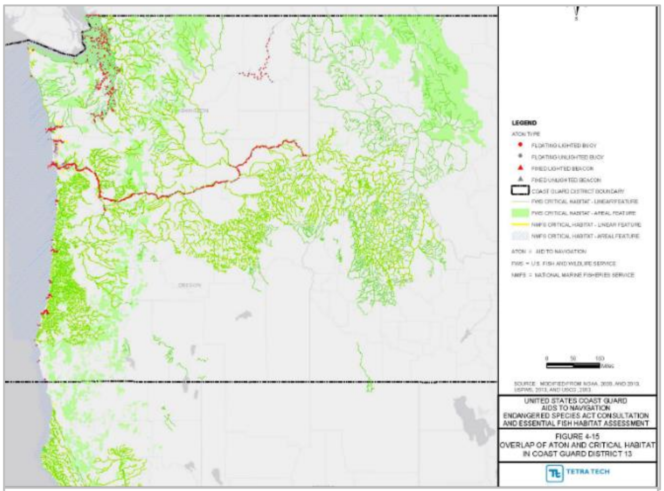

Figure 19: Sample overlap anaylysis between federal ATON and ESA listed critical habitat

3.2 NMFS Biological Opinion

In May 2015 the Coast Guard initiated a formal AtoN Programmatic consultation with National Marine Fisheries Service. The consultation was supported by the Biological Evaluation which considered the effects of the AtoN program on ESA listed species, designated critical habitat, and EFH. NMFS concluded the consultation by issuing a Biological Opinion (BO) in April 2018.[6] The BO reviewed the proposed action, action area and assessments set forth in the BE, estimates incidental take[9] which may occur as a result of the proposed action, and establishes project design criteria (PDC).

Project Design Criteria. PDC, synonymous with best management practices, serve to prevent or minimize adverse effects to protected resources by the proposed action. The PDC were developed collaboratively during the BO consultation with input from regional Coast Guard and NMFS offices. For maintenance activities, the PDC limit adverse effects to predictable levels that will not jeopardize the continued existence of ESA-listed species or destroy or adversely modify critical habitat at the individual project level, or in the aggregate from all projects implemented under the programmatic opinion. Adherence to the PDC during the course of AtoN maintenance is mandatory to remain in compliance with the BO. An important point to note, is that nothing contained in the project design criteria precludes the Coast Guard from taking necessary action in response to a safety of life issue or to prevent personal injury. For activities to establish or discontinue AtoN, the PDC serve generally to prevent or minimize adverse effects to protected resources, but may be modified as appropriate on a project-by-project basis in consultation with NMFS since these actions will all require subsequent ESA section 7 consultation and/or EFH consultation if ESA-listed resources or EFH may be affected. As part of the BO, NMFS also provided additional discretionary conservation recommendations (CR) that may be implemented by the USCG to further reduce impacts where feasible.

I**ncident Take Statement.** As part of the BO, NMFS included an incidental take statement that specifies the impact of the take, described below, reasonable and prudent measures to minimize the impact of the take, and terms and conditions to implement the reasonable and prudent measures.

[9] "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by regulation to include significant habitat modification or degradation that results in death or injury to ESA-listed species by significantly impairing essential behavioural patterns, including breeding, feeding, or sheltering. (50 CFR § 10.12)

Any take which occurs during AtoN activities is incidental to, and not the purpose of, carrying out an otherwise lawful activity. ESA Section 7 provides that compliance by USCG with the terms and conditions of the BO, exempts any incidental take from the prohibitions of take in ESA[10].

NMFS BO Conclusion. In its Biological Opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat. NMFS concluded that the proposed action will temporarily affect EFH when establishing, maintaining, or discontinuing fixed and floating AtoN. These temporary adverse effects on EFH will be minimized by implementing the agreed upon PDC as well as EFH CR.

3.3 FWS Biological Opinion

At the time of this paper, the USCG is still in process of pursuing and completing a formal AtoN programmatic consultation with FWS for the endangered and threatened species and critical habitat under their purview.

4 IMPLEMENTATION OF NMFS BIOLOGICAL OPINION

Implementation of the BO supports the protection of endangered species and their critical habitat but also serves to protect the USCG and members working on its behalf from criminal liability under the ESA when an incidental take occurs during the course of AtoN maintenance. At the AtoN unit level, implementation of the BO requires that project design criteria (PDC) be incorporated into all individual maintenance events and at least one designated and trained environmental observer must be present during all activities.

4.1 Project Design Criteria & Best Management Practices

The PDC include area (organized by USCG District) and activity specific measures to prevent or minimize adverse effects to ESA-listed resources and EFH. One of the more potentially impactful activities undertaken as part of AtoN maintenance was found to be pile driving. An example of the PDC to mitigate impacts of pile driving and removal can be seen in Appendix 1.

4.2 Environmental Observers & Job Aids

The PDC require at least one designated, trained environmental observer (EO) must be present during all activities to establish, maintain, or discontinue AtoN. EO's are not expected to become experts in species identification but must be able to recognize the various taxa (e.g., whales, turtles, corals) that include protected species in their area of responsibility. Simple EO job aids that can be easily printed and kept on hand in the field were created jointly by USCG and NMFS. Training of EO's is limited to review of their District specific job aids upon reporting the unit and annually thereafter. Prior to each AtoN patrol, the EO must familiarize themselves with the ESA-listed species, designated critical habitat, and EFH that may be in the action area of the activity and understand the PDC that apply. The EO discusses any species and habitats of concern that may be present in the area during pre-mission briefs with the AtoN personnel. Sightings of endangered species during the conduct of AtoN missions are tracked, especially sightings which cause delay to AtoN maintenance due to the presence or proximity.

Figure 20: Black Abalone found in USCG District 11

4.3 Monitoring

The activities described above will be carried out on an as-needed basis over a period of years. All individual maintenance events must incorporate applicable PDC and must not exceed the predicted take outlined in the incidental take statement of BO. As required by the BO, the USCG provides NMFS with an annual report that

[10] ESA section 7 (b)(4); 50 CFR. §402.14(i). ESA section (7)(o)(2)

documents key aspects of the AtoN program relevant to assessing impacts of the program on ESA-listed resources. To collect the data necessary to create the report, USCG queries and analyses data input by AtoN units and district waterway managers. Typical of annual average, for calendar year 2022, the USCG reported data for approximately 22,700 maintenance actions covered by BO. The annual report also includes information on AtoN actions not covered by the BO, such as AtoN establishment, discontinuance, or relocation, noting informal Section 7 consultations or no effect determinations made by the Coast Guard. The annual report offers both USCG opportunity to propose changes to PDC, or reinitiate consultation in order to consider newly listed species or revise incidental take statements.

5 ON THE HORIZON – NEXT STEPS

As the Coast Guard enters its 3rd full year of implementation of the NMFS Biological Opinion, some additional initiatives have been identified to further support the environmental compliance or the AtoN Program. Some key elements include ensuring sufficient oversight and support of field units, readily accessible geospatial data, and sufficient data capture mechanisms to monitor and report on the success of the program.

5.1 Regional Environmental Protection Specialists

Coast Guard environmental planning policy requires proponents to allocate adequate resources to comply with environmental laws including the National Environmental Policy Act. District and Sector Commanders are proponents for operations including Aids to Navigation (AtoN), marine event permitting, and the issuance of field regulations. These operations require preparation of environmental documentation and execution of consultations with federal and state resource agencies. To better meet these needs, the USCG is placing a permanent Environmental Protection Specialist (EPS) at each of its nine District Prevention and Waterway Offices. The specialists will be able to advise District and Sector Commanders on their requirements under the numerous laws and provide guidance on how to documents and mitigate potential impacts. The EPS will oversee and support the field implementation requirements for the AtoN Programmatic Endangered Species Act (ESA) and Essential Fish Habitat set forth under the NMFS BO. AtoN actions not covered under the BO, including discontinuing or establishing a new AtoN, require Districts to make effect determinations as to whether a protected species may be impacted, and pursue additional consultations as necessary. Outside the AtoN program, these EPS will conduct environmental analysis for actions to include general operations, development of area contingency plans, issuance of marine even permits, and management of Limited Access Areas via field regulations.

5.2 Geospatial Data Management

Much of the data used in environmental consultation and planning is geospatial. In determining whether a particular AtoN action may have an effect on an endangered species, one step is to determine whether or not a species may be present in the area and or if the action area overlaps with a designated critical habitat. Whereas, the USCG is responsible for maintaining data on its federal AtoN constellation, other agencies, NMFS and FWS, are responsible for maintaining data on ranges and habitats of endangered species under their purview. Comparison of the overlap of this data, e.g. an AtoN location with a critical habitat, is most easily accomplished in geospatial format using a visualization tool such as ArcGIS®. The USCG is seeking to better incorporate geographic information systems (GIS) into daily operations and planning. Ideally GIS tools will be linked to real time live data from the authoritative source such that USCG operators and planners do not have to determine if the data they are viewing is the more recent available.

5.3 USAIMS Improvements

Complying with the reporting requirements under the NMFS BO has challenged the USCG's programmatic data capture and management methods. Historically, the USCG has captured data sufficient to determine if units were complying operational policy and to be able to determine the current status of the AtoN constellation such as position, equipment status, service schedule, etc. The NMFS BO reporting requirements have required the Coast Guard to develop new techniques to query and analyse the currently available data and develop new data fields and meta-tagging to more easily assess the environmental compliance and effectiveness the AtoN program at large.

6 CONCLUSION

The USCG is responsible for maintaining AtoN placed to promote the safety of maritime traffic. While nearly every aspect of the AtoN program is focused on improving maritime safety and helping ensure that maritime activity does not degrade the human or natural environment, some aspects of the AtoN program may have adverse effects on a particular species and their designated critical habitat. The USCG has found the programmatic consultation process an efficient and effective way to address evolving environmental laws concerning U.S. navigable waters. Implementing the findings through development of mitigating measures, associated job aids, training, and reporting, has helped the USCG ensure the environmental compliance and protection of endangered species during the completion of more than 21k AtoN servicing events annually.

7 REFERENCES

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[2] https://www.epa.gov/nepa/national-environmental-policy-act-review-process

[3] Endangered Species Act (ESA), 16 U.S.C. § 1531 et seq.

[4] https://www.fisheries.noaa.gov/topic/laws-policies/magnuson-stevens-act

[5] U.S. Coast Guard & Tetra Tech, Inc. Biological Evaluation/Essential Fish Habitat Assessment; Technical Support Services for Environmental Documentation to Support a Nationwide Programmatic Endangered Species Act Consultation and Essential Fish Habitat Assessment for the Office of Navigation Systems, July 2014.

[6] National Marine Fisheries Service. Endangered Species Act Section 7 Biological and Conference Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation, April 2018.

8 APPENDIX I

Example of Project Design Criteria - 2018 NMFS AtoN Programmatic Biological Opinion

Pile Driving and Removal

- Any creosote treated piles will not be reused and will be disposed of properly, in accordance with Coast Guard policy. Any creosote treated piles that must be replaced, must be replaced with non-creosote treated piles.
- Adhere to seasonal work windows[11] described in Appendices (NMFS BO) for all routine pile driving operations, including total replacement or establishment. If a unit must work outside the seasonal work window due to operational constraints (scheduling or maintenance issues, etc.), consult with NMFS prior to pile driving to minimize potential impacts. This PDC is not applicable if emergency repairs are required to remedy a navigational hazard.
- If piles break or are damaged, Coast Guard staff, or servicing entity, must attempt to entirely remove the broken piles. If the entire pile cannot be removed, reasonable efforts must be made to cut the remnants without disturbing the sediment.
- When feasible, a vibratory driver must be used instead of an impact hammer for pile driving.
- If an impact hammer is required, pile driving must employ soft-start or ramp-up techniques (slow increase in hammering intensity), at the start of each work day or following any break of more than 30 minutes to allow any undetected ESA-listed animals to voluntarily depart the area.
- Steel piles may not be larger than 18 inches in diameter.
- Structures may not be replaced that consist of more than four steel piles.
- If using an impact hammer, use additional sound attenuation devices (e.g., cushion blocks, dewatered casings or enclosed bubble curtains around each pile to be driven) if feasible.
- If possible, drive piles during low tide periods, preferably when substrates are exposed in intertidal areas.
- Prior to the commencement of pile driving and pile removal, Environmental Observers must perform a visual scan with a radius of 1,000 meters (1,094 yards) around the project site. If any ESA-listed marine mammals, sea turtles, sawfish, sturgeon, or sharks are observed within these safety zones, work will not begin until the Environmental Observers are confident the animal has moved out of the area on its own volition. If an animal is seen above water then dives below, the Coast Guard, or servicing entity will not begin pile driving activities until enough time has elapsed without a sighting (at least 15 minutes for pinnipeds and 30 minutes for cetaceans) to assume the animal has moved beyond the safety zone. Environmental Observers must remain alert for protected species from 30 minutes prior to commencement of work until 30 minutes after shut-down. If ESA-listed marine mammals, sea turtles, sawfish, sturgeon, or sharks move within the safety zone during pile driving and pile removal, Coast Guard or servicing entity must cease the activity when safe to do so and not continue until the Environmental Observers are confident the animal has moved out of the area on its own volition. If an animal is seen above water then dives below, the Coast Guard or servicing entity will not begin pile driving activities until enough time has elapsed without a sighting (at least 15 minutes for pinnipeds and 30 minutes for cetaceans) to assume the animal has moved beyond the safety zone.
- Avoid beginning pile driving or pile removal after dark. If pile driving must occur during periods of darkness, use all available means to allow Environmental Observers to detect marine mammals and sea turtles that may be located within that zone (e.g., use thermal imaging or night vision technology). The entire safety zone must be visible to the Environmental Observer for pile driving to commence.

[11] Note that these work windows are subject to change in consultation with NMFS.

Pile Installation

- Avoid the use of treated wood timbers or pilings to the extent practicable. The use of alternative materials such as untreated wood or steel is recommended. Wood and steel pilings are considered to be less damaging, and generally do not release contaminants into the aquatic environment.
- Use a vibratory hammer to install piles, when possible. Under those conditions where impact hammers are required for reasons of seismic stability or substrate type, it is recommended that the pile be driven as deep as possible with a vibratory hammer prior to the use of the impact hammer.
- To the maximum extent possible, implement measures to attenuate the sound or minimize impacts to aquatic resources during piling installation. Methods to mitigate sound impacts include, but are not limited to, the following:
  - If equipped, surround the pile with an air bubble curtain system or dewatered cofferdam.
  - If possible, drive piles during low water conditions for intertidal areas.

Pile removal

- When possible, remove creosote-coated piles completely rather than cutting at the sediment line or breaking off the pile. Ensure creosote piles are not returned to service and are disposed of as hazardous waste, and in accordance with Coast Guard policy. Replace any creosote treated piles with non-creosote treated piles.
- To the maximum extent practical, minimize the suspension of sediments and disturbance of the substrate when removing piles. Measures to help accomplish this include, but are not limited to, the following:
  - When feasible, remove piles with a vibratory hammer rather than a direct pull or clamshell method.
  - Slowly remove pile to allow sediment to slough off at or near the mudline.
  - Shake or vibrate the pile before pulling to break the bond between the sediment and the pile. Doing so will reduce the likelihood that the pile will break and the amount of sediment sloughed.
  - If equipped, encircle the pile or piles with silt containment devices that extend from the surface of the water to the substrate.
- When practicable, remove broken/cut piling stubs.
- Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for pile driving projects.

AUTHOR BIOGRAPHY

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S11.3 Blue VTS Project (010)

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ABSTRACT

The Sustainable Development Goals (SDGs), also well known as the decade of action, were adopted by all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. As a part of the United Nations, International Maritime Organization (IMO) is also actively working towards the 2030 Agenda for 17 SDGs. Of these 17 SDS, Goal 7, "Affordable and Clean Energy", aims to ensure access to affordable, reliable, sustainable and modern energy for all. Goal 13, "Climate Action", which is interconnected with SDG 7, addresses the need for urgent action to combat climate change and its impacts. In this context, the maritime sector and IMO have a major role in achieving SDG 7 and 13 regarding energy efficiency and climate change, respectively.

Whereas Vessel Traffic Services (VTS) play a significant role globally and contribute to the safety of life at sea, the safety and efficiency of navigation and the protection of the marine environment, adjacent shore areas, work sites and offshore installations from possible adverse effects of maritime traffic. On the contrary, VTS Centres consume considerable energy while providing their services. Therefore, the main aim of this study is to explore and use their own energy sources in terms of renewable, clean and climate-neutral energy. In addition, a feasibility study was conducted to examine the applicability of all SDGs in the VTS domain in a comprehensive approach.

KEYWORDS: Vessel Traffic Service, VTS, Sustainability, Ocean Decade, Marine Conservation, SDG

1 INTRODUCTION

In many dialects, the meaning of ocean is the high, open, deep, endless and infinite waters since the seas encompass 71% of the blue planet. The oceans connect people, life, habitats and cultures. Moreover, oceans feed and protect us and absorb more than 90% of the excess heat generated by global warming. Also, they are a vital source of economic, social and cultural wealth. Approximately 3 billion people depend on marine and coastal biodiversity for their livelihoods ((UNESCO-IOC (2021). The United Nations Decade of Ocean Science for Sustainable Development .(2021-2030) Implementation plan – Summary. Paris, UNESCO. (IOC Ocean Decade Series, 19.)). In connection with this interaction, human activities significantly impact the ocean (Polejack A. (2012). The Importance of Ocean Science Diplomacy for Ocean Affairs, Global Sustainability, and the UN Decade of Ocean Science. Front. Mar. Sci. 8:664066.) due to climate change, over-exploitation and consumption, transportation, pollution, population growth and shanty settlements. As a consequence of these activities, we urgently needed to support decision-making to achieve sustainability.

In 2017, the United Nations proclaimed a Decade of Ocean Science for Sustainable Development (2021-2030) for adaptation strategies, and science-informed policy responses to global change are urgently needed (UNESCO-IOC (2022). Ocean Decade Progress Report 2021–2022. UNESCO, Paris. (The Ocean Decade Series, 37).). According to the report, ocean science is broadly competent in diagnosing problems, and the ability to offer solutions of direct relevance to sustainable development requires a massive upgrade. Therefore, the world needs a large-scale and adequately resourced campaign of transformational ocean science; that the Intergovernmental Oceanographic Commission (IOC) invites the global ocean community to plan in ocean science and technology to deliver, together, with the motto of "the ocean we need for the future we want" ((UNESCO-IOC (2021). The United Nations Decade of Ocean Science for Sustainable Development .(2021-2030) Implementation plan – Summary. Paris, UNESCO. (IOC Ocean Decade Series, 19.)). To reach this target, scientists addressed ocean-dependent peoples' needs and priorities and evaluated potential solutions (Singha, G.G., Davies, H.H. Edward, Andres, H.A., Montemayor, M.C., Swartz,W., Crosman K.M., Ota, Y. (2021)., Will understanding the ocean lead to "the ocean we want"?, Opinion, PNAS Vol. 118. https://doi.org/10.1073/pnas.2100205118). However, no single nation can achieve these targets (Polejack A.

(2012). The Importance of Ocean Science Diplomacy for Ocean Affairs, Global Sustainability, and the UN Decade of Ocean Science. Front. Mar. Sci. 8:664066.), and it needs collaboration and the exchange of information, capacity, knowledge, experience and tools. This cooperation, collaboration, and shared vision constitute among researchers from all disciplines, policy, management, stakeholders and the public (Heymans, J.J., Bundy, A., Christensen, V., Coll M, de Mutsert K., Fulton, E.A., Piroddi, C., Shin, Y-J., Steenbeek, J., Travers-Trolet, M., (2020)., The Ocean Decade: A True Ecosystem Modeling Challenge. Front. Mar. Sci. 7:554573. https://doi.org/10.3389/fmars.2020.554573). Now, the UN is calling partners, scientists, governments, philanthropists, industry, civil society, and indigenous and local knowledge holders from across the globe to join action ((UNESCO-IOC (2021). The United Nations Decade of Ocean Science for Sustainable Development .(2021-2030) Implementation plan – Summary. Paris, UNESCO. (IOC Ocean Decade Series, 19.)). In other words, everyone must be involved to deliver a truly transformed relationship between society and the ocean

(E. McKinley, D. Burdon, R.J. Shellock, (2023). The evolution of ocean literacy: A new framework for the United Nations Ocean Decade and beyond,, Marine Pollution Bulletin, Vol.186. https://doi.org/10.1016/j.marpolbul.2022.114467).

In summary, under existing circumstances and time constraints, a holistic and immediate approach is needed to benefit from experienced and still using –effective and efficient– instruments that utilise ocean observation, monitoring and protection along with novitious manners. One of these instruments is VTS (Erlevent, B., Kum, S., (2023). Does it work? An analysis of marine aids to navigation on historical marine accident data.), and VTS Centres could significantly support and contribute to Ocean Decade. Furthermore, in a comprehensive approach, efforts could be made for the UN SDGs during the Decade of Actions instead of merely the Ocean Decade. Therefore this study aims to take action by designing a draft concept called the "Blue VTS Project" within the framework of the SDGs during the Decade of Actions (2021-2030).

2 BACKGROUND AND SCOPE

In 2018, a small group consisted a VTS operator, supervisor, and engineer initiated the feasibility study for transformation to use fully green energy in İzmir VTS Centre. The first target was a creation of a green and smart building, in theory, more than we have. Later, the study evolved from a green to a blue concept concerning the seven outcomes that describe the 'ocean we want' at the end of the Ocean Decade. Finally, this work culminated in the Blue VTS Project in 2020 as regards the UN Decade of Actions. Therefore, an analysis has been conducted among the UN 17 SDGs to specify and better understand compatibly in the VTS domain.

2.1 Goal 5: Gender Equality

Gender equality ensures women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life (Target 5.5)

(https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

In order to achieve this goal in the VTS domain, VTS providers or component authorities may adopt or revise the recruitment system for VTS personnel and employees serving in the administration, security, catering and other departments. However, some difficulties could arise in recruiting women operators with a marine background in some countries. This social fact explicitly addresses the lack of women in the maritime domain. In this context, gender equality could ensure in the total employee figures of VTS Centres.

2.2 Goal 6: Clean Water and Sanitation

Target 6A of Goal 6 highlighted expanding international cooperation and capacity-building support to developing countries in water-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies. Moreover, improving water quality by reducing pollution, eliminating dumping and minimising the release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and substantially increasing recycling and safe reuse globally by 2030 is one of the targets of this goal (Target 6.3)

(https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

In this perspective, controlling and managing water consumption in VTS Centres and sites concerning hygiene, cleaning, and gardening is possible. In addition, water harvesting, greywater or wastewater management contribute to achieving this target. VTS Centre also may utilise different models and methods, i.e. using nature-friendly detergent and gardening with climate-appropriate plants.

2.3 Goal 7: Affordable and clean energy

The aim of this goal is to ensure universal access to affordable, reliable and modern energy services (Target 7.1) and substantially increase the share of renewable energy in the global energy mix (Target 7.2). By 2030, enhancing international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promoting investment in energy infrastructure and clean energy technology is another target (7A) of this goal (https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

The feasibility study reveals that it is challenging to generate all of the energy used in VTS Centres and sites with their own means. However, the energy consumed can be generated by solar panels, windmills and other innovative methods or procured from renewable energy producers and distributors. Furthermore, the annual energy consumption rate can be significantly reduced using smart systems such as passive climatisation, lighting sensors, solar water heating systems, and equipment with appropriate energy ratings.

2.4 Goal 12: Responsible consumption and production

Goal 12 is regarding ensuring sustainable consumption and production patterns, which is vital to sustaining the livelihoods of current and future generations. By 2020, one of the targets (12.4) of Goal 12 is to achieve the environmentally sound management of chemicals and all wastes throughout their life cycle under agreed international frameworks and significantly reduce their release to air, water and soil to minimise their adverse impacts on human health and the environment. Furthermore, target 12.5 highlights substantially reducing waste generation through prevention, reduction, recycling and reuse.

(https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

In this regard, the environmentally sound management of chemicals, including lubrication oils and all wastes throughout their life cycle, is subject to a standardised management system in the VTS.

2.5 Goal 13: Climate action

The global temperature has risen 1.1°C above the pre-industrial level, with glaciers melting and rising sea levels. Climate change impacts also include flooding and drought, displacing millions of people, sinking them into poverty and hunger, denying them access to essential services like health and education, expanding inequalities, stifling economic growth, and even causing conflict.

(https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

To limit warming to 1.5° Celsius above pre-industrial levels, as set out in the Paris Agreement, global greenhouse gas emissions will need to peak before 2025. Then they must decline by 43 per cent by 2030 and to net zero by 2050. Countries are articulating climate action plans to cut emissions and adapt to climate impacts through nationally determined contributions. However, current national commitments are insufficient to meet the 1.5°C target.

(https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

VTS Centres may collaborate with intuitions, scientists and industry acting against climate change by sharing their site, energy, information and efforts during the Ocean Decade. In this way, VTS Centres may contribute significantly to ocean monitoring and protection, such as measuring and predicting sea levels, calculating emissions from marine vessels, and monitoring marine protecting areas (MPA).

2.6 Goal 14: Life below water

Goal 14 regard conserving and sustainably using the oceans, seas and marine resources. Healthy oceans and seas are essential to human existence and life on Earth. Therefore, it is necessary to conserve and sustainably use, yet, human activity is endangering the oceans and seas – the planet's largest ecosystem – and affecting the livelihoods of billions of people (https://www.un.org/sustainabledevelopment/sustainable-development-goals/).
This goal target is already one of the main objectives of VTS in terms of the safety of life at sea, the safety and efficiency of navigation and the protection of the marine environment, adjacent shore areas and offshore installations from possible adverse effects of maritime traffic, i.e. pollution.

2.7 Goal 15: Life on land

Goal 15 is about conserving life on land. It is to protect and restore terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and stop biodiversity loss. Healthy ecosystems and the biological diversity they support are a source of food, water, medicine, shelter and other material goods. They also provide ecosystem services – the cleaning of air and water – which sustain life and increase resiliency in the face of mounting pressures.

(https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

Nevertheless, human activities have profoundly altered most terrestrial ecosystems: around 40,000 species are documented to be at risk of extinction over the coming decades, 10 million hectares of forest (an area the size of Iceland) are being destroyed each year, and more than half of key biodiversity areas remain unprotected (https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

In the VTS Centres, some denouncements are for forest fires, illegal hunting, and dumping. Navigators should take a sharp lookout during their bridge watch. Therefore they have a good sight from sea to land. They have preferred to call by VHF radio and inform the VTS on time.

3 RESULTS

According to the comparative analysis, VTS Centres can contribute to at least seven goals in Decade Action. Some of the targets belonging to the SDGs are straightforwardly connected to the VTS domain and their aims/objectives; most targets are secondarily associated with the VTS domain.

This study is preliminary, and further detailed analysis may reveal new targets related to the VTS domain.

4 CONCLUSION

Today, action to meet the Goals is not yet advancing at the speed or scale required overall. Therefore, the UN Secretary-General called on all sectors of society to mobilise for a decade of action concerning the needed transitions in the policies, budgets, institutions and regulatory frameworks of governments, cities and local authorities, including by youth, civil society, the media, the private sector, unions, academia and other stakeholders, to generate an unstoppable movement pushing for the required transformations. Everyone must be involved to achieve SDGs, including the VTS domain.

Since the first radar-based port control station was established in 1948, the VTS Centres have rendered service 7/24 basis in general. Today, most VTS took responsibility for additional duties other than marine traffic issues. Moreover, some already use green energy and retain waste management systems. Nonetheless, these initiatives are not broad-range implementations.

In summary, for urgent solutions for urgent times, VTS usher in a decade of ambitious action in the maritime domain to reach the Goals by 2030. To achieve that globally, it needs guidance for implementing SDGs in VTS

Domain. Undoubtedly, the Guide on Blue VTS provides a tangible approach for levelling (class) and nominating their centres as Blue VTS. The project may transform a campaign at the global level. Also formerly called "Zero Accident Campaign", it may become one tool for scoring in Blue VTS nomination rules.

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AUTHOR BIOGRAPHY

Burçin Erlevent is a master mariner. He joined the Directorate General of Coastal Safety in 2005 and began his VTS career as an operator at the Istanbul VTS Centre. In 2013, he was assigned VTS supervisor and VTS trainer. After that, he started his doctorate in VTS training at Istanbul Technical University and was promoted to manager for Izmir VTS Centre. Currently, he contributes to the safety of life at sea, the safety and efficiency of navigation and the protection of the marine environment as a marine pilot in Çanakkale Strait.

S11.4 Climate Change Challenges (093)

Julian Mitchell, Greg Hansen, Samuel Hawkins, Australian Maritime Safety Authority, 82 Northbourne Avenue, Canberra, Australia, AtoNProjects@amsa.gov.au

ABSTRACT

This paper examines the changes that impact Australia's aids to navigation, and specifically the impact of climate change. Using practical examples, the authors will examine how climate change has created challenges in addressing the resilience and risk profile of assets. The paper will look at the challenges that uncertainty presents to decision makers when balancing risk, resilience, and the cost of investment. It is important to note the uncertainty around the impact of climate change, in particular extreme weather events. Asset resilience and risk profiles for new or existing assets may not be as static as once assumed. The need to design structures to cope with extreme and unpredictable weather events is not always viable. The inevitability is the need to accepting some risk. Controls and a better understanding of the risk can limit an organisation's operational and financial exposure. The paper will also consider how the broader impacts of climate change impact AtoN networks, including changes to shipping channels and the potential migration of natural features and the AtoN that protect them.

KEYWORDS: climate change, engineering, aids to navigation, design codes, Great Barrier Reef

1 INTRODUCTION

The Australian Maritime Safety Authority (AMSA) manages approximately 480 aids to navigation at some 360 locations, guiding mariners around Australia's 34,000 kilometres of coastline and through sensitive areas such as the Great Barrier Reef. Changes to climate are impacting the reliability and resilience of assets throughout the network. Two thirds of AMSA's AtoN network are in tropical cyclone regions, and the intensity of severe weather events is increasing.

Structures that were installed as recently as 20 years ago are already likely to experience greater environmental forces than they were designed to cope with. While the environment is changing, the design codes that structures are built to, and decision-making processes, have been static. Using practical examples, this paper will consider the challenges facing those charged with maintaining the AtoN network, and planning for the future.

2 CONTINUOUS ASSESSMENT OF RELEVANCE

Australia's AtoN network is assessed periodically to ensure the aids are relevant, fit for purpose and meet the needs of the commercial shipping industry. Every year, 20% of the network is reviewed which ensures the entire network is assessed over a 5-year period. The guiding principles of the review are:

- providing visual AtoN for spatial awareness, aiming for at least one AtoN to be visible throughout a voyage and,
- using virtual AtoN to complement the physical AtoN where it improves safety of navigation.

The review considers:

- waterway significance,
- areas of environmental sensitivity,
- the type of vessel and navigation,
- traffic density,
- the mix of AtoN types across the region,
- climate, and
- national priorities.

This assessment also validates the critical infrastructure within the network, which is important in identifying the assets that may require special attention to maintain resilience.

2.1 Great Barrier Reef Marine Park

The Great Barrier Reef lies in the Coral Sea, off the northeast coast of Queensland, Australia. It comprises 2,500 individual reefs, more than 900 islands, and covers an area of 346,000 square kilometres. The reef is under stress; in the north, significant areas are reported to have died. Bleaching events caused by warmer sea temperatures are occurring more frequently, especially in the northern areas. Reef-building coral appears to be migrating south where the subtropical climate suits its temperature requirements. In the long term this may mean the environmentally sensitive areas shift south and AMSA's ship routeing measures, VTS and AtoN network will also need to adapt to protect these new environmentally sensitive areas.

2.2 Changes to Shipping Patterns

Decarbonisation to counteract climate change will affect the type of vessels we can expect in Australian waters, the ports they will be visiting, the cargo they will be carrying, the countries we will be trading with, and therefore the export routes and traffic volumes. The emergence of low/zero-carbon energy as the primary energy source may result in energy being imported across larger distances. Demand for offshore renewable energy will mean windfarms competing with shipping for space in our waters and may change the way vessels transit coastal areas.

Innovative solutions to reduce risk will be required and may include a range of AtoN-marking solutions using physical and virtual AtoN, dedicated shipping routes, waterway monitoring, and regulation. Through its periodic reviews, AMSA continues to critically assess the need for individual AtoN, to ensure the safety of coastal navigation for domestic and international trading vessels.

Iron ore and coal remain Australia’s largest bulk commodity exports, while LNG exports (mainly from Queensland and Western Australia) continue to grow. Increasing energy security concerns, and concerns over global warming, mean that the global energy transition away from coal is accelerating, and the long-term outlook for Australian thermal coal exports is declining.

Australia exported 359 million tonnes of coal in 2022. If the world is to achieve the Paris Agreement’s aim to limit the temperature increase to 1.5 degrees, we could see trade halved by 2050.

Green hydrogen export plans are currently being researched and developed. Green hydrogen has become a stand-out clean fuel of the future, with one of the world’s largest renewable hydrogen plants planned to be built in the Pilbara region of Western Australia. Feasibility studies are also being conducted into the development of a green hydrogen hub at the Port of Newcastle in Eastern Australia. Similar studies are also being conducted for areas in South Australia. With the export of green hydrogen comes changes to shipping density and traffic patterns.

AMSA will need to stay abreast of all emerging climate change initiatives and the effects they have on shipping traffic and density, to ensure the AtoN network remains aligned and is well placed to aid the safe navigation of commercial vessels around Australia. Additional AtoN, or changes to enhance or optimise the network, may be required.

We will need to be agile in how we manage AtoN to keep up with climate change initiatives and understand the effects they have on the placement and requirement of AtoN.

2.3 Changes to Weather Patterns

The Australian Bureau of Meteorology plays an important role in monitoring, analysing, and communicating observed and future changes in Australia's climate. Their 2022 report12 enhanced understanding of the state of Australia's future climate. In coming decades, Australia is projected to experience:

- Continued warming, with more extremely hot days and fewer extremely cool days.
- A longer fire season for the south and east, and an increase in the number of dangerous fire weather days.
- More intense short-duration heavy rainfall events, even in regions where the average rainfall decreases or stays the same. This will lead to a complex mix of effects on streamflow, and associated flood and erosion risks, including increased risk of small-scale flash flooding.
- Fewer tropical cyclones, but a greater proportion projected to be of high intensity, with ongoing large variations from year to year. The intensity of rainfall associated with tropical cyclones is also expected to increase and combined with higher sea levels, is likely to amplify the impacts from those tropical cyclones that do occur.
- Ongoing sea level rise through this century and beyond, at a rate that varies by region. Recent research on potential ice loss from the Antarctic ice sheet suggests that a scenario of larger and more rapid sea level rise can't be ruled out.
- More frequent extreme sea levels linked to coastal inundation and coastal erosion. For most of the Australian coast, extreme sea levels that had a probability of occurring once in a hundred years are projected to become an annual event by the end of this century with lower emissions, and by the mid-21st century for higher emissions.
- Continued warming and acidification of surrounding oceans with consequent impacts on biodiversity and ecosystem processes.
- Increased and longer-lasting marine heatwaves, which will further stress marine environments, such as kelp forests, and increase the likelihood of more frequent and severe bleaching events in coral reefs around Australia, including the Great Barrier Reef and Ningaloo Reef.
- An increase in the risk of natural disasters from extreme weather, including 'compound extremes', where multiple extreme events occur together or in sequence, thus compounding their impacts.

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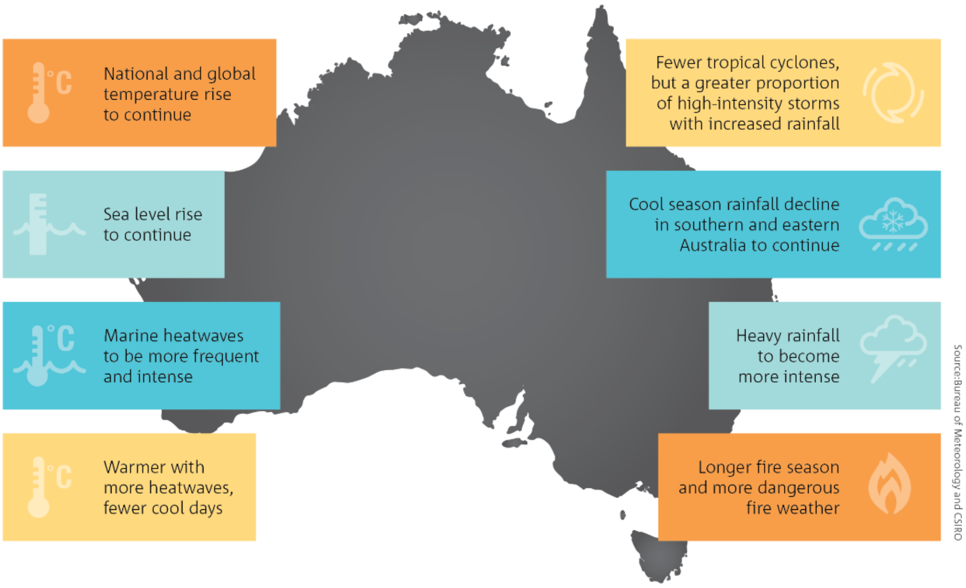


Figure 1: Observed and future changes in Australia's climate

3 ENGINEERING CHALLENGES

3.1 Can Assets be Future Proofed?

AMSA recognises that climate change is impacting the reliability and resilience of AtoN assets along the Australian coast. The Australian region is subjected to many cyclones. The Australian Bureau of Meteorology indicates 675 cyclones have occurred in the Indo-Pacific Southern Hemisphere region since 1990. Two thirds of AMSA's AtoN network are in Tropical Cyclone Regions.

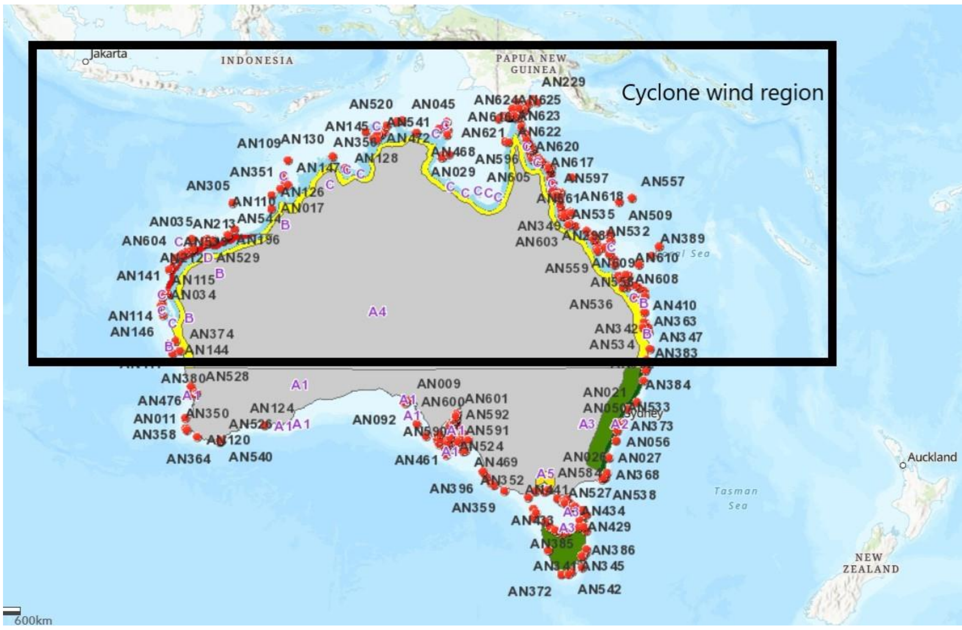


Figure 2: Concentration of AMSA Aton in cyclone wind regions

The resilience of AtoN structures is decreasing as the impacts of climate change appear to be causing increased storm damage across the network. This impacts the wind, wave, and current loading on structures. Infrastructure is being subjected to larger forces than they were designed to withstand. New structures need to carefully assess the predicted loadings over the expected life cycle. Making predictions about future state storms is challenging.

As outlined above, future climate cannot be predicted with any certainty. Weather events are subject to not only individual storm variability, but longer-term cycles such as the El Nino / La Nina Southern Oscillation, Pacific Decadal Oscillation, and Interdecadal Pacific Oscillation (IPO).

A structure designed 10-20 years ago will likely experience larger environmental forces than it was designed for. The operational risk profile has changed significantly and will continue to do so.

While the environment is becoming more unpredictable, the engineering and design codes that structures are built to comply with have been static. It is often not economically viable to design a fully resilient infrastructure. Designers, managers, and decision makers are therefore presented with a risk / probability of failure scenario.

An annual exceedance probability (AEP) expresses the probability of a structure exceeding its capacity due to a scenario of environmental forces. This is an extremely complicated proposition to explain to non-technical decision makers.

3.2 Case Study – Port Hedland

Port Hedland is a bulk commodity export port that has around EURO 150M in exports through it daily. AMSA has a number of AtoN leading into the Port that were constructed in the 1980s. Over the last 10 years the structures have experienced damage including waves breaching platforms that were originally designed to be well above wave height. Continued damage has impacted the cost of maintenance and brings risks to shipping. The economic impact of slowing port movements or closing them, due to a fallen AtoN blocking the channel, would be significant.

3.2.1 Design review

Due to the ongoing storm damage to the Port Hedland AtoN in 2019, AMSA undertook a design review. This review highlighted that when extreme ocean conditions and storms were applied to the design, wave crests were higher than the AtoN platforms. The structures were likely to fail well below any current industry design code, at more than 2% chance per year. There was no significant corrosion identified through non-destructive testing with the existing underwater piles installed in the mid 1980's. The main issue experienced being the inundation of the platforms, and forces imposed on the structure, in extreme weather events.

If the AMSA piles were to fail, the worst case would be for them all to fail at once, depositing debris and blocking the channel. AMSA would need to charter a survey vessel to locate the obstructions (which could take a few weeks) and would then need specialist plant to recover any material in the channel (a further few weeks). Once re-opened, the channel would likely run at reduced capacity without the navigation aids to guide ships, particularly at night. Fully re-instating the navigation aids would take 6-12 months. With EURO 150M in exports through the Port daily, the economic impact of a blocked channel would be significant.

The structural analysis was based on ultimate (i.e. survival) environmental load conditions for combinations of wave, current and wind. This combination is the critical loading for the structure, with the wave contributing most of the loading action.

A risk resilience review was undertaken on several options including strengthening, complete replacement with platforms built higher, and replacement of the pile above water section with a raised platform above the wave crests.

3.2.2 Decision

The option of strengthening the existing piles was discounted and was not considered a cost-effective solution as it did not address the platform height issue. Replacement of the pile above water section with a higher platform height offered a 1.0% AEP Annual Exceedance Probability (AEP) (1% chance annually of failure), complete structure and pile replacement offered a 0.5% AEP for an additional 40% of project cost.

AMSA accepted the 1% AEP (chance of failure annually) which involves cutting the existing pile above the water line and replacement with raised platform above the wave crest.

The preferred option provides enhanced resilience and lowers the risk of disruption to shipping. The cost for this work was three times the annual capital investment that AMSA typically makes across its entire AtoN network.

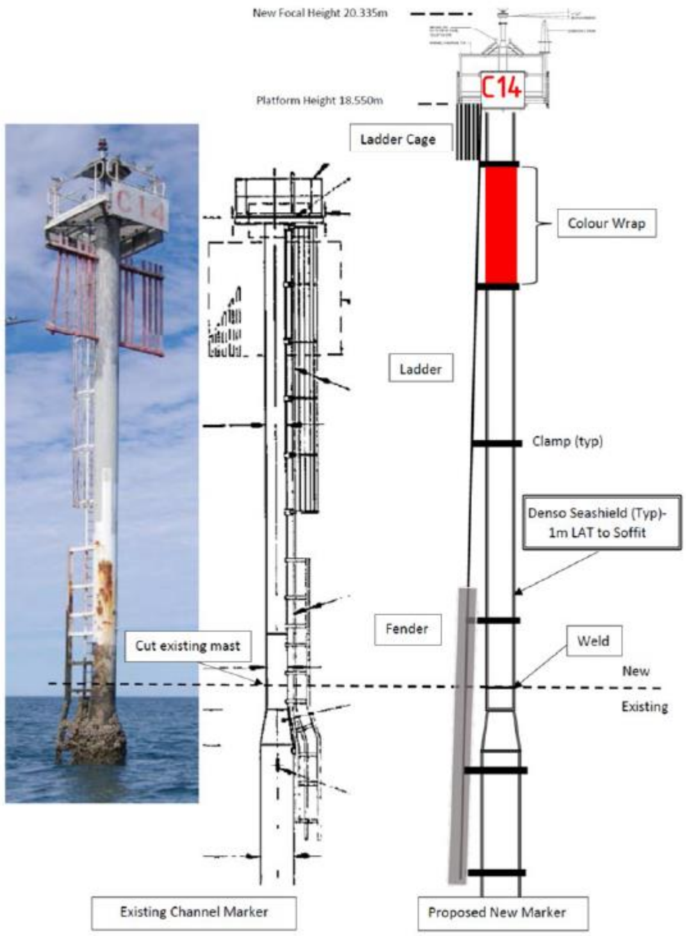
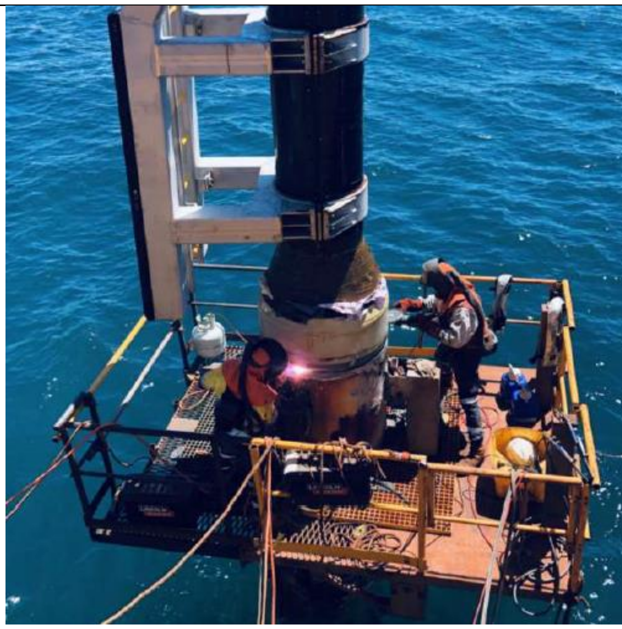


Figure 3: Concept design of refurbished pile vs existing

3.2.3 Solution

AMSA undertook a design and construct procurement activity in 2021 to refurbish 13 piles in the Port Hedland channel. At the time of writing this paper, site works are near complete.

	
Fabricated top section ready for transport	Demolition of existing pile
	
Existing pile cut for new top section	Weld preparation

	
Lifting new top section into position	Fabrication of new top section
	
Old pile	New pile

Jack up barge used for construction

Figure 4: Fabrication and construction photos

3.3 Other resilience considerations

Acknowledging the need to accept some risk of damage to assets due to extreme weather events, it is usual to plan for the worst. AMSA has implemented a standardised modular and simplistic solar design across the network allowing quick restoration of services. Structural and framing components will be resilient, and AMSA plans for the likelihood that the solar system and light will be impacted.

4 CONCLUSION

Climate change is hard to predict accurately and is having a tangible impact on AtoN structures. Understanding current and future resilience risk profiles is important, while communicating these with decision makers can be challenging. AtoN providers need to be agile and practical in how they identify the risks and then make sound risk-based decisions to sustain networks. Understanding how climate is changing, and the potential impact on AtoN assets now and into the future, is the first step.

Climate change is also contributing to changes to traffic patterns and the volumes of vessels leaving ports, which may lead to changes to AtoN networks.

Designing structures to deal with the effects of climate change is expensive and not well supported by engineering standards. It can be unaffordable or impractical to design a completely resilient structure, and authorities need to be ready to deal with the unexpected.

It is never going to be easy explaining to decision makers that even when using a 100-year design standard, an expensive new asset could be damaged in a storm next week. Equally challenging is explaining to a budget holder how a relatively new structure may have been damaged in a weather event, while an adjacent 100-year-old classic lighthouse survived unscathed.

AUTHOR BIOGRAPHY

Greg Hansen is Principal Advisor AtoN Engineering at Australian Maritime Safety Authority, and manages the asset management, engineering, and project delivery functions relating to AtoN and emergency response assets. Greg has 30 plus years' experience in the engineering sector primarily in the maritime field, covering areas such as marine aid to navigation, defence ordnance, ship construction / repair and renewable energy.

Greg holds a Bachelor Engineering specialising in Marine & Offshore Systems (which incorporates mechanical, electrical, systems, and civil engineering disciplines). And has achieved chartered engineering status in, Marine and Offshore Systems, and Marine Engineering. Greg has been working with AtoN for over 15 years, has been involved in the renewal of major maintenance services contracts, development of strategic asset management plans, heritage asset refurbishment programs, implementation of new technology, standardisation and building resilience of structural assets. Greg represents Australia at IALA Engineering and Sustainability Committee.

Sam Hawkins is a Master Mariner (Class 1) with over twenty years' experience in the Australian domestic and international maritime industry. He has served on a wide variety of vessels including chemical tankers, self-discharging bulk carriers, roll-on roll-off cargo ships and large modern cruise ships.

In 2021 Sam worked as Principal Advisor Maritime Safety for the South Australian Department of Infrastructure and Transport, before starting with The Australian Maritime Safety Authority (AMSA) in February 2022. In his role at AMSA he is responsible for the provision of high-level nautical advice, with a focus on marine aids to navigation and hydrography. Sam has a graduate certificate in international maritime law from the University of Wollongong and an advanced diploma of nautical science form the Australian Maritime College. Sam is an Associate Fellow of the Nautical Institute.

S11.5 Sustainability in Marine AtoN provision within the context of Climate Change (179)

Simon Millyard, Outgoing Chair of the IALA Engineering Committee and ex Head of Engineering and Operations, Trinity House, UK

ABSTRACT

Since the 2010 General Assembly in Cape Town, there has been a marked increase in climate change and our attitudes towards it. The 2007 Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report stated “It is likely that there has been significant anthropogenic (human induced) warming over the past 50 years…..” 14 years later in 2021 the IPCC 6th Assessment Report reports “It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.”

AtoN provision does not rank highly as an enabler for climate change but we have a duty to look at the impact we have on climate change and how we can improve our environmental footprint. This approach is supported by the IALA Council in their Drivers and Trends document and the 17 United Nations Sustainability Goals.

This presentation looks briefly at the background to climate change to set the scene and then will explore proposals, some radical, on how AtoN providers can reduce their environmental impact. Finally, the presentation will propose work that IALA committees can engage in to support members to assess and reduce their impact on climate change.

AUTHOR BIOGRAPHY

Simon started his career as a Marine Engineer cadet with the Royal Fleet Auxiliary in 1973 gaining his 1st class certificate of competency in 1983 and a Chartered Engineer with IMarEST in 2011. After 10 years travelling the world with the RFA as a ships Engineering Officer, he left the sea to join his new wife ashore. Ashore, Simon worked in Technical Sales before returning to production engineering in Printing and then Brewing to pursue his interest both in brewery engineering and a taste for fine ales.

The call of the sea was never far away and in 2003 he joined the Royal National Lifeboat Institution as a Divisional Engineer responsible for maintaining the engineering standards on a fleet of fast modern lifeboats. The RNLI introduced Simon to the world of maritime safety which was to prepare him well for his next career move. In 2008, he joined Trinity House and until 2019 was Head of Engineering & Operations responsible for the design, maintenance and operation of maritime Aids to Navigation. Since 2010 he has represented Trinity House at IALA and is Chairman of the IALA AtoN Engineering & Sustainability Committee. He is now working part time for Trinity House in training and IALA representation.

Simon is a family man with 4 children, one of whom has followed his footsteps into a career at sea. He spends his spare time with the second love of his life which is sailing.

SESSION 12 – SUSTAINABILITY (CONTINUED)

S12.1 Optimization of the energy demand of regeneratively powered lights through the use of energy-efficient R (069)

Peter Schneider, Federal Waterways and Shipping Office Ems-Nordsee, 26725 Emden, Am Eisenbahndock 3, Germany, Peter.schneider@wsv.bund.de

ABSTRACT

Standard PLCs (programmable logic controller) for the control and monitoring of lights in conjunction with classic light sources lead to relatively high energy consumption.

Especially in the case of regenerative power supply this sometimes requires complex solar and wind energy systems including large storage batteries. In some cases additional fuel cells are installed to cover the energy demand in the winter months at all and to meet the requirements of IALA GUIDELINE G1039 DESIGNING SOLAR POWER SYSTEMS FOR MARINE AIDS TO NAVIGATION.

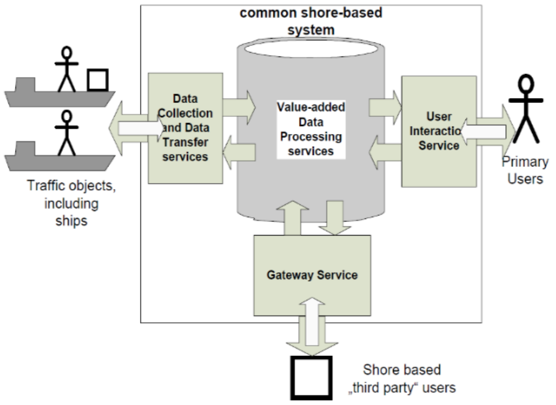
Meanwhile energy-efficient RTUs (remote telemetry unit / remote terminal unit) and PLCs are increasingly available on the market. With a simultaneous conversion to LED light technology, these can be used to optimize energy supplies and infrastructure components of lights.

The presentation compares the energy consumption of different automation devices (RTU and PLC) and presents optimization potentials.

KEYWORDS: PLC, RTU, RCMS, energy demand, sustainability, renewable energy

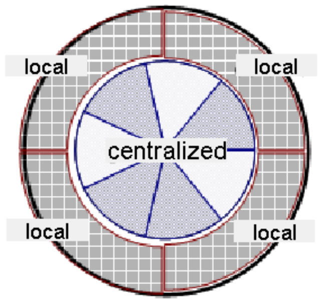
1 THE "MARINE TRAFFIC TECHNOLOGY SYSTEM" (MTTS)

The integral "Marine Traffic Technology System" (MTTS) has been realized on the German coast. Detailed system information are included in the IALA Guideline “G1114 A TECHNICAL SPECIFICATION FOR COMMON SHORE-BASED SYSTEM ARCHITECTURE (CSSA)”.



The main MTTS advantages are:

- Coast-wide standardization of technology
- Use of low-maintenance technology
- Use of remote maintenance options
- Bundling of technology and centralization of data processing in 3 data centers
- Split of maritime traffic technology into “services", which are fully encapsulated and work against each other largely non-reactive.
- Modular design of services, open interfaces: Manufacturer independence
- Personnel bundling

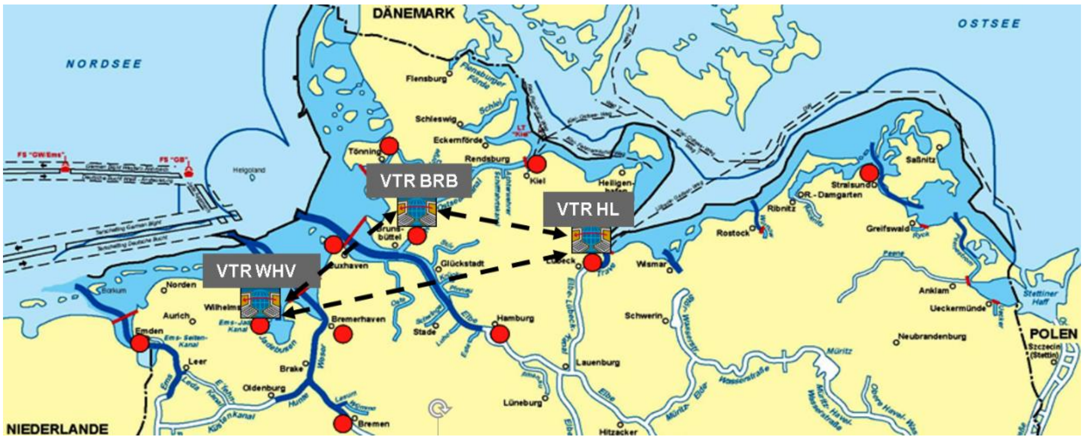


integral "Marine Traffic Technology System" (MTTS)

2 FIXED VISUAL AIDS SERVICE (FXA = VIF - SERVICE)

Among other things, the Fixed Visual Aids Service (FXA = VIF - Service) of the MTTS consists of:

- Nearly 900 lights
- Nearly 1500 shore lights
- Central Components of a Remote Control and Monitoring System (RCMS) in 3 data centers (Wilhelmshaven, Brunsbüttel, Lübeck)

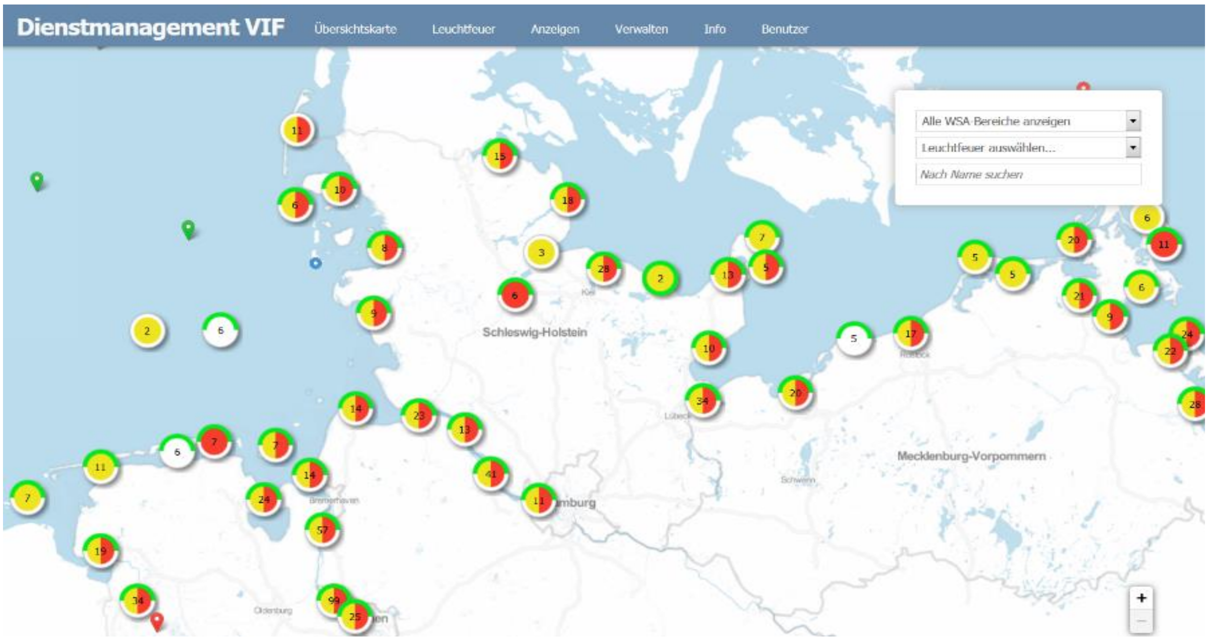


While the central RCMS components have been completed, the renewal of the lights is still in the implementation phase.

3 CENTRAL RCMS COMPONENTS

The main functions of the already completed central RCMS components are as follows:

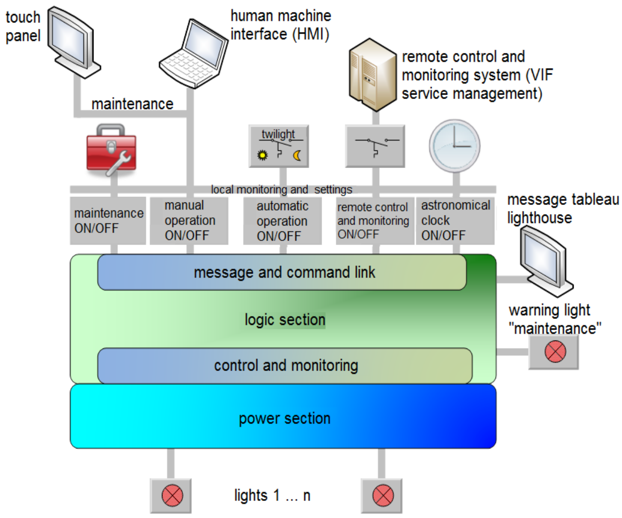
- Coast-wide georeferenced overview of the status of the lights
- Extensive RCMS functions
- Different configurable remote control interfaces
- Interfaces to other MTTS - services, including visualization functions for maintenance and nautical observers
- Remote maintenance
- High availability: Data replication across data centers
- User management (roles / rights)
- Management of technical data
- Freely definable database queries



4 RCMS COMPONENTS FOR LIGHTS - SPECIFICATIONS FOR THE LIGHT CONTROL UNITS

During the realisation of the central RCMS components, the interfaces to the lights and their RCMS functionalities had to be defined. The light sources have been reduced to the necessary level and assigned to light classes. Each light class needs individual control functions, to be realized by the light control unit:

- Data communication with the central RCMS components
- Human machine interface (HMI)
- Configurable flash character generator
- Astronomical clock, time synchronization
- Twilight switch
- Different operation modes: Automatic, Manual, Maintenance
- Measurement, monitoring, control and calculation functions
- Handling of energy sources



Normally a PLC is used to implement those functions in a light control unit.

5 RCMS COMPONENTS FOR RENEWABLE POWERED LIGHTS

Most lights on the German coast are powered by the public grid. Depending on the required availability, elaborate emergency power systems and uninterruptible power supplies are also installed.

Small lights and lights on positions, where no public grid is available, are mostly powered by renewable energy sources. At present some of them are not monitored or are monitored by systems with limited performance. The goal is to integrate them into the MTTS by:

- Implementation of all functions according to the specifications for light control units
- Wireless RCMS communication, using the IEC 60870-5-104 protocol
- Ensuring cyber security:
  - Regular installation of security updates
  - Data encryption

Standard PLC´s need too much energy. Specially developed microprocessor solutions can be very energy-saving, but they are tailored to the individual application.

The MTTS design requires standard products with open interfaces.

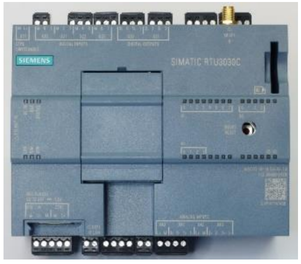
6 RCMS COMPONENTS FOR LIGHTS – TESTING DIFFERENT RTU´S / PLC

6.1 Devices to be tested

The goal was to find a PLC or RTU that could realize all requirements. First, a rough hardware layout for a power-saving light control unit was developed.

After a market recherché and a pre-selection, the following PLC / RTU´ seemed to be suitable:

1) ILC 151 from Phoenix Contact (typical industry-PLC, generally low power consumption)
2) “WebRTU” from “EES”
3) “RTU3030C” from Siemens (new on the market)

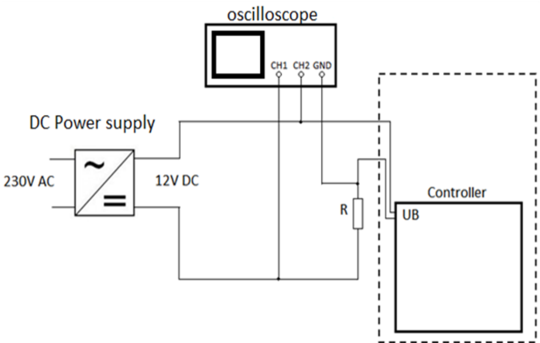


These devices were tested both:

4) Theoretically by data sheet comparison
5) Practically by measurements

During the measurements the controllers operated under the same conditions: Each device was programmed to realize comparable functions.

6.2 Test Results



ILC151:

- Performant PLC
- Not really suitable for low power applications (3.67 W)

WebRTU:

- Low power consumption (1.28 W)
- Performant PLC

RTU3030C:

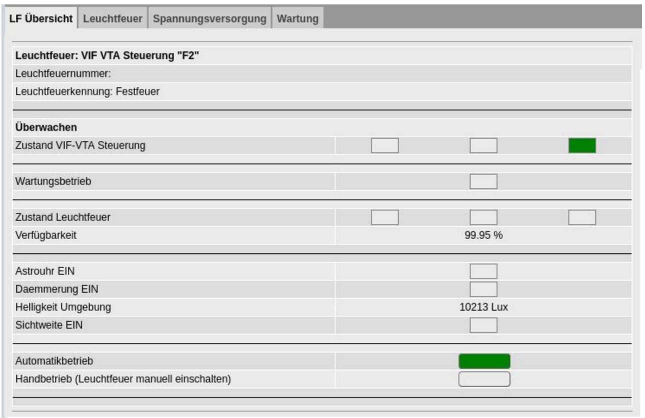
- Very low power consumption (theoretically: 0.5 W, running with the program: 1.18 W)
- Further reduction of power consumption possible (sleep mode, switching sensors on/off)
- Easy to handle: Configuration instead of programming
- Simple “Quasi PLC” with limited functions, the realization of all WSV - functions was not possible.
- The number of digital and analogue inputs was not sufficient.

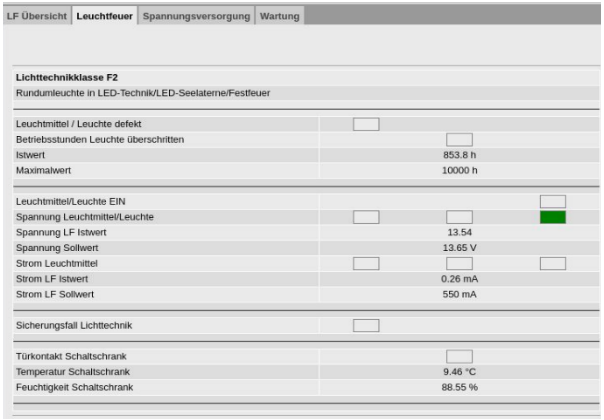
The goal was to decrease the power consumption as far as possible. The WSV contacted the Siemens development department and got possibilities to realise WSV – specific functions in the TRU3030C. This was done together with the local “University of Applied Science Emden –Leer”.

7 FURTHER DEVELOPMENT OF THE RTU 3030C IN COLLABORATION WITH SIEMENS: WSV - SPECIFIC FUNCTIONS

7.1 WEB interface

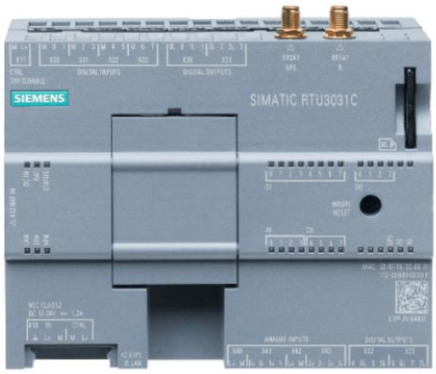
For a quick overview of the light functions, maintenance and configuration a WEB interface was implemented.

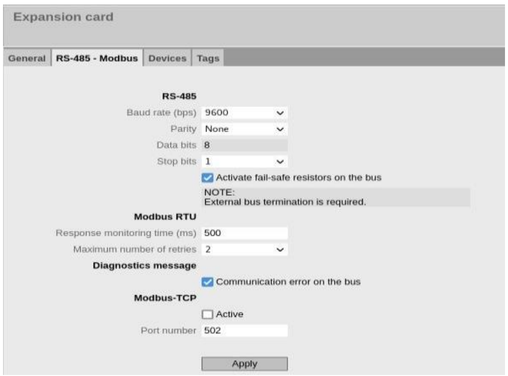




7.2 Modbus expansion card

A retrofitable “Expansion card” was developed, to have the possibility for reading out sensors / transducers by Modbus. So the number of inputs was increased by software.





7.3 Optimization of the digital outputs

Originally the RTU had only outputs with mechanical relay contacts. These have a limited number of switching operations. Therefore the RTU could not be used permanently as a flash character generator for the light source.

- The mechanical relay contacts were partially replaced by electronic contacts.

7.4 Further optimizations

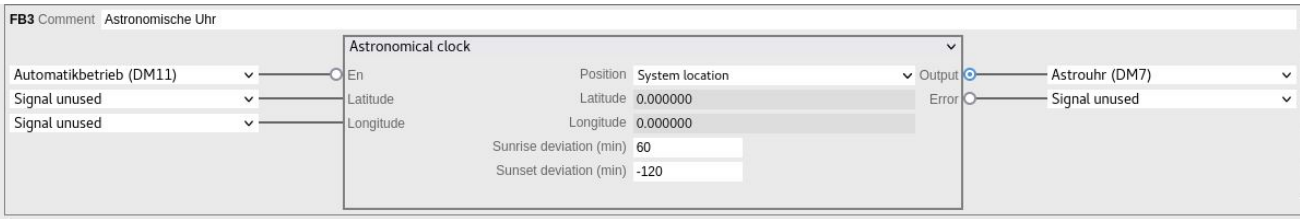
For having more control functions, the number of flags and variables was increased. Additional logic functions with regard to light control were realized:

7.4.1 Flash character generator

A configurable flash character generator was implemented, which runs independently of the PLC cycle.

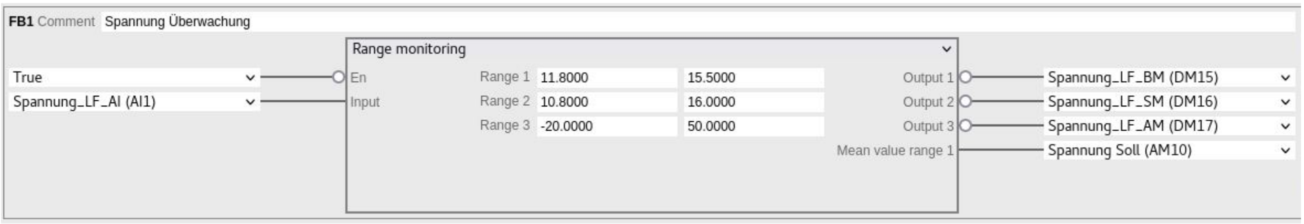
7.4.2 Astronomical clock

Parallel to a twilight switch and automated visibility functions the lights at the German coast are switched on one hour before sundown and switched off one hour after sunrise. For realizing this easily, a configurable astronomical clock was developed. A geographical time offset is adjustable.



7.4.3 Automated traffic light function

For an easy monitoring and assessment of measured values a configurable traffic light function has been implemented. This makes the automatic generation of OK-, fault- and alarm messages possible, which can be send easily to the central RCMS components.



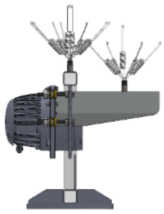
7.5 New versions of the RTU

The relatively deep changes led to a new version of the RTU, the RTU 3031C, which was equipped with a 3G modem. In the meantime, the 4G version (RTU 3041C) is on the market, 5G is in preparation.

8 USE OF THE SIEMENS RTU 303XS SERIES FOR LIGHTS ON THE GERMAN COAST

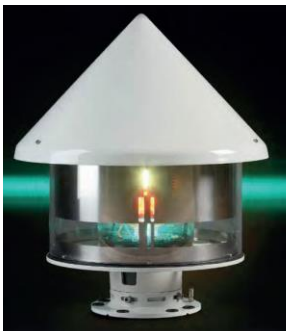
Using the configurable energy saving options an overall power consumption of the light control unit of less than 1 W is possible. With a modular solar energy system and efficient LED light sources a high percentage of all lights can be operated renewable.

In the moment a low power GNSS synchronization module is in development. In combination with the new WSV leading light lantern the RTU also can be used for the RCMS of leading light lines.



Instead of PLC programming, the automation devices of the RTU 30X1C series can be parameterised without deep programming knowledge. So a wide range of applications is easily possible.

In the meantime WSV has developed a universal light control unit for a quick and easy connection of different light sources to the central RCMS components.



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54 years old, married, one child, education as radio electronics technician, studying telecommunication engineering, worked as development engineer and product manager, since 2003 working at Federal Waterways and Shipping Administration, Germany. Member of the IALA ENG Committee since 2014, Vice Chair of Working Group 2.

S12.2 The role of digital technologies in enhancing sustainability and reducing shipping emissions (167)

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ABSTRACT

There is an increasing awareness of dynamic under keel clearance technologies, and their value as decision support tools as articulated in IALA G1110. DUKC®, as a decision support tool for port operators and VTS, is delivering the dual benefits of enhanced safety and improved efficiency through the application of real-time data, advanced hydrodynamic modelling, and AI enhanced forecasting. Safety is enhanced as DUKC® provides the advanced analytics, real-time insights and predictive capabilities for ports to manage shipping operations in the context of vessels that are getting larger, and more frequent and severe weather events. Ports are expected to accommodate new vessels in conditions that operators may have never previously experienced.

Efficiency is enhanced as vessel sailing drafts and tidal windows are optimised through precise UKC management considering both the specific vessel and environmental conditions at the transit time. This paper will present an overview of the technology, and recent case studies detailing the reductions in shipping related CO2 emissions achieved with DUKC®, and the safety benefits being realized by ports receiving larger vessels.

KEYWORDS: Sustainability, DUKC, Reducing Shipping Emissions, Safety,

RESUMEN DEL ARTICULO

En este documento, se describen los requisitos de formato para la 20ª Conferencia de la IALA. Revise este documento para obtener información sobre el formato del texto, los títulos de las tablas, las referencias y el método para incluir la información de indexación. Las actas de la conferencia se publicarán en formato electrónico. El trabajo completo en archivo MS Word se redactará de conformidad con estas instrucciones. En una etapa posterior, se convertirá a formato de documento portátil (PDF).

Un resumen de no más de 250 palabras debe aparecer en la parte superior de la primera página, después del título del trabajo en una sección titulada "RESUMEN" (sin número de sección), después de los nombres de los autores.

PALABRAS CLAVE: Sostenibilidad, DUKC, Reducción de las emisiones del transporte marítimo, Seguridad

RESUME DE L'ARTICLE

Dans cet article, les exigences de formatage pour la 20e Conférence de l'AISM sont décrites. Veuillez consulter ce document pour en savoir plus sur la mise en forme du texte, les légendes des tableaux, les références et la méthode pour inclure les informations d'indexation. Les actes de la conférence seront publiés sous forme électronique. Le document complet dans le fichier MS Word doit être rédigé conformément à ces instructions. À un stade ultérieur, il sera converti en format de document portable (PDF).

Un résumé n'excédant pas 250 mots doit apparaître en haut de la première page, après le titre de l'article dans une section intitulée "RÉSUMÉ" (sans numéro de section), après les noms des auteurs.

MOTS CLÉS : Durabilité, DUKC, Réduction des émissions du transport maritime, Sécurité

1 INTRODUCTION

Ports and shipping channels are critical components of many nations' transport infrastructure and make a significant contribution to the economy. As reported by UNCTAD [1]: "Over 80 per cent of global merchandise trade by volume, and more than 70 per cent by value, is seaborne. International shipping and ports provide crucial linkages in global supply chains and are essential for the ability of all countries to access global markets. Ports are critical infrastructure assets that serve as catalysts of economic growth and development."

In 2015, in recognition of the growing awareness of the importance of sustainability, United Nation's 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) was adopted by 193 countries. The United Nation's SDGs are far reaching and provide a framework for peace and prosperity for people and the planet. They cover concepts from the elimination of poverty and hunger through to clean energy and sustainable cities. The IMO recognises that most of the elements of the 2030 Agenda will only be realised with a sustainable transport sector supporting world trade and facilitating global economy and is actively working towards the SDGs. Ports, as critical nodes in the global supply chain, must respond to worldwide, regional, and local challenges such as climate change and digitalisation.

IALA also supports the SDGs [2], recommending that National members and other authorities responsible for the provision of Marine Aids to Navigation endeavour to support the SDGs and implement formal systems to protect the marine environment and promote sustainability to minimise their impact on the world's resources.

Digitisation to improve productivity is a growing trend in many industries and the maritime sector is no exception. The importance of digitisation to assist sustainability is also being better recognised. UNCTAD has a project to raise awareness among ports and national authorities about the strategic importance of "Sustainable Smart Ports" (SSP) and in the importance of everyone competing on a level playing field. Sustainable Smart Ports take advantage of the new data environments and the energy transition of the maritime sector, artificial intelligence, and green technology-based solutions to enhance port operational efficiency."[1]

This paper will consider the impact of digital technology on enhancing sustainability through a set of case studies, highlighting where the implementation of digital solutions for economic or safety reasons has also improved sustainability. Thereby showing that there is not necessarily a conflict between sustainability and other objectives. The digital technologies that will be studied are DUKC® and TransitAnalyst.

2 SUSTAINABLE DEVELOPMENT GOALS

To support sustainability in the ports, in 2017 the International Association of Ports and Harbours established the World Ports Sustainability Program [3]. As part of the WPSP, the SDGs were grouped into six specific themes that align with the areas in which ports operate. Of these themes, the focus of this study are the themes of Digitisation and Infrastructure, and in particular, three of the SDGs which they encapsulate: #9 Industry, Innovation and Infrastructure, #13 Climate Action, and #14 Life Below Water. The IMO has developed a position on each of the SDGs to provide a maritime focus [4]

In relation to SDG #9, Industry, Innovation and Infrastructure, the IMO states that technological advances in the port sector are key to building resilient infrastructure and central to the effective functioning of the whole transportation sector. A more efficient shipping sector, working in partnership with the port sector, will be a major driver towards global stability and sustainable development for the good of all people. Furthermore, investment, growth and improvement in the shipping and ports sectors are clear indications of a country or region that is enjoying success in the present and planning for future success.

On #13 Climate Action, the IMO's position [4] is that responding to climate change is one of the greatest challenges of our era, and requires appropriate, ambitious and realistic solutions to minimise shipping's contribution to air pollution and its impact on climate change.

Because international shipping takes place on the world's oceans #14 Life Below Water, is the SDG most aligned with the work of IMO, which is responsible for measures to improve the safety and security of international shipping and to prevent pollution from ships [4]

These three SDGs will be explored in this paper through a focus of the following sustainability issues:

- CO_2 reduction
- Reduced dredging
- Risk of shipping accidents.

2.1 Shipping CO_2 Emissions

Although, shipping is the most efficient mode of transport on a CO_2 per tonne-km basis, Greenhouse gas emissions (GHG) from maritime transport are estimated to exceed one billion tonnes per annum, representing around 3% of global anthropogenic GHG emissions [5]. International shipping accounts for approximately 87% of total shipping related CO_2 emissions [6]. Despite improvements in engine technologies and operational practices such as slow steaming aimed at reducing vessels' fuel efficiencies, the total GHG shipping related GHG emissions have continued to climb, largely due to the increase in shipping [7].

The Paris Agreement requires emissions to be reduced by 50% by 2050. Achieving this result will require new innovations in the areas of ship and engine design, and alternative fuels. However, an option that is available immediately is to reduce the amount of shipping by increasing the cargo on each vessel. Reducing shipping CO_2 emissions directly addresses SDG #13 Climate Action.

2.2 Dredging

Dredging is an essential maritime industry activity. The periodic removal of sediment a debris that accumulates under natural processes maintains channels and port accessibility for shipping. By maintain or increase the depth of navigation channel or berths, dredging plays a vital role in the nation's economy be facilitating the most economic method of transporting bulk goods around the world.

Although dredging is a necessary activity there are well understood negative environmental impacts of dredging (E.g., [8]). Some examples of the types of potential impacts associated with dredging include Impacts to benthic communities and habitats.

- direct loss of benthic communities and habitats by removal or burial
- indirect impacts on benthic communities and habitats from the effects of sediments introduced to the water column by the dredging and disposal.

Other types of impacts are covered in [9]. A reduction in Dredging directly addresses SDG #14 Life Below Water

2.3 Risk of shipping accidents.

The negative impact of shipping accidents on the marine environment has been widely studied (e.g., [10]). The most obvious consequence of shipping accidents is the release of pollutants into the environment, or which the most common are oil spills, which contain toxins, are difficult to clean and persist in the environment for years. However, the cargo transported by vessels can also be hazardous with examples of cargo such as cyanide being spilt during shipping accidents [11], and a growing understanding of marine pollution from container ship accidents [12]. Reducing the occurrence of shipping accidents directly addresses SDG #14 Life Below Water

3 DIGITALISATION TECHNOLOGIES

Digitisation of the maritime sector potentially covers all aspects of the industry. In this paper two technologies will be reviewed to highlight the potential for enhancing sustainability, in addition to their primary justifications of safety and / or economic benefits.

3.1 Dynamic Under Keel Clearance (DUKC®)

DUKC® is a comprehensive digital solution for UKC management, underpinned by detailed modelling of port operations, numerical analysis of ship motions, hydro-dynamic models, channel survey data, and the AI assisted assimilation of real-time and forecast environmental conditions. Connecting advanced calculation engines with the port's available IoT devices and digital data sources, DUKC® allows the sailing draft of every vessel to be safely maximised [13].

The DUKC® functionality allows the port and its customers to evaluate what the maximum sailing drafts will be for future tides. DUKC® calculates these maximum sailing drafts based on the specific vessel, its unique stability characteristics for that voyage based on the cargo and how it is loaded, and the prevailing environmental conditions during the transit.

This planning functionality is complemented by critical risk management functions such as vessel speed control, and real time UKC monitoring capabilities through AIS, including dynamically updated chart overlays which display high risk areas within the channel on the portable pilot units (PPUs). By optimising the use of the total water column, DUKC provides a benefit over static under keel clearance (UKC) rules which are the mechanism by which shippers and regulatory authorities have traditionally managed UKC.

3.2 TransitAnalyst

TransitAnalyst is a digital tool that collects vessel position data from AIS and other sources (i.e., PPUs) and processes these data streams to identifiable transits being a distinct journey of a vessel between two locations (e.g., from anchorage to a berth). These transits are continuously identified and stored together with the associated meta data including the environmental conditions during the transit. Over time, TransitAnalyst builds a up database of transits that can be searched and analysed to identify transit trends. Furthermore, by identifying safety margins and reserve areas within the area of interest, Transits that use safety margins or breach reserve areas can be automatically identified and tagged for investigation. Similar limits can be set for navigational data (SOG, COG, Heading etc.) within regions of interest along the channel and transits exceeding those limits are also automatically tagged.

TransitAnalyst development was motivated by the concept of "Flight Operational Quality Assurance (FOQA) and the desire to help enable this concept to be applied to maritime operations. FOQA is a voluntary program for the routine collection and analysis of flight operational data to provide more information about, and greater insight into, the total flight operations environment.

A FOQA program combines these data with other sources and operational experience to develop objective information to enhance safety, training effectiveness, operational procedures, maintenance and engineering procedures, and air traffic control (ATC) procedures.” [14].

Figure 21: Example of TransitAnalyst interface contrasting selected transit with the channel safety margin.

By facilitating the ease of performing Quality Analysis of operations, TransitAnalyst is a digital tool for enhancing safety. Its functionality of automatically identifying and tagging of transit that exceed pre-defined limits that provides the basis for a Pilotage Operations Quality Assurance program that regularly reviews transits within an area and for outlines (transits that exceed threshold limits) to be investigated in detail. An example of the TransitAnalyst interface is shown in Figure 21 showing the intersection of a selected transit and a channel Safety Margin in the centre of the frame.

4 CASE STUDIES

4.1 SAQR - Digitisation reducing CO2 emissions.

Saqr Port in Ras Al Khaimah is one of five ports operated by the Ras Al Khaimah Port Authority (RAK Ports). Saqr is one of the Middle East's leading centres of maritime and industrial commerce. Saqr Port is comprised of an Inner Harbour with 12 berths, and a Deep Water Bulk Terminals that has capacity to berth two Capesize or three Panamax vessels. At a depth of 12.2m, the Inner Harbour caters to vessels from Handy to Panamax size, although draft restricted. With a cargo handling capacity of over 100 million tonnes annually, Saqr is the region's largest dry bulk port.

With the ambition of enhancing their operational efficiency, RAK Ports commissioned OMC International to implement its Dynamic Under Keel Clearance System (DUKC®). This project was unique as Saqr Port was the first in the MENA region to implement this type of innovative technology. DUKC® was commissioned for use on January 1st, 2020, and the benefits for the port and its customers were immediate and significant. The first vessel to load with DUKC® was the LMZ Phoebe on January 9th, 2020. It sailed at a record draft of 12.76m with an additional 3,000t of cargo than it would otherwise have achieved. That record was exceeded regularly over the following months and by August 2020 the MV Soho Mandate became the first vessel to exceed 13m from the Inner Harbour, at a draft of 13.02m.

As well as the economic benefits of the DUKC implementation, it has become clear that by carrying extra cargo on vessels that cargo exported from Saqr is transported with fewer CO2 emissions than previously. The impact on DUKC on CO2 emissions at Saqr has been investigated [15] with the conclusion that the average increase in draft achieved with DUKC® was 0.63m. Of the 225 transits, there were 27 unique destinations. Of these 27 ports, 12 had only a single transit. Chittagong was the most frequented port with 99 transits. It also has one of the longest distances as well as the highest average benefits in terms of increased draft and tonnage.

Taking into consideration the increased tonnage and distance for every DUKC® transit and applying the CO2 emissions per tonne km value of 6.3g, the reduction in CO2 resulting from the efficiencies achieved with DUKC® is estimated at 53,243 tonnes.

4.2 Lyttelton - Digitisation reducing dredging volumes.

The Port of Lyttelton services the New Zealand South Island city of Christchurch and is a critical link in both New Zealand and global trade networks. In addition to a container terminal and the country's largest coal terminal, Lyttelton has facilities for loading and unloading bulk products such as petroleum, fertiliser, gypsum, cement, logs, conventional break-bulk, and imported vehicles. Historically, Lyttelton managed grounding risk by operating a static UKC rule of 10% of draft and apply judgement to avoid sailing some vessels when the swell was high .

With the size of container vessels increasing globally Lyttelton commenced a channel deepening project to accommodate larger vessels. An increase in the depth of the existing shipping channel of up to 5-6m was envisaged to allow for these larger, deeper ships at an estimated cost of NZD $80 – $120 million.

After considering the option of a traditional channel design with a static rule, Lyttelton instead decided to implement a DUKC® system which allowed the channel design to be DUKC® optimised channel. This decision was based on an economic cost benefit analysis that considered the significant saving in capital expenditure and an ongoing reduction in operating risk.

The original PIANC channel design required a dredge volume of 9.7M cubic metres. The DUKC® optimised channel required a dredge volume of 5.5M cubic metres, a reduction of 4.2M cubic meters or 43%. The significant amount of dredging saving was directly due to the implementation of DUKC® digital technology, which minimized the environmental damage while achieving the economic objectives.

An additional example of digital technology reducing dredging volumes comes from another New Zealand Port that was an early adopter of TransitAnalyst. When preparing for channel maintenance, and needing to reduce volumes due to economic constraints, the port pilots identified that an area of a channel bend was never being passed over by the transiting vessels. After consideration it was decided that this area did not need to be dredged and accordingly dredging was reduced via the use of digital technology.

4.3 Digitisation reducing shipping accident.

The Port of Fremantle services the city of Perth in Western Australia. The approach to Fremantle commences with a cut Deep Water Channel (DWC), then transitions to a naturally deep section before the Inner harbour entrance channel. In 2015, a container ship *Maersk Garonne* grounded in after being taken outside the shipping channel in an attempt to delay the transit due to concern that tugs would not be ready for the entrance manoeuvre.

A subsequent Australian Transport Safety Board (ATSB) investigation [16] identified that the pilot had conducted the ship along a route to the east of both the planned track on the ship's chart, and his own intended transit on the MPX form. Further, the port's operational parameters stated that a deep draft vessel like the container ship should not exceed 13 knots in the DWX, and the master's passage plan for pilotage anticipated a speed of 12 knots departing the DWC and less than 8 knots for the entrance channel. The *Maersk Garonne* actually transited DWC at around 16 knots, The ship's speed as the pilot started the turn towards the entrance channel was 14.5 knots.

While various recommendations were by the ATSB, a contributing factor identified was that Fremantle Pilots' publicly available provided consisted essentially of a list of waypoints, which was routinely not followed. Considering this fact, the accident could potentially have been anticipated. An analysis of the previous 2 months of tracks of similar sized vessels (more than 40), revealed that while all tracks were within the port approved transit corridor (Figure 22), none of the tracks was consistent with port's published waypoint list. In other words, a clear trend of vessels deviating from the published way points existed prior to the accident.

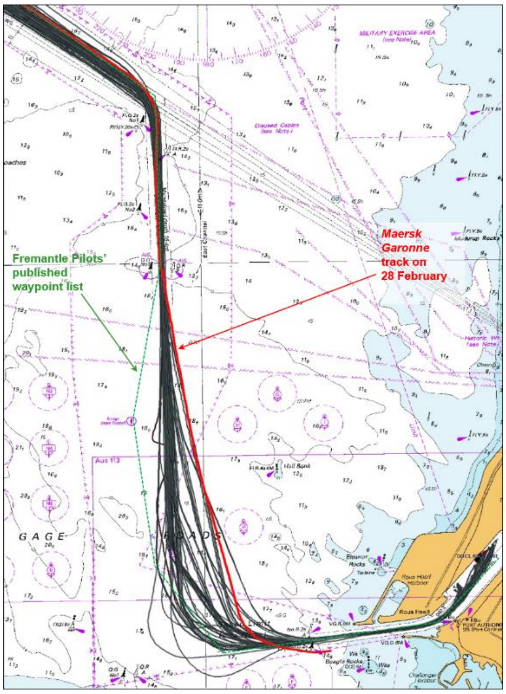

Figure 22: Analysis by ATSB showing similar vessel tracks in months prior to the accident: Source [16]

The ATSB investigation identified that there was a trend of vessels deviating off the proscribed route prior to the accident. This trend could be found in publicly available AIS data. The warning signs were available but had not been recognised. Anecdotally other maritime accidents follow a similar trend, where warning signs of variations from port guidance are missed, are not corrected and ultimately an accident occurs. In essence such an accident could be deemed preventable in the sense that warning signs were available but not detected.

Recently developed digital technology is being adopted by New Zealand and Australia ports to reduce the number of such preventable accidents. Taking a lead from the Aviation industry these ports are implementing Quality Assurance on their operations. Using TransitAnalyst, transits are being continuously monitored and compared against predefined parameters and outliers identified for further analysis by the Marine Operations team. An example of the output of operational TransitAnalyst are shown in Figure 23 and highlighting occasions the frequency of vessels exceeding pre-defined limits.

Implementations of TransitAnalyst in at least three New Zealand ports have all highlighted deviations in marine operation practice from the norms set expected by the Marine Operations team (an example of such analysis is shown in Figure 23). By identifying such deviations through routine Quality Assurance, it is expected that potentially dangerous trends will be identified ahead of time and accidents such as the *Maersk Garonne* avoided.

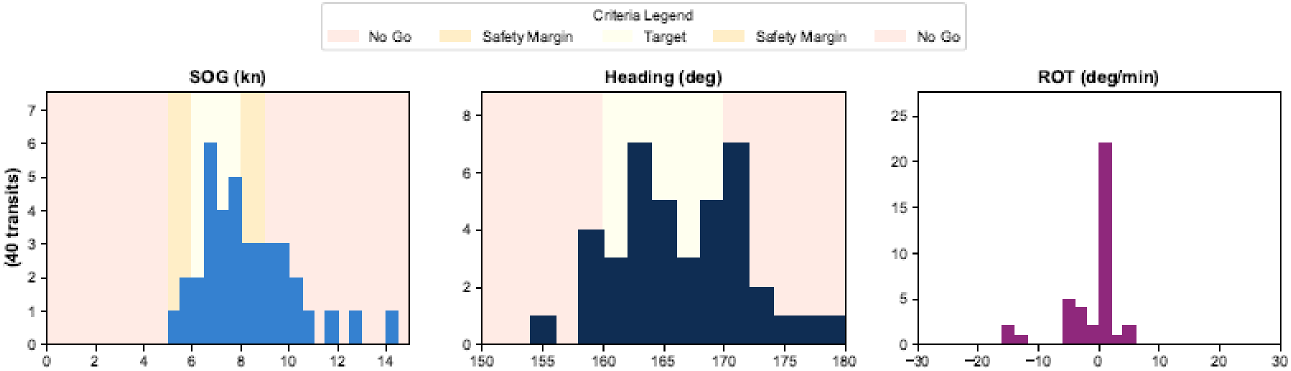

Figure 23: Example of TransitAnalyst results identifying transit outliers relative to operational parameters.

5 CONCLUSION

Addressing the UN's Suitability Development Goals (SDGs) is an important focus for all industries and especially important for the maritime industry given its significant contribution to global commerce. This paper contends that the implementation of digital technologies has an important role in achieving SDGs. To support this contention two digital technologies and their impact in assisting sustainability have been highlighted through three case studies covering sustainability issues of CO2 emissions, dredging and shipping accidents.

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AUTHOR BIOGRAPHY

Matthew Turner is OMC International's General Manager for Delivery and Services. A Senior Engineer with over fifteen years' experience in coastal engineering and coastal science and project management in international settings. Particular MetOcean expertise includes the development and application of numerical models of coastal processes including tides and currents, the forecasting of environmental conditions, assimilation of forecasts into coastal numerical models. Maritime engineering experience includes conducting port under keel clearance risk assessment studies, DUKC® configuration and dredge optimisation studies, and port capacity modelling.

S12.3 Sustainability in the provision of aids to maritime navigation (035)

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ABSTRACT

In addition to the performance of the equipment, the preservation of the environment must be one of the main concerns of the purchaser when selecting eco-designed and economically efficient aids to navigation.

In order to extend the life of these aids to maritime navigation, experts must strive to constantly reinvent durable products that are easy to use. The question of recycling must therefore be taken into account from the design stage.

It is then necessary to select quality materials capable of withstanding the extreme conditions in which the equipment is deployed. Thus, it is a question of optimizing the life of equipment while reducing maintenance costs and offering affordable solutions for the greatest number. This quality requirement must also be apparent at the time of manufacture and be illustrated by tests carried out on materials and equipment.

Finally, it is a question of being able to choose solutions that have been proven over the years: there are many sites where aids to navigation have been deployed for more than fifteen years and are still able to perform their function, before being recycled.

Thus, sustainability in the provision of aids to maritime navigation is ensured, if the needs are clearly identified.

KEYWORDS: aids to navigation, sustainability, recycling, environment.

RESUMEN DEL ARTICULO

La preservación del medio ambiente debe ser una de las principales preocupaciones del comprador a la hora de seleccionar ayudas a la navegación marinas reciclables, duraderas y económicamente atractivas.

Para prolongar la vida de estas ayudas a la navegación marítima, los expertos deben esforzarse por reinventar continuamente productos sostenibles y fáciles de usar. Por tanto, la cuestión del reciclado debe tenerse en cuenta en la fase de diseño.

A continuación, es necesario seleccionar materiales de calidad capaces de soportar las condiciones extremas en las que se despliega el equipo. El objetivo es optimizar la vida útil de los equipos al tiempo que se reducen los costes de mantenimiento, y ofrecer soluciones asequibles para el mayor número de personas. Esta exigencia de calidad debe reflejarse también en la fase de fabricación e ilustrarse mediante ensayos efectuados en los materiales y equipos.

Por último, se trata de poder elegir soluciones que hayan demostrado su eficacia a lo largo de los años: hay muchos sitios en los que las ayudas a la navegación marítima llevan desplegadas más de quince años y siguen cumpliendo su función, antes de ser recicladas.

Así pues, la sostenibilidad en el suministro de ayudas a la navegación marítima es posible, si se identifican bien las necesidades.

PALABRAS CLAVE: ayudas a la navegación marítima, sostenibilidad, reciclado, medio ambiente.

RESUME DE L'ARTICLE

La préservation de l'environnement doit être l'une des principales préoccupations de l'acheteur lors de la sélection d'aides à la navigation maritime recyclables, durables et économiquement intéressantes.

Afin d'allonger la durée de vie de ces aides à la navigation maritime, les experts doivent s'employer à toujours réinventer des produits durables à l'utilisation facilitée. La question du recyclage doit donc être étudiée dès la conception.

Il est alors nécessaire de sélectionner des matériaux de qualité capables de résister aux conditions extrêmes dans lesquelles les matériels sont déployés. Ainsi, il s'agit d'optimiser la durée de vie des équipements tout en réduisant les coûts de maintenance et de proposer des solutions abordables pour le plus grand nombre. Cette exigence de qualité doit transparaître à la fabrication et être illustrée par des tests effectués sur les matériaux et le matériel.

Enfin, il s'agit de pouvoir choisir des solutions éprouvées au fil des années : nombreux sont les sites où des aides à la navigation maritime sont déployées depuis plus de quinze ans et toujours en mesure d'assurer leur fonction, avant d'être recyclées.

Ainsi, la durabilité dans la fourniture des aides à la navigation maritime est possible, si les besoins sont bien identifiés.

MOTS CLÉS : aides à la navigation maritime, durabilité, recyclage, environnement.

1 INTRODUCTION

Since 1990, MOBILIS has stood out to be today the world reference in the navigation aids sector. Specialized in the design, development, manufacture, and distribution of navigation aid equipment, MOBILIS provides products of uncompromising quality thanks to a sales network present on five continents.

MOBILIS selects solutions at the cutting edge of technology to respond to the problems of tomorrow. Our know-how and our desire to innovate allow us to be a world reference for navigation aid products, mooring buoys and data acquisition equipment for the benefit of port authorities, industry and the safety of all browsers.

MOBILIS offers long-lasting, high-quality solutions that respect the environment and recommendations from IALA / AISM. An internal engineering office is dedicated to improving and supplementing the wide range of models. This constant innovation offers a variety of solutions that are relevant and appropriate to the situations encountered by our customers on oceans, seas and rivers, all around the world.

In order to strengthen and complete its offer, MOBILIS distributes products selected for their performance and quality, and monitors them with the same rigor as for its own products. With a view to quality control, MOBILIS took the decision in 2012 to create its own rotomolding factory in Agen. Quality is at the centre of the concerns of the company which strives day after day to provide robust and efficient products, adapting to the needs of its customers.

MOBILIS customizes its projects with an industrial solution. At MOBILIS, modularity makes it possible to adapt solutions to all market demands. Since 1990, MOBILIS has been designing customizable platforms : each element is optimized and assembled to obtain the appropriate equipment in response to the specifications.

MOBILIS has supplied more than 60,000 buoys in more than 90 countries. To adapt to the demanding needs of our customers, MOBILIS teams prioritize quality of service, from request through to manufacturing, delivery and monitoring.

Our objective : to develop adequate solutions to bring added value to our products and services, always with respect for the environment. That is why, we will study the question of the environmental protection regarding MOBILIS solutions. Then, the issue of sustainability will be highlighted.

2 ENVIRONMENTAL PROTECTION

The issue of environmental protection is increasingly present in the public debate. It has even become a central issue in recent years. But, MOBILIS has not waited for this issue to be brought to the forefront of public debate before putting it at the center of its thinking when designing new solutions. The aim is to offer the most efficient solutions possible that have the least negative impact on the environment.

Regarding the environmental protection question, we can identify three main areas of reflection. First, the environmental issue. How does MOBILIS work to have the minimum impact of the environment? Then, why the study of recyclability and of the life cycle is so important to bring solutions. Lastly, how an economic aspect emerges from the environmental issue and how to combine these two aspects: how can economy helps environment.

2.1 Environmental questioning

For all its products, MOBILIS seeks the best compromise between technical solution, economical solution and environmental solution.

This is why eco-design is part of the company's standards and values.

Eco-design at MOBILIS is based on, among other things, the use of easily recyclable materials, simple solutions that meet current standards, and transportation that is as optimized and simplified as possible.

The materials in question are steel, aluminum, plastic (Polyethylene) and cast iron.

These simple materials were chosen for technical and mechanical reasons, but also for environmental reasons. Thus, it is not only the technical aspect of the project, although it is primordial, that guides the choices of MOBILIS, but also the environmental consequences that these choices will have.

MOBILIS buoys are modular and are all based on the same model:

Figure 1 : Jet 9000 buoy

- an aluminium topmark and its support ;
- an aluminium or polyethylene mast ;
- a steel or polyethylene structure ;
- a polyethylene float in several elements.

One of the main environmental issues concerns the polyethylene, which is a petroleum derivative, float. From experience, Medium Density Polyethylene (MDPE) is the best compromise for making buoy floats. The floats are built in several interchangeable elements constituting several watertight compartments. They are made using the roto-molding process which guarantees an equal quality of each part (shapes, dimensions and thickness) and does not generate any rejects. The quantity of plastic required to produce a float can be controlled and adjusted to maximize the ratio of plastic consumption to mechanical characteristics.

The mains benefits are:

- it does not require any foam or any type of filling inside: it is important to be able to propose unfoamed and unfilled floats because the foam of the floats is not recyclable. In addition, in the event that the float is damaged, its contents would be exposed and would disintegrate in the water, as can happen with polystyrene;
- easy to transport in containers: the float being composed of several elements, it is possible to optimize the number of containers and thus to have a less important environmental impact related to transport;
- easy to repair: only the damaged element can be replaced or repaired, no material is produced “for nothing”.

Moreover, the great majority (nearly 90%) of the production is French and local and that for all the Mobilis products. The company implements everything to limit the distance of its factories and the subcontractors for reasons of costs, deadlines, control of the quality and ecology.

Indeed, the environmental impact of transport is a major issue for the sustainability of products. Transportation contributes to greenhouse gas emissions that are responsible for climate change, as well as air and noise pollution.

To reduce the environmental impact of transport in the life cycle of a product, several elements are taken into account by MOBILIS.

- First, the choice of transportation mode is crucial. Transportation by boat is generally the most chosen by the company because it is more environmentally friendly than transportation by plane or truck; it emits less greenhouse gas emissions per unit of distance traveled.
- Secondly, the choice of containers also plays an important role in reducing the environmental impact of transportation. Optimized containers maximize the use of space and reduce greenhouse gas emissions per unit of cargo transported. Optimized containers also reduce transportation costs by allowing products to be loaded and unloaded more quickly. In addition, since container transport is very popular, it is very easy to find.
- • Finally, packaging is an important element in the life cycle of a product. Environmentally friendly and eco-responsible packaging materials help reduce environmental impact. Reusable or recyclable packaging can help reduce waste and costs.

It is by taking into account all these elements that MOBILIS always studies the best solution and the best optimization to transport its products and thus limit the environmental footprint of this stage.

In addition, the modularity of the buoys allows an optimization of the transport and thus the limitation of the carbon footprint related to transport. The buoys are dismantled and the space they take up during transport is therefore optimized.

Moreover, all the elements of the buoy (except batteries and electronic equipment) are designed with very common and easily recyclable materials.

Therefore, at the end of its life, a MOBILIS product is 100% recyclable (not including the electronic elements and batteries).

The question of environmental impact can be studied through the prism of the question of recyclability and the life cycle.

2.2 Recyclability, life cycle

A product life cycle assessment is a systematic process for evaluating the environmental impact of a product over its entire life cycle, from the extraction of raw materials to the end of the product's life. It allows us to understand the environmental strengths and weaknesses of the product and to identify opportunities for improvement in order to reduce its impact on the environment.

The aim is to schematically illustrate the classic life cycle of a MOBILIS buoy in order to see how this life cycle illustrates the company's desire to offer sustainable solutions. We will focus on three main stages: design, production and recycling

Design is one of the most important stages because it is this stage, along with the technical choices, which will influence all the stages of a product's life cycle. This is why MOBILIS is committed to eco-design: it sees the design stage of its products as a way of making the environmental issue a major stake in its production. It is a question of proposing the best adapted product with the least possible environmental impact.

Following the design stage comes the manufacturing stage. MOBILIS floats are rotomolded and it is clear that the production of MOBILIS products uses simple and democratized manufacturing processes. MOBILIS has its own production unit and can thus control the manufacturing process of its products. This allows MOBILIS to put sustainability at the center of its thinking and to make its production an eco-friendly step that will have the least impact on the environment. MOBILIS uses mainly polyethylene, steel and aluminum in its production. For steel and aluminum, MOBILIS uses subcontractors to whom it imposes the same rigorous specifications as it applies to its own production

After being manufactured, MOBILIS solutions are put in place to perform their role. It is a fact that in many sites with extreme conditions, MOBILIS buoys are still in place more than 15 years after their deployment. This illustrates the durability of the solutions proposed by the company.

When the time comes to remove the MOBILIS buoys, the question of the recyclability of the material will be raised. Several points are to be noted on this subject :

- The recycling of PEMD is easy and many channels exist throughout the world ;
- The two main metals the company works with (steel and aluminum) are easily recyclable ;
- No manufacturing product is thrown away. All manufacturing waste is either recycled or recovered.

Thus, we can see that the question of sustainability is at the centre of MOBILIS' thinking and that it is reflected in the life cycle of its products. It is therefore possible to propose sustainable maritime navigation aids whose life cycle is optimized.

In addition to the ecological dimension, there is also an economic dimension to sustainability.

2.3 Economical dimension

When producing materials, it is impossible to deny the importance of the economic dimension. Solutions must be sustainable, but they must also be economically attractive. MOBILIS places great emphasis on the quality of its products, from the design and choice of raw materials to the manufacturing process. Despite this high level of quality, the company makes every effort to reduce its costs as much as possible and thus be able to offer solutions that are interesting both ecologically and economically. For this reason, the company makes a point of reducing maintenance costs, for example. Even if the buoy were to be more expensive at the time of purchase, the maintenance costs are low and will compensate for this difference; the cost must be considered over the full lifespan of the buoy. Another lever on which the company can play is the cost of transport. Indeed, the most popular means of transport is by boat, as it is often less expensive than other modes of transport, which can contribute to reducing the overall cost of the product.

Thus, MOBILIS is not satisfied with analyzing only one aspect of its production but studies the projects in their totality in order to propose the best adapted solutions.

We have therefore analysed the issues of environmental protection and how MOBILIS is acting in this regard. We will now focus on the issue of sustainability.

3 SUSTAINABILITY

MOBILIS has been offering marine navigation aids for more than thirty years and the question of the durability of its solutions has not arisen because it was obvious to offer products that respect the environment and are sustainable. This is why MOBILIS floats are mainly not foamed, as this foam is not recyclable, or why the mooring solutions that the company proposes are ecological: the company regularly proposes mooring solutions that involve a subsurface float to avoid the drag of the chain on the sea bed. Thus, three central points are important to note when considering the issue of sustainability: identification of the need, maintenance management, and the life span of the equipment.

3.1 Identifying the need

The provision of quality marine aids to navigation is essential to ensure the safety of users. Indeed, we must not forget the primary role of these maritime aids to navigation: a signaling role that allows safe navigation. The first need identified is to signal dangers. But when we talk about the need, we also talk about the need as it is perceived by the end user. It is important to be able to define the end customer's need, to know what solution he needs. Depending on the site conditions, for example, a buoy may be suitable in one place but absolutely not in another. You have to be able to make that judgment and explain to the customer why one solution is proposed rather than another. Solutions should not be over- or under-dimensioned. Every project is different and MOBILIS must be able to identify the specific need in each situation. Once this need is clearly identified, the company can make the most suitable offer. This offer will respect the company's criteria: quality, traceability, respect for the environment and will have an optimized cost.
This cost optimization is possible thanks to the care given to the maintenance issue. Moreover, reducing maintenance is a solution to propose more sustainable solutions.

3.2 Maintenance

Maintenance is an important lever for offering sustainable solutions. Indeed, the less maintenance there is to be done on MOBILIS products, the more maintenance costs will be reduced and the durability of the solutions improved. If there is less maintenance to be carried out on products, we can think that it is because they will last over time and do not need significant maintenance to keep their performance as long as possible. The question then is how MOBILIS manages to reduce its maintenance costs.
By the very composition of its buoys, the company manages to reduce the number of necessary interventions. MOBILIS buoys are modular and therefore easy to repair: only the damaged part can be replaced without having to change the whole buoy, or even repaired with a heated PE tape if the damage is limited. Furthermore, since quality materials are used by the company, operations are few in number over time and, when they do occur, they are easy to implement: it will mainly be a matter of cleaning the elements to avoid biofouling.
The importance MOBILIS places on the issue of maintenance allows it to optimize the durability of its products and to offer responsible production. This has an impact on the life of the company's equipment.

3.3 Equipment life span

If we make the question of lifespan a central point in the thinking of MOBILIS, it is because the sustainability of maritime navigation aids is a major issue. Marine navigation aids play a vital role on the seas and it is important to ensure that they can fulfil this role for as long as possible and in an efficient manner. To do this, MOBILIS optimizes the service life of its equipment. Despite the extreme conditions in which the buoys are deployed, they are still fulfilling their role more than ten years after their installation. Such longevity is a record in such a demanding and hostile environment.
Furthermore, Mobilis has been conducting accelerated and natural aging tests on polyethylene for over 15 years to determine the mechanical strength of the raw materials used. As a result, Mobilis' polyethylene products are "UV16", which means that they maintain their mechanical and colorimetric properties for at least 16,000 hours of direct exposure to sunlight. In addition, the materials used, such as aluminum, are marine grade, which also guarantees the durability of the solutions offered by MOBILIS.
All these elements ensure the quality of the products, their life span and therefore their durability.

4 CONCLUSION

MOBILIS eco-design policy consists of integrating environmental protection into the design of goods or services. It aims to reduce the environmental impacts of products throughout their life cycle : extraction of raw materials, production, distribution, use and end of life. It is characterized by a global vision of these environmental impacts : it is a multi-stage approach (taking into account the various stages of the life cycle) and multi-criteria (taking into account material and energy consumption, discharges into the natural environment, effects on the climate and biodiversity).

Thanks to all the elements we have noted, we have been able to see how MOBILIS manages to make its marine navigation aids sustainable and environmentally friendly solutions. From the design of the buoys, the way the materials are chosen and the recyclability of the products, MOBILIS ensures the longevity and durability of its solutions.

AUTHOR BIOGRAPHY

After a scientific baccalaureate with a mathematical science option and two years of scientific preparatory classes, I did a philosophy thesis, working on the deep connection between science and philosophy. This thesis was completed at Aix-Marseille University (France) and the University of Florence (Italy). The goal of this study was to demonstrate the enduring connection between science and philosophy across various historical periods, with a particular emphasis on how the Renaissance marked a significant turning point in the evolution of intellectual thought. Philosophy allows for a step back and a new perspective on science. Afterwards, in order to be prepared for the professional world, I obtained a master degree in general management at IAE Aix-Marseille Graduate School of Management. I was able to follow this master degree in alternation and integrate the company MOBILIS at the end of 2020, where I am still employed.

I have been working in Mobilis' sales department for 2 years, and am also responsible for creating documentation that demonstrates the longevity of our Aids To Navigation equipment. In relation to this task, I collaborate with one of Mobilis' engineers who is responsible for conducting lifespan analysis on all products manufactured at our factory in France. I have the chance to be a part of large-scale projects and I can measure the impact of the provided solutions all around the world. Therefore, the topic of sustainability has become crucial, and ensuring sustainable practices in the provision of aids for maritime navigation is a significant challenge.

S12.4 UN Sustainability goals drives the requirements for AtoN integration in e-Navigation Suites (113)

Bjorn Hjollo, NAVTOR, Chief Sustainability Officer, Norway

ABSTRACT

Since the SOLAS Carriage requirement for ECDIS entered into force in 2011, the shipping industry has clearly shifted from Paper based information to Digital, and the e-NAV industry has significantly supported this transformation. Innovative solution including data/license distribution (e.g., PAYS for ENC), back of Bridge e-NAV stations with layers of mandatory information on top of ENCs and related Passage Planning SW, are all central parts. Cyber secure updating and exchange of digital information with ECDIS system is today standard procedure on many vessels. In addition, we see an increasingly exchange of data ship shore, supporting related services for safe and sustainable navigation.

With the urgent focus by UN, IALA, IMO (and the world in general) on sustainability, the Shipping industry must contribute by meeting the UN's goal of "net Zero CO2 emissions by 2050". The leading e-Nav industry have already made great impact by combining Safe navigation with Efficient navigation into Sustainable Shipping. The platforms used for traditional e-Nav, e.g., NAVTOR Suite, is extended to integrates new services for AI supported safe and sustainable Shipping.

Still there are challenges to be solved related to standards, e.g., for Ship-Shore Reporting, where IMO, IALA and the main e-NAV actors should emphasize working even better together to facilitate sustainable Shipping e.g., by "Just in time arrival". This presentation will show State of Art of e-nav services today, including sustainable services and automatic M2M Ship-Shore reporting, using ISO28005 (Electronic Port Clearance) to report into a Maritime Single Window solution. However, the shore side and ship side need to adopt same standards; today only a few MRS and Ports can receive M2M reporting using the ISO-standard.

(No paper submitted)

AUTHOR BIOGRAPHY

Bjørn Åge HJØLLO has a Master in Meteorology, and started his carrier in Norwegian Meteorological Institute's R&D division in 1992, worked later as a Marine Forecaster and for the three years heading the Marine Forecasting Centre in Norway. In 2004, he joined C-MAP Norway as General Manager for C-MAP Marine Forecasting Centre. He became Product Manager in C-MAP, later Jeppesen Marine.

In 2011 he joined a group of managers leaving Jeppesen Marine, establishing NAVTOR AS to focus on e-Navigation. He is today Chief Sustainability Officer and a minority owner in NAVTOR. In this position he guides NAVTOR's internal, national and international R&D projects focusing on the strategy for "One Platform for Sustainable solutions" supporting Safe and Efficient Navigation, with the basis in NAVTOR's widely used e-Navigation platform.

S12.5 Renewal of 900 lights at the German coast regarding sustainability (070)

Peter Schneider, Federal Waterways and Shipping Office Ems-Nordsee, 26725 Emden, Am Eisenbahndock 3, Germany, Peter.schneider@wsv.bund.de

ABSTRACT

The current technical renewal of 900 lights at the German coast is a special challenge due to the following boundary conditions:

- The existing equipment is a result of a development over many years. Therefore, the lights show a great technical variety caused by local developments and the historical period in which they were built up.
- A coast-wide uniform technical approach and monetary constraints require a high degree of standardization. A minimum of standard solutions must be identified and implemented.
- The parameters of each light need to be confirmed by intensity calculations and a nautical assessment in an elaborate process.
- There is a need to switch to modern LED technology, which may lead to a complete redesign of a light: Optical, electronically and mechanical.
- The measure will be carried out during ongoing operation of the lights, so detailed planning with intense care and several migration phases are necessary.
- Short product lifetime of modern technology.

The paper gives an overview about the ongoing measures.

KEYWORDS: sustainability, leading light lanterns, RCMS, infrastructure components, shore lights

1 INTRODUCTION

The Federal German Waterways and Shipping Administration (WSV) is currently running a project to modernize all approx. 900 lights on the German coast. Parallel to this, 1500 shore lights need to be replaced. Both, the light technology as well as the remote control and monitoring systems (RCMS) need to be renewed.

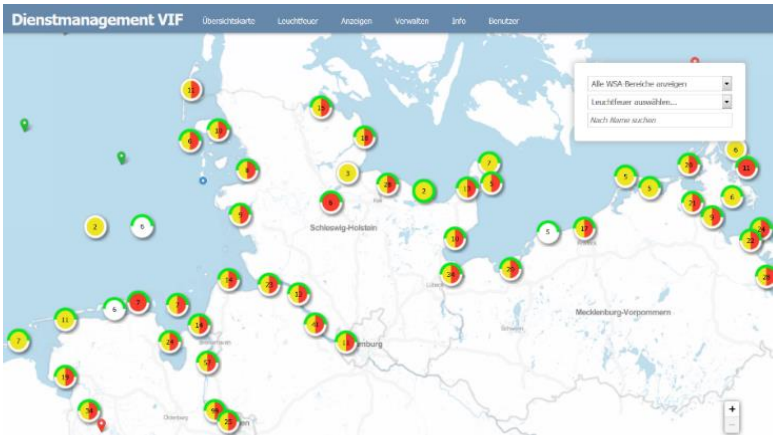
As already mentioned, the project is a special challenge due to the following boundary conditions:

- A coast-wide uniform technical approach and monetary constraints require a high degree of standardization.
- But: The lights show a great technical variety…
- The parameters of each light need to be confirmed by:
  - Nautical assessment: Need for the light, required availability
  - Intensity calculations
  - Technical status of the sites
- The change to LED technology often leads to complete redesigns: optical, electronically and mechanical

1.1 Central RCMS components for the lights

Completed are the central RCMS components including the following main functions:

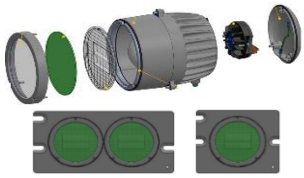
- Coast-wide georeferenced overview of the status of the lights
- Extensive RCMS functions
- Different configurable remote control interfaces
- Interfaces to other MTTS - services, including visualization functions for maintenance and nautical observers
- Remote maintenance
- High availability: Data replication across data centers
- User management (roles / rights)
- Management of technical data
- Freely definable database queries



1.2 Main goals for the light renewal and for sustainability

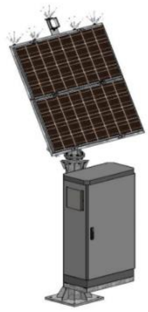
The main goals for the renewal of the lights are as follows:

- Modular structure and open interfaces for manufacturer independence
- Reduction of the number of different light sources: classification
- Use of LED technology as far as possible
- Standardization of the light control units and their interfaces to the central RCMS components:
  - Protocols
  - Messages
  - Commands
- Increase of remote maintenance functions



The main sustainability goals are:

- No disposable solutions: Use of durable and individually replaceable components
- Reducing the energy consumption of the light- and RCMS technology as far as possible for:
  - Renewable power supplies where possible
  - Independence from the public electricity grid
  - Avoidance of fossil fuel-fired emergency power systems



1.3 Project overview

To manage the 42 Million € project under limited personnel resources, individual measures were identified. Their priority is as follows:

- Project 1: Leading light lanterns
- Project 2: Self-contained LED lanterns
- Project 3: Remote control and monitoring systems (RCMS) for leading lights
- Project 4: Remote control and monitoring systems (RCMS) for infrastructure components
- Project 5: Sector lights
- Project 6: Shore lights
- Project 7: Sea lights

The projects marked in red are currently being implemented. They will be presented in the following, especially with regard to sustainability matters.

2 PROJECT 1: LEADING LIGHT LANTERNS

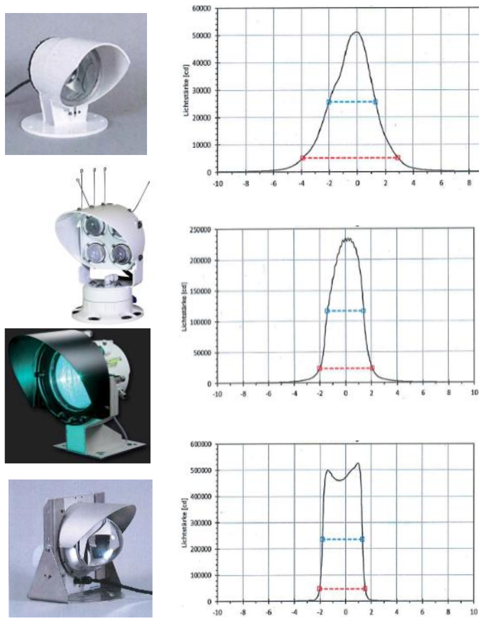
2.1 Current status

Leading lights on the German coast have a wide variety regarding:

- Light intensities: 10 cd up to 5 Mio cd
- Light sources:
  - Old classic lanterns
  - Classic optics with lamp changers
  - LED - lanterns of different generations
- Buildings: From small masts to large offshore structures
- Infrastructure: None to extensive
- Energy demands and supplies:
  - Public electricity grid
  - Emergency power systems
  - Renewable power
- Remote control and monitoring systems (RCMS): Minimal to extensive
- Nautical availabilities: 97 % - 99.8 %

In order to optimize economic efficiency and spare parts inventory, a leading lantern should be procured, which can be used for all light demands.

2.2 Market check



Tests of market available lanterns did fulfill WSV - demands:

- One-way lanterns
- No modularity
- No possibility of light adjustments using spreading lenses or colour filters
- No optical feedback systems
- Manufacturer - specific electrical interfaces
- No mechanical compatibility with existing equipment
- Time - consuming installation and adjustment
- Permanently installed light source, in case of failure:
  - New lantern and adjustment from the water are necessary

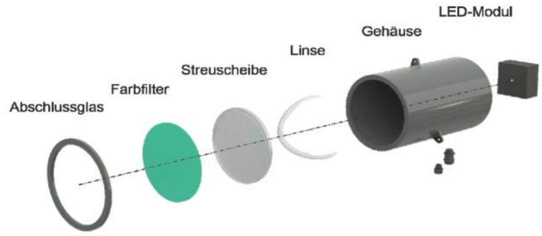
The consequence was a tender for the procurement of lanterns according to WSV – demands

2.3 Specification of a WSV - leading light lantern

The WSV leading light lantern had the following specifications:

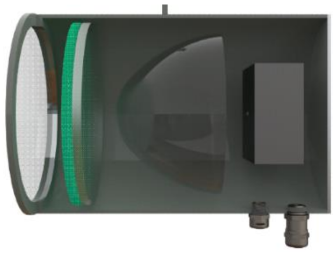
Sustainability goals:

- High luminous efficiency (lumen / watt)
- Robust durable housing for long - term use
- Long-life and replaceable LED light sources



Adaptation possibilities for different light tasks:

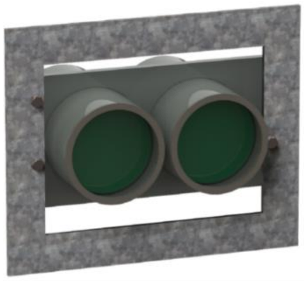
- Light intensity: Adjustment via Modbus interface and mobile programming device
- Light distribution: Adjustment via different spreading lenses
- Different light colours: Colour filters
- Multiple arrangement possibilities of lanterns to increase the luminous intensity and the range

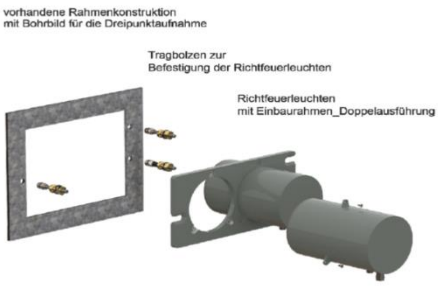


High availability:

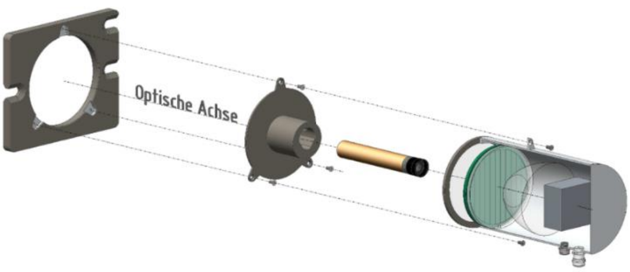
- Optical feedback of the LED function
- Measurement of LED data: Voltage, current, temperature, operating time, etc.
- Output of data via Modbus interface to RCMS systems

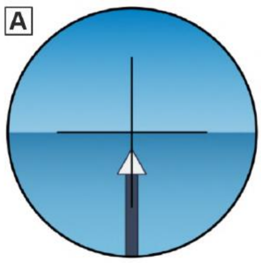
Use of proven mechanical interfaces:

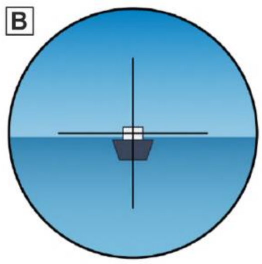




Similar procedure as before for the optical adjustment to the fairway by telescope and ship (A = rear light, B = front light)





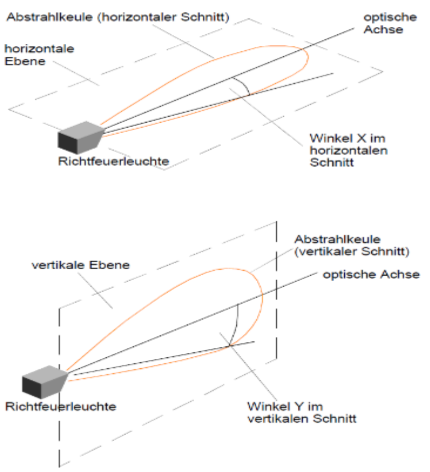


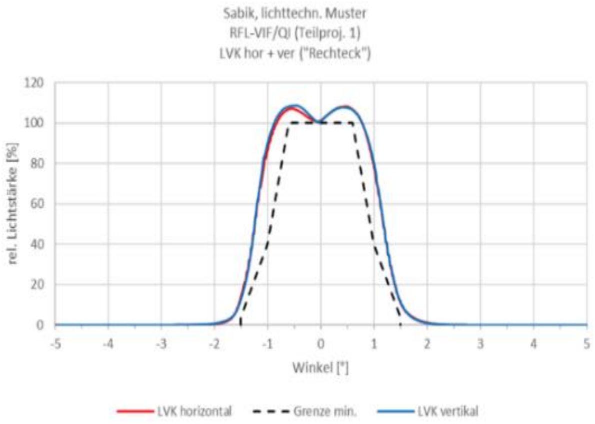
2.4 Important tender criterions regarding sustainability

An important tender criterion was the “Maximum power consumption at 250.000 cd”:

- Max. 10 W were allowed
- The procedure during the bid evaluation was: Lower energy consumption = higher rating
- Contractually agreed were: 8.41 W
- The final product needs only 6.9 W for 250.000 cd

From the light sight, the most leading lights can be powered renewable!





Wide range of light intensities:

- Minimum 155 cd at level 1 and spreading lens
- 13500 cd at level 1 without spreading lens, only 0.48 W
- Maximum 250.000 cd at level 15 without spreading lens, only 6.9 W

Level	Leistung [W] *)	Lichtstärke [cd] *)				
		Streuscheibe				
		ohne	R80T12	R80T16	UE	UA
0	0,21**)	0	0	0	0	0
1	**0,48**	**13 500**	8 850	2 500	930	**155**
2	0,54	16 800	11 000	3 200	1 150	193
3	0,63	20 800	13 700	9 400	1 400	239
4	0,74	25 700	16 900	11 700	1 700	296
5	0,88	31 900	21 000	14 500	2 200	370
6	1,05	39 500	26 000	17 900	2 700	450
7	1,28	49 200	32 300	22 200	3 400	560
8	1,56	60 700	39 900	27 500	4 200	700
9	1,92	75 000	49 400	34 000	5 100	860
10	2,37	93 000	61 600	42 200	6 400	1 070
11	2,93	115 000	76 000	52 700	7 900	1 330
12	3,64	143 000	94 000	64 800	9 800	1 640
13	4,5	177 000	117 000	80 000	12 200	2 000
14	5,6	219 000	144 000	99 000	15 000	2 500
15	**6,9**	**250 000**	178 000	123 000	18 800	3 100

Another sustainability criterion of the tender was the MTBF of the lantern:

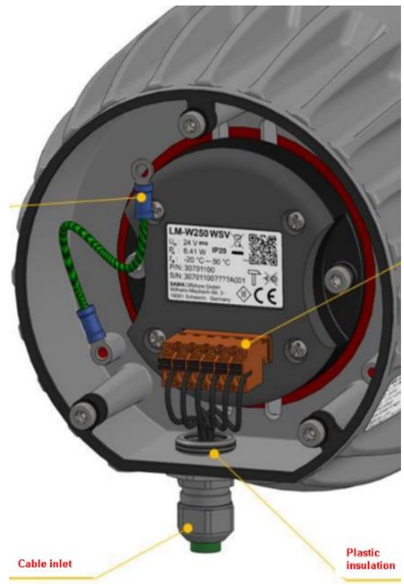
- The minimum tender requirement was: 1.000.000 h
- Contractually agreed and mathematically proven were: 1.750.604 h

2.5 Leading light lanterns - Tender results

The following pictures are showing the final product and the mounting method.

6) The lantern is compatible with the old housing.

7) The adjustment to the fairway is also done as before.



3 PROJECT 3: RCMS FOR LEADING LIGHTS

3.1 Goals and important functions

The goal was to develop a standard leading light control unit for all leading light lines. The energy consumption should be reduced as far as possible. RCMS systems for leading light lines need the following functionalities in particular:

- Shutdown of both lights in case of a defect of one of the two lights (mutual shutdown).
- Flash character synchronization between front- and rear light, max. time delay < 50 ms
- Connection to the central RCMS components

A highly available design for this often requires cable connections. This can be technically complex and expensive:

- If new cables have to be laid, the costs can increase immensely.
- This applies in particular to submarine cables.
- Cables through nature reserves are complicated…

3.2 Evaluation of existing RCMS topology

The current status of the leading light control units was evaluated by site profiles. The site profiles were checked regarding:

- Existing cables between front- and rear lights
- Efforts for new cables between front- and rear lights
- Existing connections to central RCMS components
- Existing energy supply:
  - Public electricity grid / renewable supply?
  - Availability / available power?
- Number and characteristic of infrastructure components

Important results of the site evaluation were:

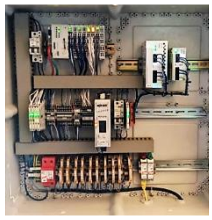
- Many very different cable connections are existing.
- A lot of them are in poor condition and not future proof!

Based on the evaluation, two different types of leading light control units were developed. The individual selection and configuration for each leading light line depends on:

- Economic aspects
- The required light availability
- Sustainability aspects

3.3 Leading light control unit Type 1: Configurable, Multifunction

The configurable multifunction leading light control unit “Type 1”is based on a performant industrial PLC. The power supply is selectable between 230 VAC or 24 VDC. Up to 8 lanterns can be connected.
The synchronization methods for the flash character generator are selectable:

- GNSS: A GNSS receiver can be mounted. He delivers the time by NMEA and the PPS pulse.
- NTP: A common NTP-server delivers the same time to the front- and the rear light control unit.
- Direct by wire: A cable connection between front- and rear light is used for the flash character synchronization.

The communication methods between front- and rear light can be configured as follows:

- None
- Wire (RS485 or Ethernet)
- Radio link

The communication methods to the central RCMS components are also selectable between LAN and mobile radio modem. Further a window heating and a structure illumination can be connected to the control unit. They will be supplied with energy, switched on / off and monitored.

The restrictions of this leading light control unit are:

- The PLC and the periphery components for measurements, communication etc. need approx. 9 W. So it is not well suited for renewable power supplies.
- It needs considerable installation and configuration efforts on site and at the central RCMS components.

3.4 Leading light control unit Type 2: Energy saving, simple

The energy saving leading light control unit “Type 2” is based on RTU 30X1 series from Siemens and uses special WSV – functions. The power supply can be 230 VAC or 24 VDC or 12 VDC. Up to 2 lanterns can be connected. Because of its low overall power consumption (less than 1.5 W) it is well suited for renewable powered lights.

The flash character synchronization between front and rear light is done by a GNSS-Synchronization-Module with a high long-term accurancy (TCXO). An integrated mobile radio interface can be used for the communication to the central RCMS components, LAN is also possible. It has a simple and robust design as well as low configuration efforts.

The restrictions of this leading light control unit are:

- It has less functions than the type 1 control unit and is better suited for smaller leading light lines
- The missing direct communication between front- and rear light may have the following impacts:
    - The shutdown of the whole leading light line in case of a defect of one of the two lights (mutual shutdown) is done by the central RCMS components.
    - So the mutual shutdown may not be as highly available as with a Type 1 control unit.

4 PROJECT 4: RCMS FOR INFRASTRUCTURE COMPONENTS

In particular the large light sites are usually equipped with an extensive infrastructure. For a high light availability the infrastructure components need to be monitored. Standardized monitoring units of 3 sizes have been developed. These are easy to configure (IP address, ASDU from the IEC protocol) and scalable (selection of the infrastructure components on the individual site and the number of messages per infrastructural component). Thus, a very efficient connection to the central RCMS components of the infrastructure monitoring can be achieved. Overvoltage protection of the inputs and an emergency power supply are integrated. For Example, the “small” monitoring unit is equipped with:

- 48 digital inputs
- 8 digital outputs
- 8 analogue inputs
- MODBUS interface

5 PROJECT 6: SHORE LIGHT LANTERNS IN LED TECHNOLOGY

Most shore lights are equipped with low-pressure sodium lamps (SOX), which have been discontinued by the lamp manufacturers. Retrofit solutions are available, but they have the following disadvantages:

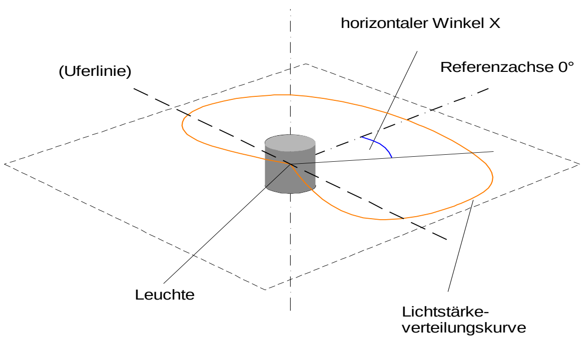
- They do not save as much energy as possible.
- Their long - term quality may be not sufficient.
- Modifications to the lanterns are required, CE conformity is no longer guaranteed.

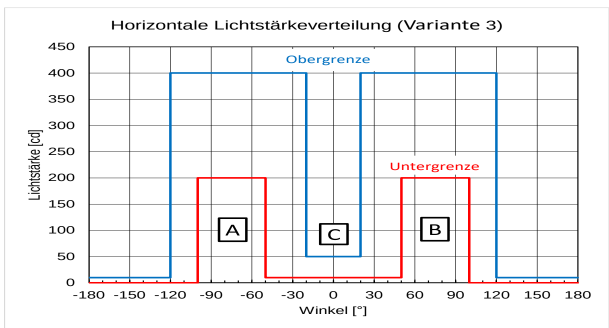
Because of that and for the following sustainability reasons an own development was started:

- Ensure the best energy efficiency
- Long term use based on individual replaceable components (LED - module, current driver, glazing)

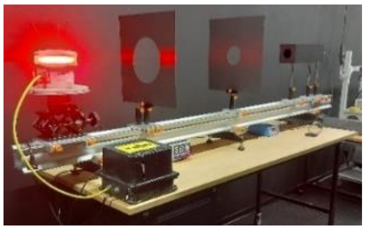
Both, a 230 VAC version and a 24 VDC version were required. Furthermore a retrofitable function monitoring should be implemented.

A very energy - saving light profile was designed: Light emission only where absolutely necessary!



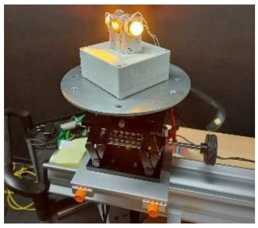


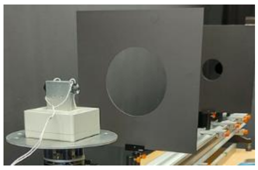
Pre-developments were carried out on the basis of experimental set-ups. In particular, the required electrical power for the intended light profile was determined. Sustainability tender criterions were:



Efficiency of the LED-unit:

- Max. LED power consumption to meet the light profile: 11 W
- Procedure during the bid evaluation: Lower energy consumption = higher rating
- Contractually agreed: 6,3 W

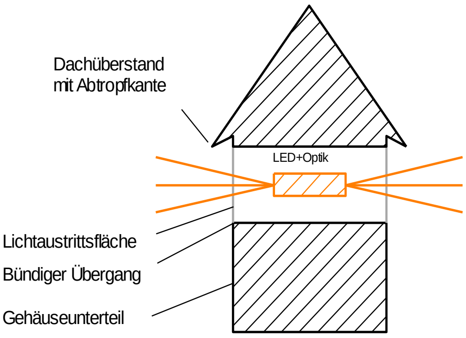


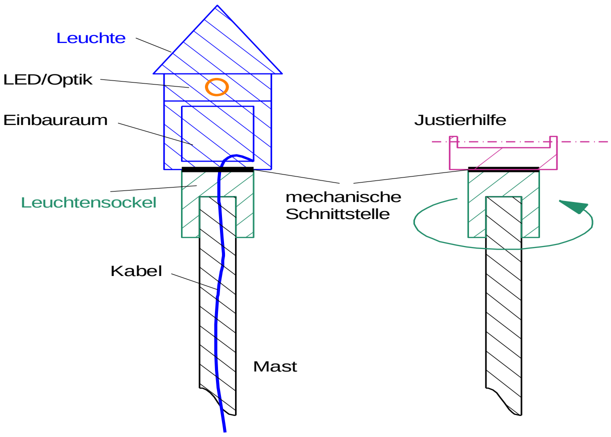


Efficiency of the LED-ballast:

- Ballast efficiency: Minimum 75 %
- Procedure during the bid evaluation: Higher efficiency = higher rating
- Contractually agreed: 85 %

Intended was also the compatibility with proven mechanical interfaces. They were specified in the tender:





The bid evaluation has been finished, the order has been placed. The execution planning will be available soon…

AUTHOR BIOGRAPHY

54 years old, married, one child, education as radio electronics technician, studying telecommunication engineering, worked as development engineer and product manager, since 2003 working at Federal Waterways and Shipping Administration, Germany. Member of the IALA ENG Committee since 2014, Vice Chair of Working Group 2.

Index by Conference paper number (paper no. in parentheses)