MASTER THESIS

Titel der Master Thesis / Title of the Master's Thesis

„Understanding implementation challenges of Early Warning Systems as dynamic decision support for Mission Critical Control Centres like Vessel Traffic Services and Maritime Rescue Coordination Centres targeting disaster risk reduction."

verfasst von / submitted by

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I Abstract

Every single seagoing vessel in international voyages count 2 sunken wracks charted on the ocean's seabed. Officially estimated 372,000 people drowning every year with a significant higher occurrence 97% in developing countries. Vessel accidents are often followed by human and environmental disasters e.g. mass fatalities or huge oil spills.

This work elaborates how organizational change can help Early Warning System (EWS) to become an accepted tactical decision support for mission critical control centres (M3C) like maritime rescue coordination centre (MRCC) and vessel traffic service (VTS).

Over 90% of global transportation go still increasing via the sea. This traffic is handled by app. 75.000 commercial IMO SOLAS vessels engaged in international voyage. Higher commercial pressure and more traffic with old ship and shore technology increases the Incident Crisis Disaster (ICD) accident risk.

IMO history showed unfortunately only real happened disasters pushed safety regulation and technology implementation e.g. EWS into our domain. A lack of coordination and awareness on relations between Regulations Standards and Guidelines (R&G), Human Factors (HF) and Technology and Solutions (TEC&SOL) is rising maritime vulnerability. Today's maritime accidents could proactive be avoided to mitigate the Dynamic Risk Assessment Gap (DRAG) by EWS.

Keywords

IMO, UNISDR, EWS, DSS, M3C, DRR, IALA, VTS, RCC, MRCC, IAMSAR, SAR, ICD, Dynamic Risk Assessment, Human Factors, Change, Innovation, Disaster

Abstract

Auf jedes heutige Berufsschiff der internationalen Handelsmarine kommen 2 als gesunken kartierte Wracks. Offiziell geschätzte 372,000 Menschen mit einer signifikanten 97% Verteilung in Entwicklungsländern ertrinken jedes Jahr. Schiffsunglücke sind gefolgt von Menschlichen wie Umwelttragödien z.b. Massentoten oder großflächigen Öl Katastrophen.

Dieses Papier erarbeitet Aspekte zur Etablierung und Veränderung in Organisationen zur unterstützen der Akzeptanz von Frühwarnsystemen zur taktischen Entscheidung-Hilfen in Einsatzzentralen. Focus der Arbeit sind Maritime Verkehrs- und Rettungs- Leitstellen z.b. Maritime rescue coordination centre (MRCC) und Vessel traffic service (VTS).

Über 90% des globalen Warenverkehrs, immer noch steigend, geht über das Meer. Dieser Transport wird mit den etwa 75.000 IMO SOLAS Handelsschiffen im internationalen Seeverkehr bewerkstelligt.

Höherer Kostendruck mehr Verkehr mit alten Schiffen wie veralteter Küsteninfrastruktur steigern das Umfalls- und Katastrophen- Risiko. Die IMO Geschichte zeigte leider, dass nur real passierte Katastrophen auf See die Sicherheitsstandards und die Technologie z.b. Frühwarnsysteme (EWS) in der maritimen Domäne vorangetrieben haben.

Schwachstellen in der Koordination und dem Bewusstsein der zusammenhänge von Regulationen, Gesetzen, dem menschlichen Faktoren sowie Technologien und Lösungen steigern die Maritime Verwundbarkeit.

Es wird gezeigt wie heutige maritime Unfälle proaktiv verhindert werden könnten, sowie die dynamische Risko- Wahrnehmungslücke mittels Frühwarnsysteme (EWS) vermindert werden kann.

Keywords

Frühwarnsysteme, Einsatzleitzentrale, Marine, Maritime Verkehrszentrale,

II Acknowledgments

Thanks, to my family and individuals, from whom I learned my navigational skills, which have been so useful for my interesting exciting and challenging life's voyage.

Thanks, to my colleges, IMO and IALA workgroups for their work on,

"Safe, secure and efficient shipping on clean oceans"

(UN IMO 2016)

Thanks to Vienna University Professors and study colleges working to,

"Connect and convince to save lives and reduce disaster impacts"

(UN INSDR 2015)

Thanks to my colleges at Frequentis working,

"For a Safer World"

(FREQUENTIS 2019)

Thanks to WOSM which initiated my idealistic passion to stand challenges.

"Scouting is Friendship"

III Foreword

The Goal

The Goal for this work is, to support individuals and organizations, independent of previous experience, within governments, NGO's, the public, competent authorities, control centre organizations, operators and dispatchers including solution providers, for a better understanding the complex overall maritime centre situation and to provide a comprehensive method and tooling to establish and build up resilience, for the protection of human lives and maritime environments by decisions related to Mission Critical Control Centres (M3C) and Early Warning Systems (EWS).

The success of this work is avoided accidents, but avoided accidents are unseen, they never happen, therefor it is invisible – this is the well-known EWS paradox. Risk supersede, and risk acceptance is a sensitive topic of human relations and interest. Similarity is the globalized capitalism trend which also invisible increase our vulnerability public unseen! Therefore, this work needs to use examples on incidents, crisis and disasters to depict its relevance and to underline the risk communication part of it.

Any fault assignment or legal liability is not relevant to this work. Ship masters, navigators and operators do a great job in harsh technical sometime even usability hostile human factors (HF) environment. All public material available was researched and analysed to investigate EWS as improvement for M3C's like VTS's and MRCC's safety and security aspects only.

IV Content & list of tables & figure & acronyms

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Acronyms and Abbreviations

To ease reading and organize the document to the readers convenience this section provides the most important and widely used acronyms and abbreviations at this central point within the document. In the following state-of-the-art chapter, the reader additionally will find a selection of given definition and explanation for the most relevant organizations and technologies also listed below. The control centre entities relevant for this work are from different domains therefore this ontology process is of specific importance. In brackets the context of the topic is mentioned e.g. GMDSS, ITU, IMO, M3C.

AIS	Automatic Identification System (ITU, IMO)
DMC	Disaster Management Cycle
DRAG	Dynamic Risk Assessment Gap
DRC	Disaster Risk Cycle
DRR	UN INSDR - Disaster Risk Reduction
DSC	GMDSS Digital Selective Calling Service (ITU, GMDSS)
DSS	Decision support systems
ENAV	IMO E-Navigation
EWS	UN INSDR - Early Warning Systems (Sendai Framework)
GMDSS	Global Maritime Distress and Safety System, SOLAS /ITU 1988
HF	Human Factors (M3C)
HighA	Competent higher authority (M3C)
IALA	International Association of Lighthouse Authorities
IAMSAR	International Aeronautical and Maritime Search and Rescue (IMO)
ICD	Incident crisis and disaster (M3C)
ICM	ICD Management
ICS	Incident Command System (US, FEMA, NIMS)
ICT	Information and Communication Technologies (ITU)
IHO	International Hydrographic Organization
IMO	UN International Maritime Organization
M3C	Mission Critical Control Centre
MDA	Maritime Domain Awareness
MRCC	SAR - Maritime Rescue and Coordination Centre
R&G	Regulations Standards and Guidelines (M3C)
SAR	International Convention on Maritime Search and Rescue, 1979
SKKM	National Crisis and Disaster Management (AUT, MOI)
SOLAS	IMO International Convention for the Safety of Life at Sea, 1974
TEC&SOL	Technology and Solutions (M3C)
UN	United Nations
UNISDR	(now UNDRR) United Nations Office for Disaster Risk Reduction
VTM	Vessel Traffic Management
VTS	UN-IMO Vessel Traffic Service

1. Chapter: INTRODUCTION

1.1. Section Information

This chapter provides an insight into the objective and goals of this work, the experience that simplicity is needed for successful missions and services the background of the work and underline the urgency of the operated topic by historical triggering example on maritime incidents, crisis, disasters manly ship accidents.

1.2. Introduction on global relevant figures

On every single seagoing vessel in international voyages, there are 2 sunken wracks charted on the ocean's seabed, each one an urgent exhort disaster evidence. 72% of earth surface is water and in 2015 global transportation traffic via the sea is increasing 90% (EU,2015) handled by app. 75.000 commercial IMO SOLAS vessels engaged on an international voyage (Lloyd's, 2019) which is app. half of the globally known 149.324 reported ship wrecks hydrographically charted (Wrecksite EU, 2019) in combination that human factors and errors count for 90-95% of traffic accidents (Smith, 2013) it opens a field for EWS to improve that situation.

A lack of coordination and awareness on relations between Regulations Standards and Guidelines (R&G), Human Factors (HF) and Technology and Solutions (TEC&SOL) is rising maritime vulnerability. It is accelerated by VUCA (volatility, uncertainty, complexity, ambiguity) effects from economic pressure by the digital transportation revolution. Commercial companies enter traditional authority business directly or via PPP's. Today's maritime accidents could proactive be avoided to mitigate the Dynamic Risk Assessment Gap (DRAG). This approach shall help using innovations like EWS in ICT context.

This work developed the Mission Critical Control Centres (M3C) concept to provides a supportive relation-oriented model to evaluate trends and establish innovation in mission and safety critical environment. It is exemplary demonstrated via the UN INSDR EWS as an example for maritime command and control (C2) centres like e.g. VTS, MRCC, CSS, JRCC, VTMIS, SAR centred authority control centres.

During the last decades a delta has been observed, in the global implementation of UN-INSDR Early Warning Systems (EWS) for Disaster Risk Reduction (DRR) and the possibilities modern and future Information and Communication Technologies (ICT) could offer to maritime Mission Critical Control Centres (M3C) e.g. like UN-IMO Vessel Traffic Service (VTS), Maritime Rescue Coordination Centres (MRCC). This innovation gap seems to have a maritime tradition, but also provides a vision in IMO E-Navigation (ENAV) activities to be overcome innovation resistance.

The last century showed, that the only observable systematic, concerning maritime disaster risk reduction (DRR), has been, incident crisis and disaster (ICD's) by major accidents, a reactive driven approach, which finally leaded to Regulations Standards and Guidelines (R&G). e.g. Halifax Disaster, Exxon Valdez, Achille Lauro, Andrea Doria, Eagle Otome, as the last 100 years showed. (Duda, 2017)

Decision support systems (DSS) if even used, only occur during the Disaster Risk Cycle (DRC) phase of prevention/mitigation in form of new (R&G's) mainly for ships, and it took years to be international available via competent higher authority (HighA) e.g. the IMO R&G's. SOLAS address from life rafts, processes to complicate GMDSS radios, lots of entities to increase safer shipping and cleaner oceans.

Rarely used, nor as dynamic a risk oriented modern DSS could be, can it be found in today's M3C's e.g. VTS, MRCC. Common M3C's are mainly working in the Disaster Risk Cycle's (DRC's) response phase. They already support their mission by its own pure existents. By pure Human Factor (HF) driven dynamic risk reduction using certified technologies and solutions (TEC&SOL) without todays ICT innovation possibilities available. This is the case due to today's long M3C system life cycles and other reasons like e.g. R&G, which is researched in that paper.

The introduced M3C concept basically is universal usable, here demonstrated as Maritime example, but also for Public Safety, Air Traffic Management Defence and Public Transport control centre solutions suggested.

2. Chapter: HYPOTHESIS and SCIENTIFIC QUESTION

2.1. Hypothesis background information

The last 20 years working in maritime navigation and entering the field at one of the most innovative times the compulsory carriage requirement of Automatic Identification Systems (AIS) on all SOLAS Vessels from 2001 made me curious. It took a decade before AIS came internationally in pace after the GMDSS DSC innovation in 1988. For 20 years now all commercial vessels are visible due to VHF transponder technology like airplanes with their secondary radar on maritime charts. Nevertheless, AIS even has the collision prevention in its definition and is indeed the great help to the marines but it never came to an onboard use of collision detection systems nor to EWS's based on that technology up to our days. AIS is mainly used manually for the navigation on ships and in VTS, although the automatic detection of a collision of electronically tracked objects with each other or with obstacles is available for decades and even used with radar next to AIS.

This was even more curious and deem to have other reasons than technically ones. The introduction of innovation and the connected change in organisations which can come with it seems to be the subject of this research. This isn't a pure technically subject it is more a transdisciplinary issue with humans' behaviour, several stakeholder interests, and politics as influencing factors.

Time is ready for 20 years already for maritime Early Warning Systems (EWS) innovations and it is heavily needed for Disaster Risk Reduction (DRR). This work is driven by experience and the believe that, most maritime accidents and disasters could have been proactively avoided by proper used knowledge and technology available at the point they occurred in history.

Mr Paul Moller, 1964 pioneer of flying cars did characterize his experience in emerging technology in an aphorism, which match my individual innovation experience for accident prevention since 2001. Moller's Aphorism: "First, it is ridiculous by those ignorant of its potential. Next, it is subverted by those threatened by its potential. Finally, it is considered self-evident." he presented in TED. (Moller, 2004) also Dr. Jacque Fresco the promoter of Resource based economy as global holistic solution. e.g. already in his interview by Larry King (Fresco, 1974) explained beside lot sources until he died with 101 in 2017, several EWS types of systems for traffic management and the positive effects scientific methods will have in comparison to irrational complex political human factors (HF) on nature and society by e.g. solution thinking and accident prevention design.

Rolls-Royce expected remote-controlled cargo ships by 2020, (we have them today) large cargo vessels will navigate the oceans without human crew onboard. Vice President of Innovation Rolls-Royce Marine Oskar Levander said: *"This is happening. It's not if, it's when. The technologies needed to make remote and autonomous ships a reality exist."* at the Autonomous Ship Technology Symposium 2016 in Amsterdam. (Levander, 2016, p1) Currently more than 50 years later in Feb. 2019, an Austrian company FACC starts to build on an industrial scale Autonomous Aerial Vehicle (AAV) based Air Taxi Drones. (FACC, 2018) Mr. Moller and Mr. Fresco saw it coming already decades ahead, as well as the need for EWS to safely catch up with such innovation.

The urge of the EWS also as Independent dynamic Verification and Validation (IV&V) system is not limited to the maritime Mission Critical Control Centre (M3C) domain. If individual traffic e.g. cars enter the off-road 3D airspace of flying, the navigational skills and maritime and aviation innovations in accident prevention EWS need to be available for safety and security also in that new upcoming trend fields and future domains.

Especially the public notice and subjective individual risk awareness will heavily influence the acceptance of those technologies. E.g. The fact that street cars and ships accidents are widely accepted, does not mean that airborne accidents on an individual UAV transport level will face the same tolerance. In a Nutshell: It is probably accepted getting into a common car accident with the street taxi, but no one will accept an infrequent AAV Air-taxi accident. First step of research will be the maritime 2D sector within that work.

Therefore, the subject of this hypothesis needs to be researched to catch up also with knowledge concerning organizational change to enable technically possible solutions for a safer navigation.

2.2. Hypothesis

Today maritime vessel accidents could be mitigated and avoided by dynamic decision support innovation like Early Warning Systems (EWS). A systematic organizational lack of relation management is hindering such innovations. A transdisciplinary approach to visualize and manage cross domain stakeholder relations supports the implementation of innovations like EWS enabling organizational change.

2.3. Scientific questions

The first question already pointing to the core problem which seem to be in the organizational structure of the todays globally governmental organized control centres and its international standardization process which need to be worked out here.

- Q1: What is hindering Mission Critical Control Centre-organizations like Vessel Traffic Services (VTS) and Maritime Rescue Coordination Centres (MRCC) to implement innovations like EWS?

The second question basically points to the feasibility of EWS as appropriate measure for avoiding accidents. It shall be researched if EWS can hold the promising expectations of its accident mitigation. In case of falsification there is no innovation need.

- Q2: Could maritime vessel accidents be mitigated and avoided by today's innovations like EWS?

The third question point to possible solutions to overcome hindering effects if they could be found and sufficient defined.

- Q3: Which approach could be supportive to implement EWS in a cross-domain stakeholder driven environment to sustainably mitigate accidents?

3. Chapter: Review State of the Art

3.1. Definitions and Clarifications

Section information

This definition and clarifications are a selection of the most relevant and important organizations and entities for this work. It shall enable the reader to build up his knowledge and landscape within that paper was written already at the beginning of the core parts and as additional support to the already given acronyms and abbreviation. The specific nature of the work is that it touches several domains therefore the introduction of the most relevant organizations also takes place here. There are organizations like IMO and IHO which share common working groups and domain overlapping aspects and others e.g. UNDRR which are beside the maritime domain. Both are relevant and this work tries to be part of standardised cooperation enabler.

International Maritime Organization (IMO)

"IMO – is a United Nations (UN) agency for safety and security of international shipping and to prevent pollution from ships, it is basically the highest authority providing resolutions and conventions, following summarized as the Regulations Standards and Guidelines (R&G), for international SOLAS vessels and maritime costal countries." (IMO, 2020)

UNISDR (now UNDRR) United Nations Office for Disaster Risk Reduction

"UNDRR (formerly UNISDR) is the United Nations focal point for disaster risk reduction. UNDRR oversees the implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030, supporting countries in its implementation, monitoring and sharing what works in reducing existing risk and preventing the creation of new risk." (UNDRR, 2020)

International Hydrographic Organization (IHO)

"Hydrography provides the basis for all activities which involve the sea. The International Hydrographic Organization works to ensure that all the world's seas, oceans and navigable waters are surveyed and charted, thereby supporting safety of navigation and the protection of the marine environment. It coordinates the activities of

national hydrographic offices and sets standards in order to promote uniformity in nautical charts and documents. It issues survey best practices and provides guidelines to maximize the use of hydrographic information." (IHO, 2020)

IHO – is basically performing the S-100 standardization process which is a great enabler and key for EWS usage in a scalable international manner, see in the explorations of scientific question Q3.

International Association of Lighthouse Authorities (IALA)

"IALA is a non-profit, international technical association. Established in 1957, it gathers together Marine Aids to Navigation authorities, manufacturers, consultants, and, scientific and training institutes from all parts of the world and offers them the opportunity to exchange and compare their experiences and achievements."(IALA, 2020)

IALA – is basically performing supporting a lot of R&G work for IALA but also for the papers which only IMO member states can forward as country to IMO. Therefore, IALA working groups are important entities to lift new and innovative topics e.g. EWS into international recognition and standardization.

Early Warning System (EWS)

Early Warning – basically is a pre-warning in time for a standard warning or alarming. The warning is automatically triggered by a human selected classified dangerous situation. The type of response or action can implicit be part of the EWS by either automated processes or initiating exiting M3C procedures.

EWS today is mainly seen as pure TEC&SOL and hardly addressed by R&G's nor HF due to the VTS Navigation Assistance Service (NAS) warning and alarming is an operator's (VTSO) task therefore a pure human operation.

Vessel Traffic Service (VTS)

"A VTS is a service implemented by a Competent Authority, designed to improve the safety and efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and respond to traffic situations developing in the VTS Area." (IMO A.857(20),1997) (IALA, 2012)

Vessel Traffic Service – is basically a Mission Critical Control Centre (M3C) which command and control ships traffic within predefined coastal and harbour areas. It is demanded by UN IMO SOLAS Chapter V (Safety of Navigation) which states governments may establish VTS when, the traffic volume or degree of risk justifies such services. A VTS centres performing VTM is a potential future operator and user of Early Warning Systems (EWS).

Vessel Traffic Management (VTM)

“Vessel Traffic Management (VTM) is the functional framework of harmonized measures and services to enhance the safety, security and efficiency of shipping and the protection of the marine environment in all navigable waters.“ (IALA, 2012)

VTM - is basically the operation performed in a Mission Critical Control Centre (M3C) by HF and TEC&SOL according to the R&G’s and technical possibility. The availability and use of EWS as a service in VTM is heavily dependent on all three M3C aspects R&G, HF, TEC&SOL.

Maritime Rescue and Coordination Centre (MRCC)

The MRCC – is basically a Mission Critical Control Centre (M3C) which is the operative part for the competent higher authority (HighA) to run the coastal ship-shore services for the Global Maritime Distress and Safety System (GMDSS). It is demanded by UN IMO UNCLOS Article 98 to provide SAR assistance. Important parts are covered by the International Convention on Maritime Search and Rescue, 1979. Countries show various MRCC, GMDSS and SAR implementations from coast guard, navy, telecom- or voluntary organizations. MRCC SAR areas are defined by the IMO SAR Plan and procedure are provided by the ICAO and IMO International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual. The MRCC operation currently is mainly response phase of the Disaster Risk Cycle (DRC). MRCC has a potential use for Early Warning Systems (EWS).

3.2. Review State of the Art Disaster Management and EWS

Section Information

This chapter provides the state of the art in science and domain relevant for this work, also sorted by and with reference to the M3C ontology to support the problem modelling in the exploration and finding chapter. The used ontology the terms are derived from several risk management cycles used to visualize the phases in respect to the maritime and EWS nature of this work.

Disaster Risk Cycle (DRC) and Disaster Management Cycle (DMC)

The Disaster Risk Cycle (DRC) and Disaster Management Cycle (DMC) is a widespread model and concept which exists in several forms adopted to the content needed. It first time appeared already in the seventies, in our days used by e.g. (see ÖNORM S2304, 2018) or the UNDRR GAR Global Assessment Report (see GAR, 2019) a comprehensive review and analysis of disaster risk and risk management every two years published by ISDR.

The DRC is used globally to frame the phases going around management processes of disasters this work also follows the concept. The following version is the adaption and examination for the maritime M3C context and the correlation with relevant maritime R&G papers for the DRC phases and the DRM processes and the discovered underlaying concepts in decision making.

Disaster Management Cycle IALA VTS Symposium Kuala Lumpur (VTS, 2016)

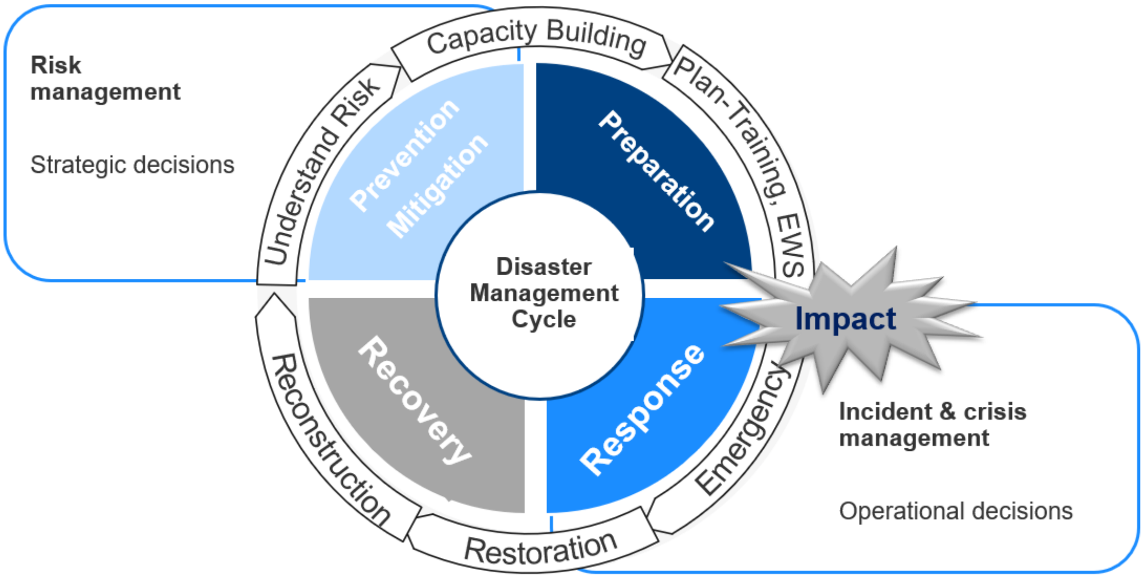

Figure 1 Disaster Risk Cycle (DRC) / Disaster Management Cycle (DMC) (adopted, VTS, 2016)

This figure shows the underlying concepts of ICM and RM in correlation to the DRC phases. There is a separation in Strategic and Operational decisions which is important for EWS.

DRC phases and DRM processes and relations

The Impact leads to an emergency, EWS did may be pre-warn, which is handled in the (blue) Response Phase, on the Disaster Management Cycle. This is the area the M3C is heavily involved in the operations, Coast Guards, VTS and MRCC's main missions are defined and designed for this phase. The Restoration initiated the (gray) Recovery phase which is also handled by the Incident & Crisis Management in more operational manner. The upper part is more Risk Management oriented in a strategic manner initiated by Understanding Risk in the Prevention/Mitigation Phase within the Capacity Building is started. This is the Phase where the R&G activities are mainly done and influenced. Within the following Preparation Phase the Planning, Training and EWS Early Warning System take place to strengthen the resilience to possible impact scenarios. Important to know is that the budgets and R&G for EWS already take place in the Prevention phase therefore this aspect is also examined in the following chapters identified by the R&G category.

The DRC basically is divided into this 4-section following each other clockwise, called

- DRC Prevention/Mitigation phase,

- DRC Preparation phase,
- DRC Response phase and
- DRC Recovery phase,

  and they are following referenced by using the term DRC-Phase Name, to give a clear ontology and domain cross reference.

For this work it also is a valuable category in correlation with the DRC to identify the two areas of

- Risk Management (RM) for strategic decisions, and
- Incident & Crisis Management (ICM) for operational decisions

Furthermore, the sub cluster and bridges between the four main sections have a good value for a deeper understanding of the process of the Disaster Managing Cycle part,

- DMC Understanding Risk process
- DMC Capacity Building process
- DMC Plan-Training process
- DMC Early Warning (EWS) process
- DMC Emergency process
- DMC Restoration process
- DMC Reconstruction process

Due to this works topic a special focus is given on the location of the EWS within the DMC and DRC. The EWS is within the DRC Preparation phase and immediately separated by the Impact and followed by the DMC Emergency process and the DRC Response phase. It is the demarcation line so to say the Alarm, the GMDSS-Distress call itself, every early warning is a specific increase of preparation quality. It differs a lot from the other DMC Plan-Training process due to the EWS is on real hazards or in best case on even developing risks – this is not a trill! Therefore it has a powerful impact for the Incident & crisis management (ICM) but also, which is a new aspect within that work, a great potential for strategic decisions in Risk management (RM) for

DRC Mitigation to influence and address the maritime Dynamic Risk Assessment Gap (DRAG) problem covered in the explorations and findings.

Simply said: Every topic and aspect in EWS and M3C is much easier explained and understood if a DRC categorization and thought is done, it helps a lot not to mix between domains in the first and offers the opportunity to translate between this domain on a meta level. E.g. A Mission Commander which is a role in the ICM could present the long-term financing department the direct benefit of their strategic decision paying full respect to the special circumstance the other department is limited within their phase. To gain a common understanding of Risk beyond ones own's DRC phase.

Existing relevant maritime DRC/DRM documents

The following documents are the assortment discovered and used for the research in that specific aspect here.

The DRC ontology on the assortment of available maritime DRM guidelines (R&G)

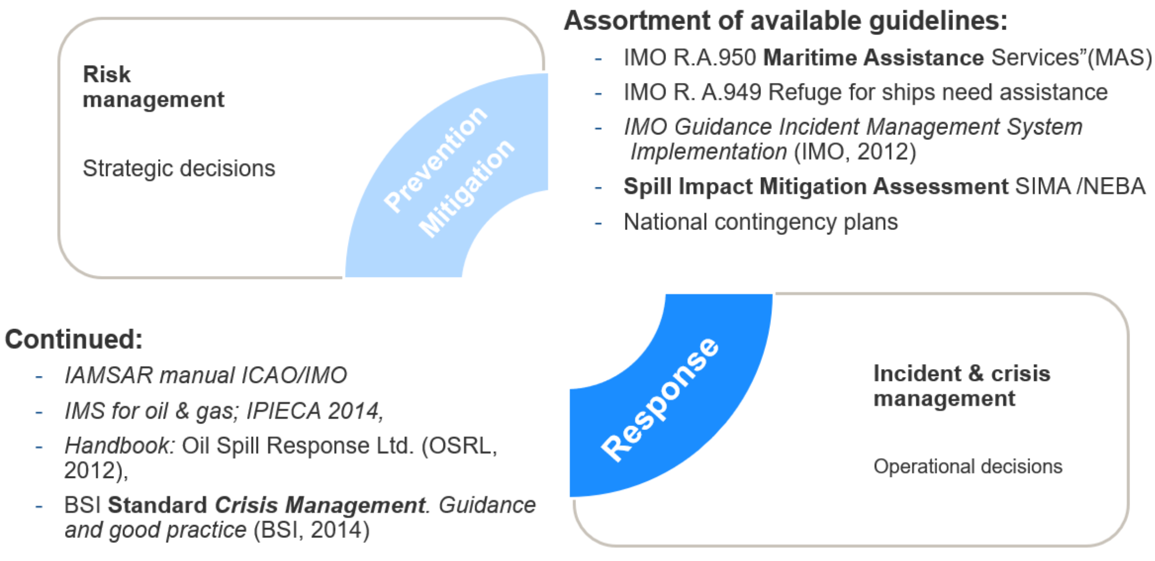

Figure 2 Disaster Management Cycle (DMC) Assortment of available R&G - (adopted, VTS, 2016)

The Figure depicts the areas this existing R&G's are focusing on, also here the domain separation is very obviously. Within maritime there was no overall describing R&G for the DRC nor the DRM.

The list represents the Incident & crisis management (ICM) and Risk management (RM) specific existing R&G's therefore the maritime state of the art.

Risk management (RM)

- IMO R.A.950 Maritime Assistance Services (MAS) (IMO Res.A.950, 2003)
- IMO R. A.949 Refuge for ships need assistance (IMO Res.A.949, 2003)

- IMO Guidance Incident Management System (IMS) Implementation (IMO I581E, 2012)
- Spill Impact Mitigation Assessment SIMA /NEBA (SIMA/NEBA, 2017)

Incident & crisis management (ICM)

- IAMSAR manual ICAO/IMO (IAMSAR, 2008)
- IMS for oil & gas Conference; (IPIECA, 2014),
- Handbook: Oil Spill Response Ltd. (OSRL, 2012),
- BSI Standard Crisis Management. Guidance and good practice (BS 11200, 2014)
- National contingency plans (of the various nations and its maritime versions)

This R&G's are expected as empowerment for efficient emergency response in maritime M3C's in some countries it is a State-of-the-art process in place, and international agreed. e.g. GMDSS, VTS.

Decision support within the DRC

Several Risk or Disaster Cycles are used to explain processes around Incident Crisis and Disaster (ICD)'s. Paying respect to the fact that it is an iterative process, along the disaster cycles several decisions from different stakeholders are made. The earlier made decisions are heavily influencing the upcoming phases and decisions. According the topic decision support the DRC points out two important decisions phases for the M3C control centres role.

First strategic decisions during Prevention/Mitigation Phase which is manly done by Ministries, Governments and International binding legislation e.g. IMO, ITU and second tactical/operational decision during Response Phase. These decisions manly must be done within the VTS, MRCC acting as Mission Critical Control Centre. These decisions are directly related to a specific incident and according their missions.

The M3C Management and the M3C Operators possibly organize their decisions in a scalable IMS Incident Management System - Command and Control (C2) structure, as prior established and trained. Following diagram depicts the standard example form the IPIECA Incident management system for the oil and gas industry - Good practice guidelines for incident management and emergency response personnel. (see IPIECA, 2014)

This tactical phase after an incident as well is organized as a cycled structure and will be run iterative until the level of objectives achievement is established. In this simple case the response to a minor oil spill.

This figure shows ongoing planning cycle after the initial incident response. It needs to be scaled up in case of bigger disasters by a full command and control structure.

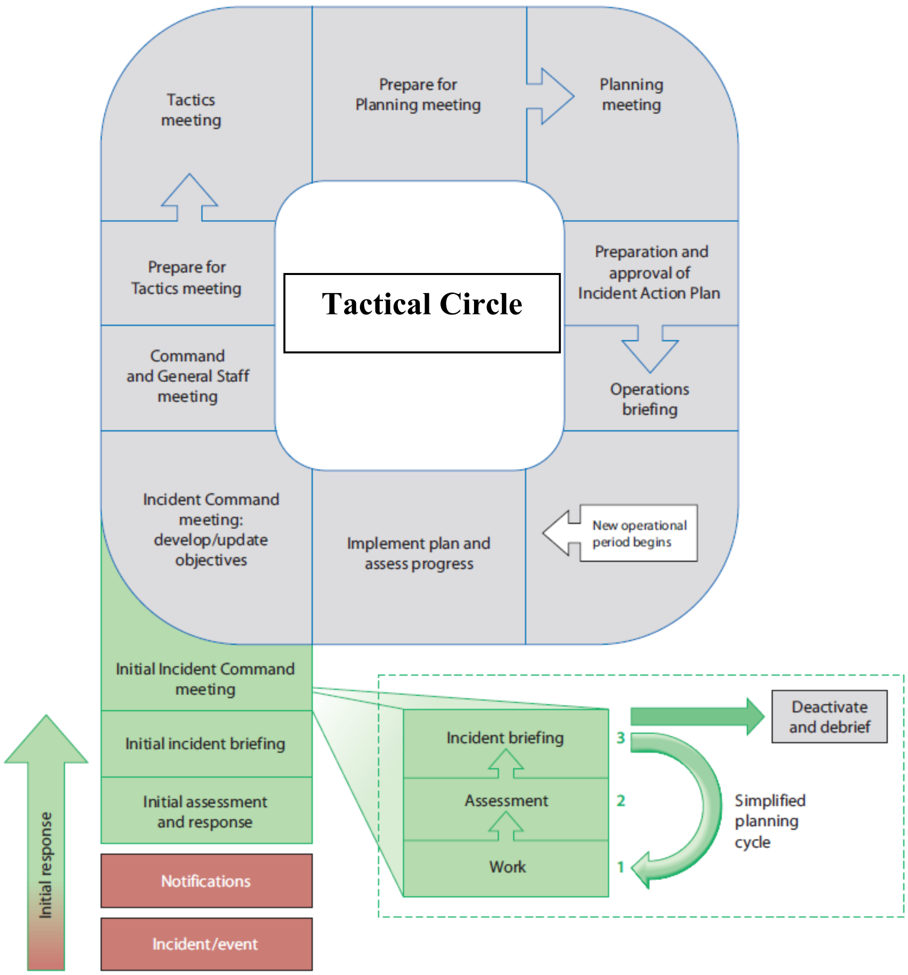

Figure 3 IPIECA IMS - Simplified planning cycle for small, medium or simple incidents

There are also different types of decision supported by Risk Assessment vs. by Situational Awareness based support this is elaborated further in this works at the EWS findings. EWS basically have their place in the disaster cycle itself, they try to totally avoid coming into the Incident cycle of planning. Therefore, several tasks or action are needed outside such a process to finally avoid an accident which was detected by an EWS. Probably the same resources and assets to run an incident management are used and therefor need to be trained towards different procedures than today. It is more work than just installing an EWS. To run it sustainable all assets, need to be EWS procedure trained too. Otherwise an EWS can end up as an accident television warning without alarming and its procedures to avoid.

3.3. Review Early Warning System (EWS) Sate of the art

Section information

Today EWS is very much seen as a technical system. If the aspect is taken into consideration of what shall be done and by whom after the warming it starts to get complex. Due to EWS today focus often to natural hazards which are an immediately threat to a big part of the population the alarming and broad training is the focus found in that context. Floods, tsunamis, earthquake, volcano are the typical hazards and the role of a Mission critical Control centre is more technically in the background in the early phase of such impacts. The disaster will happen anyway, and the main goal is to early warn as many people a possible via media and national alarm horns in combination with previous public training on the best individual mitigation and protective reaction.

Shanghai "EWSs 2003 Highlights" output in the first statement underlines it, an organizational change process is needed to harvest the theoretical and technical EWS advantages:

"While warning systems look great on paper as organization charts or as input-output diagrams, they run into difficulties (bottlenecks) at various locations (nodes and arrows) in the flow of warning preparation to communication to action." (Glanz, 2004 p5)

EWS in the maritime context to avoid vessel accidents which is the focus of this work an important aspect is as already mentioned the change of procedure within the Command and Control structure as this type of EWS has the chance to even avoid some accidents and mitigate them to just nearly misses, but therefore different action is needed.

EWS a promising maritime AIS approaches today

Automatic Identification System (AIS) is a transponder system to track vessels and all their dynamic navigational information, static ship data and voyage related data.

Technically speaking the most promising innovation influencing EWS is the maritime Automatic Identification System (AIS) Class A technology and its global introduction by IMO from 2001-2005 on all SOLAS vessels. In combination with Class B AIS Transponders for leisure craft, M2M Transponders for workboats and fishing vessels and the enrichment of terrestrial AIS Base Station networks by satellite based AIS (SBAIS) and other tracking devices there is a global near real-time tactical traffic image available today. Collison avoidance between by automatic ship-ship communication is an initial core goal of the system since the design phase. (see ITU

R.M.1371, 2001) The detection of a collision still is the navigator's manual task today. AIS did not go that far that next to automatic information the automatic detection of a collision was part of the core system like long existing ARPA Radar features do. This has several reasons which would go too far to discuss it here, but interesting for EWS is that this data is available today and external existing (e.g. ECDIS) and future systems are needed to be expanded with EWS e.g. collision, grounding, anchor watch and other EWS functionalities. Several AIS research was done concerning collision avoidance and other AIS innovation but today not standardized applications and functionality is available in current control centres technical solutions (Tec&Sol).

Papers concerning this AIS research are collected in the Chapter Data and Information source. e.g. AIS Data Analyse for Realistic Ship Traffic Simulation (Xiao, Ale, 2012) comparing the AIS situation in narrow channels in the Netherlands with vast river navigation situation on Yangtze River China. Based on such research EWS for Ship and bridge collision detection could be made. (see Xiao, Ale, 2012 p1) Such work is base to expand single accidents and EWS examples form individual fit to general valid findings. See also the feasibility Danube A Bella Rosa Bridge collision analyse done for this work in next section. Today technically everything needed is known but not used for EWS.

State of the Art traffic tracking macroscopic via AIS without EWS

Following accident example shows a state-of-the-art traffic monitoring of a real AIS tracked accident. The Systems today are according the EU Directive 2002/59/EC and Directive 2009/17/EC Vessel Traffic Monitoring & Information Systems (VTMIS Directive) which was a logical follow up to HAZMAT Directive (93/75/EEC) were hazardous goods information carried on board vessels was first included in 1993. The HAZMAT is also part of the SafeSeaNet a uniform way across Europe facilitating its implementation and operation. (EU Directive 2002/59/EC) Until today there is no EWS part of the VTMIS Directive nor the IMO SOLAS VTS resolution.

The following picture show as result of the VTMIS Directive an VTS display with a zoom level that Belgium, The Netherlands and the United Kingdome Thames river mouth is visible. Blue is the North sea and the English channel with the tense AIS traffic represented as crowded triangles each representing a SOLAS Class A type equipped with a transponder transmitting its position in real time.

The purple dashed lines are the traffic separation schemes (TTS) arranging the inbound and outbound traffic for the port areas and the Channel. Verry busy areas visible here are the port of Amsterdam, Rotterdam, Scheldt River with Antwerp and Oostende. For normal VTS operations of course the zoom level is on national and VTS area level and can be as accurate that a single Ship will be visible. This process within the VTS is a manual task by the operators and it's done manually and selected by a ship acquiring assistance by request or by local regulations for e.g. dangerous cargo, compulsory pilotage. There is no automatic or systematic approach beside the static risk analyse taken in advance deciding to give special attention to any strange vessel behaviour. Of course, if an operator is monitoring a strange behaviour a vessel in dangerous situation by coincident, they have to, and they will act.

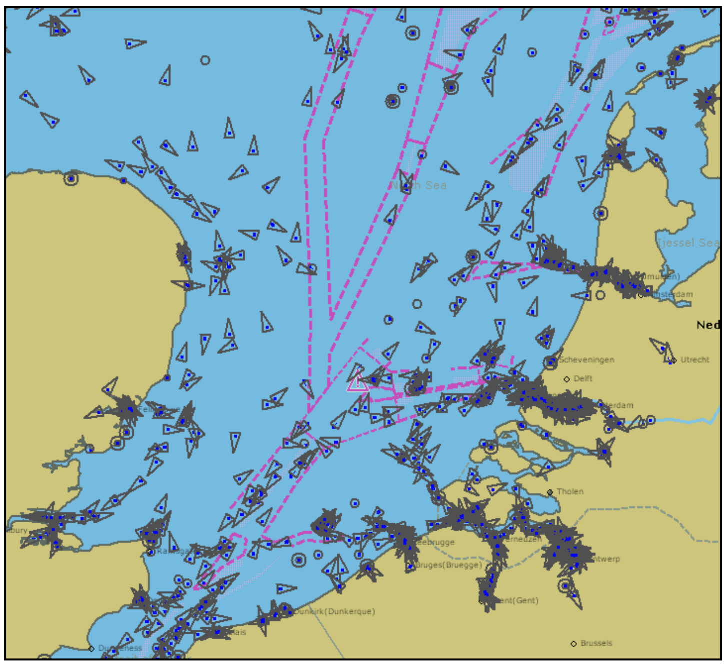

Figure 4 AIS Traffic North Sea and Channel 2007 according VTMIS Directive

Nevertheless, the figure above clearly shows that some single operators even without having the task will not be able to manually monitor all vessels technically available even on national level.

The following picture shows a screen shot of the IALA Risk Management Tool as well as the Risk Management course. The tool itself shows a so-called vessel traffic heat map to depict traffic density which is used to analyse dangerous traffic on historical data.

Figure 5 IALA Risk Management Tool - Model course L1.3

The result of such analyse is as above already explained used to plan and establish VTS areas and design the VTS services and procedures in advance for the systems and the operators. That is the global VTS situation as well as the European VTMIS Directive one today with missing EWS today.

EWS would represent such analogue risk analyse on the fly digital and in Realtime and adopted to the actual vessel traffic situation permeant learning from historical data. Real dangers situations independent from the operator's coincidental attention could be detected.

State of the Art microscopic tracking with missing accident prevention EWS

Following picture shows a real vessel accident tracked with a system according to the VTMIS Directive on the river Danube. The light blue area is the fairway the darker area is the shallow waters, brown is shore area with blue box the river km. The dark area above the river is a bridge with the poles into the riverbed. The blue dots are the tracked positions representing the pathway of the vessel and the Vessel is shaped in black with the Course over Ground (COG) dashed and top true Heading (HDT) screenshotted at the moment the vessel collided with the river bridge pol in the opposite wrong direction of the fairway separation scheme (TSS). The accident happened in very bad weather conditions with heavy raining and bad visibility.

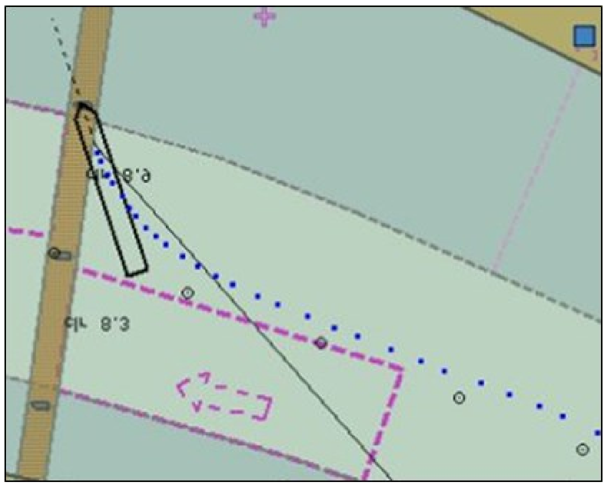

Figure 6 Vessel accident collision with a bridge Systems are according the EU VTMIS Directive

Finally, it is important to say that during this event every system worked correct and involved person acted according the until today valid regulations. EWS as concept is just unknown and not required by any of the stakeholder nor the regulations. Navigation is a pure manual process today even with the availability of the depicted systems and data in place.

The following picture is a time stamped reconstruction of the critical moments of that accident above to give a vision of this work trying to push the boundary of the state of the art.

The blue area with the two selected timestamps 1 and 2 depicts the period and area the vessel did not violate any navigational rule, but the situation already predicated the early stage of the development and dangerous situation. In terms of EWS it could be a prewarning phase especially in respect to the weather situation. The green area with the timestamp 3 and 4 the vessel already found itself in the other direction of the traffic separation scheme. Instead of passing the bridge on the left side it even collided with the bridge pol on the wrong right side of the fairway bringing additional danger to the opposite other vessel traffic.

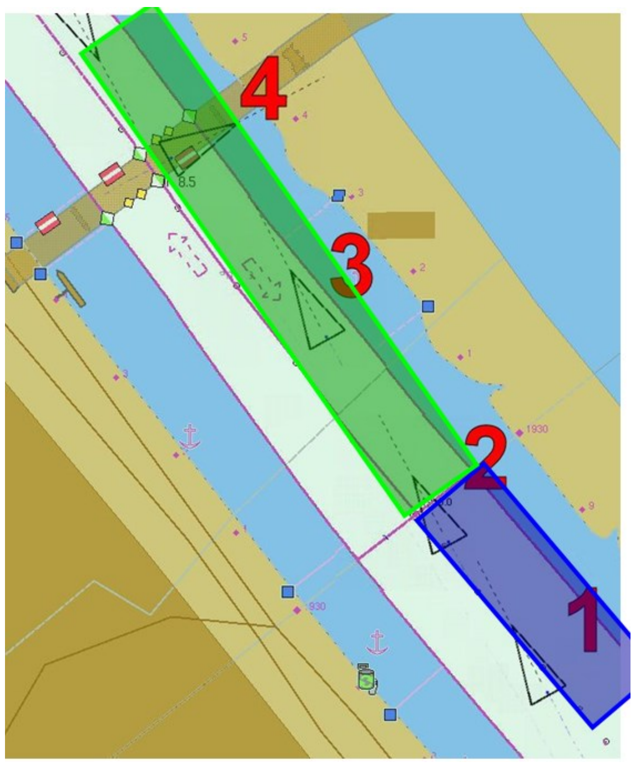

Figure 7 Vessel River Bridge Collision Accident reconstruction

Post processed accident analysis facts: 1) 2:40 min 9,3 knots, 2) 1:45 min 8,6 knots, 3) 1:24 min first speed reduction. 4) 0:0 Impact - Bridge collision and dangerous obstacle for oncoming traffic. Behaviour recognition could bring such events to operators' attention in time and a service in real-time could possibly detect such incident which would be a state of the art EWS for maritime VTS usage. Finally, it is important to realize that state of the art in maritime is the availability of such traffic data but not it is not used in any context with a standardised EWS.

4. Chapter: METHOD

Section Information

This chapter describes the selection and evaluation methods needed to development the M3C model to address this thesis specific scientific questions. The selected methods were needed to cover both maritime sectors SAR coordination in MRCC and traffic control in VTS Vessel Traffic Services. It helped to integrate the sometimes hindering interdomain silo separation, e.g. the different naming for similar things, between SAR and VTS, as well as its practical use on the EWS context. The was no existing approach for the method, it was established only for those work as well as the M3C model which is an outcome of this paper.

Process overview

Following flow chart show the step by step approach of the workflow within the methods used to build the dataset and to systematically research the regulation standards and guidelines according the defined M3C Meta categories. R&G, HF, TEC&SOL.

The most challenging part was to find an answer to the question “Why the EWS innovations is not recognized as expected” first approach was to find it in the Human Factors and psychological area but the literature brought up the find in historical organization and management theories taking effect until our days organizations structures (e.g. The Taylorism).

The following diagram shows the logic steps performed to write this work.

1.
   - Define keywords for the literature review
   - Finding the relevant domains (e.g. SAR, MRCC, VTS, INSDR)
2.
   - Selecting and defining the meta concept (state of the art e.g. DRC/DMC/EWS)
3.
   - Learning the specific used diverting domain languages (e.g. IMO, IALA, EU, SKKM, ICS, Coast Guard, VTS)
4.
   - Creating a dictionary database to identify and translate domain specific ontology (The M3C Glossary with indexing)
5.
   - Filling the database during the research with all relevant (acronyms, abbreviations, glossaries and definitions)
6.
   - Matching the entries with the domains and the selected meta ontologies form DRC, DMC, ICM, RM
7.
   - Creating the maritime ICD Accident database to evaluate the EWS relevance for the domain specific M3C implementations
8.
   - Development of the M3C Model to visualize and evaluate the relations between the EWS relevant M3C stakeholders

METHOD – The Method Vademecum

Basically, the method used and developed for this work is a human based literature research which was expanded and combined with modern data mining software and AI methods, in combination of semantic data analyses of selected relevant human written documents.

Regulation, laws, procedures, scientific papers and press articles of e.g. ICD reports have been used to build up, train and feed a Knowledge Base (KB) a kind of expert system storing complex structured and unstructured information used by a server (cloud) based computer system. This M3C Knowledge Base System (KBS) mainly based on open source components has two main components. (E.g. **Solr** – open source, apache Lucene bases search tool, as also Elasticsearch, and ELK Stack, for querying, indexing, replication and load-balanced, automated failover, recovery, search and navigation with matching capabilities including phrases, wildcards, joins and grouping)

The KB itself represent facts about the domain world and an inference engine with rules and other logic forms to find new facts, find reason about and highlight inconsistencies. The reason and advantage of the chosen method is to expand the limitation of a single human researcher by systematic used ICT systems. The manually defined M3C categories and aspects for the research have been the limitation factor to focus to only evaluation against some dozen selected officially maritime papers, regulations, scientific papers, and accident report could be done. This method enabled that research to evaluate again e.g. all available IMO, IALA documents (several hundred of them available in PDF), all press reports within one entire year (available as Rich Site Summary (RSS) news feeds), all at a time snapshot available Wikipedia pages per language, high level analyses against more than >100.000 historical maritime wrecks (wreck site EU in html) and human unstructured press type described selected 850 maritime accidents reports.

This method was used to optimize the M3C model itself and find evidence and new unexpected new pattern in a badly structured and sorted data landscape but most important to evaluate the effectiveness and efficient of the intended and proposed EWS systems. This ICT based knowledge-based system (KBS) methods are commonly known since the 80ties and expanded as explained abought. (see Hayes-Roth, 1983)

Finally, it needs to be mention that is was helpful to expand traditional heuristic computational methods with KBS and artificial intelligence (AI) software. Nevertheless, the method itself can be used truly successful also manually just a bit more time intensive, to evaluate and bring the important relation aspects in a human understandable format. This is needed for innovations like EWS which triggers organizational change within all control centre areas. The used ICT tools shall not distract from the simple nature of the method but show the potential scale up this method offers and enable scientific evidence for innovation and argumentation for EWS usage in VTS and MRCC's.

5. Chapter: Data and Information Source

DATA AND INFORMATION SOURCE

Various data and information sources were screened for their relevance within that work. The main used fields have been Maritime, Defence, ATM, Public Safety, and Public transport. The M3C categories were established during that process and rescreened for that sources while building the M3C database and its underlaying ontology. The following list are representing the most relevant selected Methods criteria's for M3C and EWS was built on.

Main data source listed:

- The M3C DATABASE (established during this work)
- IMO International Maritime Organization UN
- INSDR - PREVENTION WEB
- IALA, ITU, IEC, WMO
- National Authority e.g. MCA's, CG's, MET/Hydro – Office's
    - E.g. UK-MCA, USCG, AMSA
- UK GOV MAIB Marine Accident Investigation Branch

EWS - Do's and Don'ts Usable Science Report (Glantz, 2004)

(Glantz, et all, EWS-DD, 2004) Usable Science 8: Early Warning Systems: Do's and Don'ts, Report of Workshop, 20−23 October 2003, Shanghai, China, Michael H. Glantz, Convener, National Center for Atmospheric Research

It represents a comprehensive collection of scientific work done for EWS, used to work on the topic EWS and Innovation experience, best practice research related to that field.

Safety Study - USCG VTS Effectiveness Assessment (NTSB, 2016)

Main task of US NTSB is governmental Accident investigation (gov.AI) Primary products of an NTSB investigation are accident reports. This NTSB safety study provides recommendation U.S. Coast Guard, the American Pilots Association, the American Waterways Operators and the RTCM. There have been 21 recommendation most issued to USCG, they have been M3C-EWS analysed for the following chapters.

DMA Danish Maritime Authority as part of the Ministry of Industry AIS Data

Historical AIS data is provided for free to researchers by the DMA Danish Maritime Authority's AIS Data Platform for research, North Sea Server. The data is continuously collected by the danish shore based AIS system (available through dma.dk) it covers vessel movement at coastal waters in Denmark and parts of the north and east sea up to Iceland and Greenland see Figure.

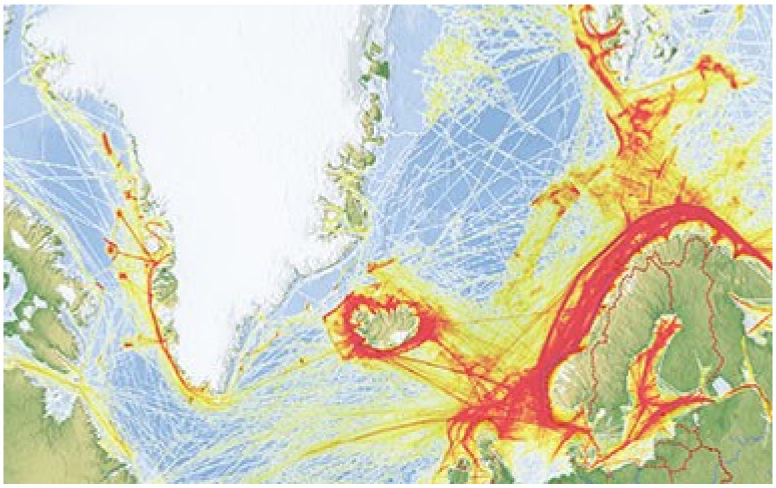

Figure 8 Open historical AIS Data from DMA Danish Maritime Authority Picture (DMA AIS Data,2021)

The AIS Data is available for download via the DMA research website, for life data they charge a fee. For this work and EWS evaluation the historical data was enough.

Example of Datasets from the DMA researcher's online data platform: (See DMA AIS Data, 2021) This data was used to analyse vessel traffic behaviour in context with its usage concerning EWS feasibility.

Safety Differently: Human Factors for a New Era. 2 Ed. (Dekker, HF, 2004)

Safety Differently: Human Factors for a New Era, 2nd Edition, Sidney Dekker, CRC Press, Published June 23, 2014, ISBN 9781482241990 is one of the classics in human factor literature and it was used to analyse the question according the acceptance of EWS by the control centre operators and the design of such EWS implementation for best acceptance.

IMO Literature

IMO provided by 27.05.2019 the data of its international literature consistent of 59 Conventions, Protocols Amendments, Agreements, they have been screened revived according the method described before partly manually and partly software based to all 59 documents within the M3C categories. This work can claim to say the EWS literature was done not only against single selected but to all IMO provides documents due to the developed partly automated process according the used method.

European Maritime Safety Agency (EMSA),

The annual overview of marine casualties and incidents 2018, Incident Crisis and Disaster (ICD) Statistics EMSA Reports retrieved on 21.12.2020 was the high-quality data source for the analyse of what type of accidents the envisioned EWS possibilities could mitigate. The percentage and therefore effectiveness of the EWS could be evaluated with those datasets. E.g. grounding, collision, near misses are easier to detect than fire, sinking or piracy attack.

6. Chapter EXPLORATION, FINDINGS

6.1. ORGANIZATIONS AND STRUCTURES

6.1.1. UNDRR EWS for Maritime Domain Awareness (MDA)

Section information

Within that section a review on UNDRR EWS as concept and the costal and expected missing maritime aspect was done and acknowledged. The progress report on the implementation of the UN plan of action on DRR for resilience from 2019 gives a comprehensive overview on the latest aspects concerning EWS. It sets EWS in relation to the UNDRR context and its reporting participants of the 50 UN partners. The IMO is one of those 50 partners. (UN Plan of Action progress report, 2019) The opposite review will be done with the UN IMO in the next following section to confirm the findings from both sides. IMO is mentioned in the report but did not deliver any input for this report in 2019.

What types of EWS are known to the UNDRR

Types of EWS are only limited by the imagination, ideas what to warn about and the technical feasibility of sensing the risk of interest. Political aspects of different stakeholders' interest and the promotion of solutions gives the topic a complex flavor too. The most comprehensive list can be collected by the review of the already mentioned UN Plan of Action progress report.

Following Table is the collection through the whole report which is the most comprehensive listing of reported EWS available today. The first two entries are DRR initiatives followed by existing EWS implementation and the number of countries of such implementations.

Table 1 Existing EWS and framing initiatives with countries 2019

All known EWS by UNDRR 2019	Subtypes and countries
Climate Risk and Early Warning Systems, (CREWS)	DRR Initiative (53 countries)
International Network for Multi-Hazard Early Warning Systems, (IN-MHEWS)	DRR Initiative (NA)
The Fall Armyworm Monitoring and Early Warning System, (FAMEWS)	EWS existing (3 countries)

Indian Ocean Tsunami Warning and Mitigation System, (TWS)	EWS existing (2 countries)
Regional Drought Early Warning Management System	EWS existing (1 countries)
Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES)	EWS existing (8 countries)
UNECE Industrial Accidents Notification System	EWS existing (15 countries)

(see UN Plan of Action progress report, 2019)

This table depicts the EWS analyze and the interesting fact that there are maritime domain aspects but no EWS in the UNDRR context related to maritime vessel accidents. Tsunami Warning and Mitigation System has a maritime costal aspect but the organizations running such systems today are not under the IMO umbrella as they are in the field of civil protection. The maritime accident EWS envisioned here could be placed under the DRR IN-MHEWS initiative.

IMO's participation in the DRR UN reporting community

IMO as the most important maritime player for safety of navigation was not reporting to the UN Plan of Action 2019 as the list of UN partners below shows.

Table 2 UN entities that submitted 2019 to the progress report

Reporting UN partners according to UN Plan of Action 2019 report						
CTBTO	ITU	UNDRR	UNESCO	UNICEF	UNU	WHO
FAO	UNAIDS	UNECE	UNFCCC	UNOCHA	UNWomen	WMO
ILO	UNDCO	UNEP	UNFPA	UNOHRLLS	UPU	
IOM	UNDP	UNESCAP	UNHabitat	UNOOSA	WFP	

Partner list from (UN Plan of Action progress report, 2019, p12)

Other UN entities next to the missing IMO also relevant on that list is the World Meteorological Organization (WMO) and the International Telecommunication Union (ITU). Both did not respond in their maritime context which would be the IMO/ITU Joint working group on GMDSS or the WMO input for the GMDSS Meteorological Maritime Safety Information. This acknowledges the already expected noninvolvement of IMO in the UNDRR and EWS topic. Next step is to have a look to the involved countries and the type of the reported EWS and its maritime relevance.

EWS and the countries usage

Looking to the countries implementation or benefiting from all different kinds of EWS the following picture can be drawn.

According the report the following can be seen: Todays existing EWS give

"…support to 138 countries, of which 78 benefited from support linked to an established global or regional early warning mechanisms…" (UN Plan of Action progress report, 2019, p19)

It can be derived that at least 138-78= 60 countries actively went into the establishment of an EWS therefore it can be expected that these countries own departments or experts which are familiar with EWS as a real implementation. Dependent on the local types of EWS a gap analyses a concrete maritime innovation e.g. EWS for vessel accidents can be made based on the existing EWS knowledge. Nevertheless, also the other countries benefiting indirectly from EWS probably have organizations and experts already knowing the UNDRR concept of EWS.

The fact that EWS is already implemented or known by some countries can be a supportive awareness in the bottom up process for the establishment of EWS on a national level. Costal state, flag state or port state countries following their national contingency strategies could implement EWS already today also without the UN background. A recognition on the UNDRR side for maritime types of EWS also can be helpful to bring forward the missing IMO strategy concerning EWS. UNDRR has its existing DRR processes like the prevention web which support countries in the implementation of e.g. EWS or other measures for disaster risk reduction. This existing UN processes can be a beneficial reuse also for the countries in international harmonization's of maritime EWSs.

EWS' focus on accidents

EWS in the UNDRR context today has its focus on natural disasters, an exception concerning accidences are mentioned only as industrial accidents e.g. UNECE Industrial Accidents Notification System available in 15 countries.

(see, UN Plan of Action progress report, 2019, p20)

Having a broader look to other maritime aspects the overall Maritime Domain Awareness (MDA) in the UNDRR context the proposals call of the, due to Corona cancelled, Global Risk Forum GRF 8th IDRC Davos 2020, need to be mentioned. The 2019 RISK Award has the topic “Coastal resilience” which of course addresses the MDA, but with a closer look the same picture arises as before. The focus also there is on natural disasters, e.g. island states, global warming, sea level rise, extreme storms, tsunami and erosion than on incidents crisis and disasters due to vessel accidents and related future maritime EWS's.

Next step of this analyses in the following chapter is the vice versa review on the UN IMO and related documents concerning the awareness on EWS as a concept for disaster risk reduction. This double checking needs to be expanded by the review of VTS and MRCC related aspects concerning EWS, as this control centers are expected to be the operational location for EWS implementation not necessary using the same naming for the function behind EWS.

6.1.2. Accidents and Regulation Progress

Section information

Maritime history showed that regulation standards and guideline (R&G) had its biggest progress triggered by accidents. Even some establishments of organizations and control centres origin in devastation accidents as an answer. Therefore, the nature of this disasters very much shaped the nature of this organizations and the regulations. This is important to recognize for organizational change which EWS could bring. Next section gives a brief historical overview with its relevance until today. (Duda, 2017)

More detail information as input for the M3C model with specific description on the mentioned accidents itself can be found in the paper of (Duda, 2017) Scientific Journal of Polish Naval Academy | Volume 211: Issue 4 The Impact of Major Maritime Accidents on the Development of International Regulations Concerning Safety of Navigation and Protection of the Environment. Daniel Duda and Ryszard Wawruch Polish Naval Academy. Such comprehensive details will go fare over the scope to be discussed within this work. Nevertheless, they need to be mentioned because exactly such overall accident description is an input for the M3C model developed within that work. Following information gives a short overview on those topics relevant for this paper.

Historical Background

The whole aspects on ships safety started according to Lloyd's Register in Ewards Lloyd's coffee house in London in 1760, basically by trading with the information on the seaworthiness of the ships of that time. A growing ship register with safety relevant information was the core aspect and is still today. Today several classification societies exist e.g. Det Norske Veritas (DNV) 1864 Oslo, German Lloyd (GL), Bureau Veritas (BV), American Bureau of Shipping (ABS), Registro Italiano Navale (RINA) 1861 and others. (see, IACS, International Association of Classification Societies, 2021) It is well known that the establishment of R&G in international level mainly was driven by disasters therefore it is helpful mention those disasters to understand the nature of the IMO R&G landscape. There are some causes of disasters leading to the todays structure following list can give orientation. Worth to mention in the early days it was the money at risk of the trading and shipping investors which was the reason for the founding of such organizations not the disaster risk reduction itself.

Disasters and Conventions

The origin or influencing factors of the conventions were disasters and lead to today's complex structure needed to be extreme and public recognized. It is interesting to see which factors were big enough to establish or change regulations and what the public focus was at that time. E.g. during wartime the focus was obviously very different.

- Life of passengers and sinking of passenger vessels
    - e.g. 1912 Titanic
    - First SOLAS convention (lifeboats)
    - 1948 Geneva UN established IMO
    - Herald of Free Enterprise 1987 RoRo, capsized
    - Estonia in 1994 RoRo, capsized
- Large Oil Spills
    - MARPOL convention
    - e.g. Amoco Cadiz 1978, grounding France
    - e.g. Exon Valdez 1989, Alaska
- Causes of relevance
    - Collision between ships, icebergs, rocks, islands
    - e.g. Titanic 1912, Costa Concordia 2012
- Fire onboard, cargo explosion, engine room blackouts
    - e.g. Halifax explosion 1917, SS Mont Blanc, Imo collision
    - e.g. Tanker Limburg 2002, bombed
    - International Ship and Port Facility Security Code (ISPS)
- Hurricanes and storms
    - e.g. Oil Tanker Erika 1999, 24year old, broke in the gulf of Biscay
    - Enhanced surveys of tankers (steel corrosion, ballast coating)

- Reason Unknown - is new since 2005
    - There are still unknown cased ship losses today

(see, Duda, 2017)

Reading the accident reports and the regulation EWS as such is not directly or indirectly addressed by any of today's regulations. This probably can be explained by the link between disaster and most obviously direct actions which is influenced and focused by the single triggering event for that regulation. E.g. Titanic and the number of lifeboats in SOLAS vs. missing measures to avoid the iceberg accident as such.

Ratifying IMO members must bring conventions into their own national low for legalization. A flag state, which is the highest authority on the ship, also do not have to accept all conventions therefor IMO provides a matrix with member states and conventions. (IMO, GISIS, 2021) The current status can be accessed by IMO's Global Integrated Shipping Information System (GISIS). Ships only must comply to their flag states ratified conventions when sailing in national waters. The entrance into international ports make all conventions compulsory for the ships. Port State officers can stop any vessel not complying to international accepted conventions. Safety at sea started with classification of ships and still is relevant today headed by the International Association of Classification Societies (IACS).

"Safer and Cleaner Shipping - Dedicated to safe ships and clean seas, IACS makes a unique contribution to maritime safety and regulation through technical support, compliance verification and research and development. More than 90% of the world's cargo carrying tonnage is covered by the classification design, construction and through-life compliance rules and standards set by the twelve Member Societies of IACS." (see, IACS, 2021)

An example for the US can be found in the later detailed discussed US National Transportation Safety Board (NTSB) assessment of the Effectiveness of the US Coast Guard Vessel Traffic Service System, concerning the VTS establishment in the US and the related accidents. It is pointing to exactly the here discussed topic on a national level, accidents are unfortunate needed for progress. Following picture shows the US timeline of desaturase ICD accidents and the establishment of Legislation and VTS.

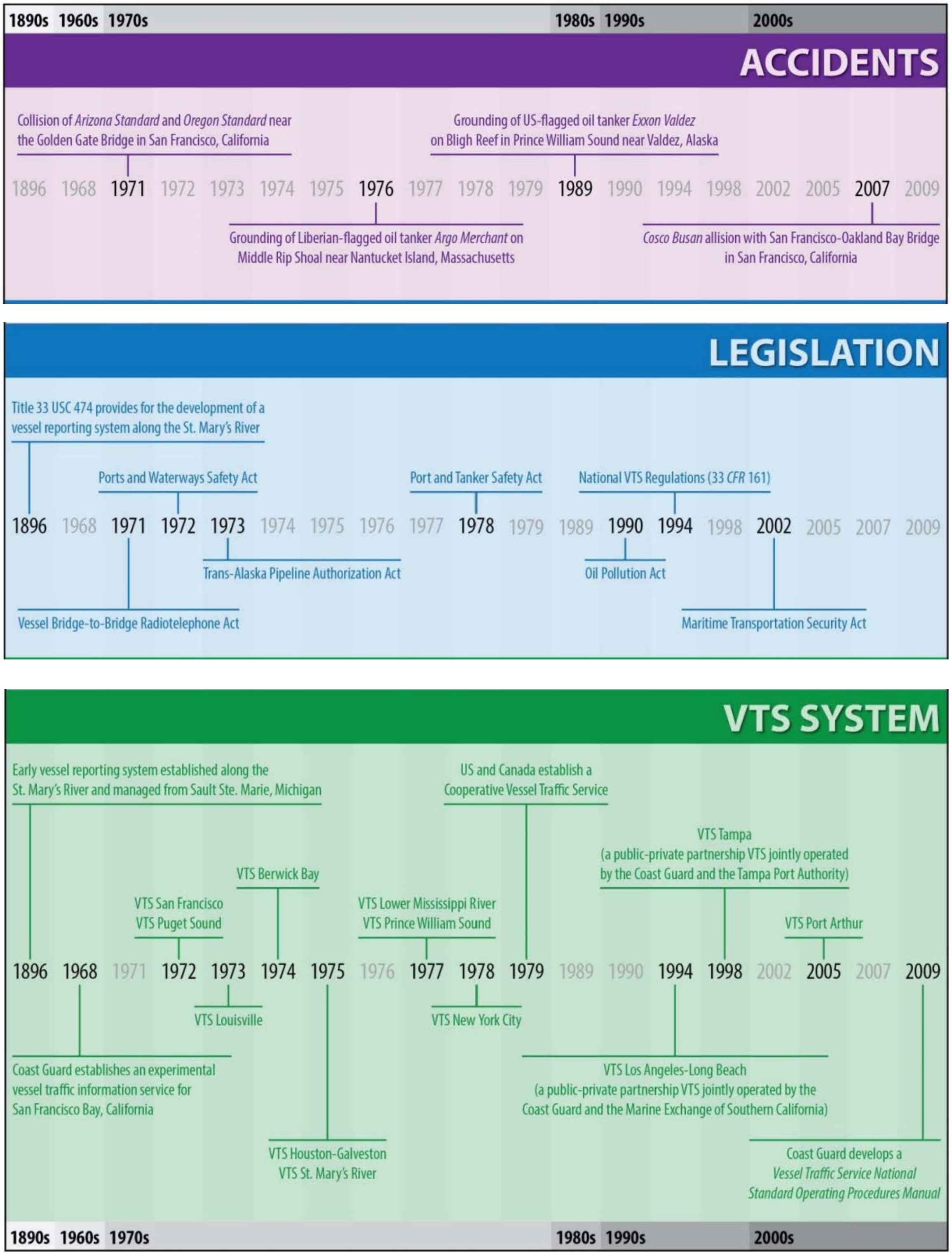

Figure 9 Time line of Coast Guard VTS system development in the United States (1896-2009), highlighting selected accidents, legislation, and VTS system components (picture NTSB, 2016 p.3)

This did not lead to EWS innovations within the maritime domain. Not national nor international. This IACS facts in combination with the UN nature of IMO, addressing all SOLAS vessels via their conventions shows, that it is an essential part needed to progress with maritime EWS innovation. Also, an international political R&G process via UNDRR and IMO member states is needed. Screening the R&G's for this work showed that EWS in the sense of UNDRR EWS would be a very helpful concept to support the IMO conventions goals and objectives but is not part of it today. A simple link between the two UN entities IMO and UNDRR would be very fruitful to reuse a lot of work already existing within the UNDRR concerning EWS. Nevertheless, also the previous described natural disaster focuses of UNDRR EWS need to be expanded.

6.1.3. The structure of Mission Critical Control Centre (M3C)

The hindering aspect of the traditional C4IS structure

Section Information

This section is to briefly draw the leitmotif and logical historical steps which lead to the todays M3C structures in MRCC and VTS and the theory on organizational change which digitalization and EWS will probably bring. The todays official M3C structures are authority bureaucratic oriented to enable a state to execute their legislations, therefore they follow certain rules and theories, and due to maritime nature internationally harmonized. The bureaucratic authority versus commercial aspects selected are overlapping and basically addressing the same thing, just only named different in civil companies vs. military organizations. Therefore, a review from Clausewitz the military strategist over the industry influencing Taylorism via the pioneer of modern management education Peter Drucker is done for M3C within that chapter.

Finally, there are also trends to evolve and innovate the hole C2 concept, which also is considered by analyzing this M3C EWS research.

Command and Control (C2) vs. Management by Results (MBR)

Nearly every authority organization especially military, navy, coast guards, MRCC's but also civil entities like VTS, even companies prevailing ruled by the universally Command and Control C2-Models already for quite some time at least more than a century. Similar structured models are documented and dating back to ancient armies e.g. the Greeks or Roman Legions.

In the 19th century Carl von Clausewitz a Prussian general and military theorist set the base of a lot of modern C2 aspects for M3C already in his main work "On War" in 1832 which are also common in today's company's management. Basic management terms as strategy, planning, tactics including psychology named "moral" in that military days are such principles and dogmas. Analog statements like *"only simplicity succeed in mission"* (SKKM 2006, p13), are already discussed in Clausewitz work in very different words of course. The soldier will forget the orders and only will do what he was trained after the first bullet is fling over his head. This basic knowledge is still present in today's incident, crisis and disaster management (ICM) like in e.g. Austrian SKKM 2006 p.13. or the FEMA's US Incident Command System (ICS). (see Clausewitz, On War, 1832), (see SKKM, RFiK, 2006).

Other pioneers on a more industrial and production view still influencing the C2-models today are Henry Gantt and Frederick Winslow Taylor, developing the so-called scientific management a theory to analyze and synthesizes workflows to improve efficiency and productivity. The use of science to engineer processes including management was primary done end of the 19th century also known as Taylorism named by its founder. (Mitcham 2005, p. 1153), (Taylor, Sci. Mng, 1911).

The following picture shows the basic structure of the Taylorism which is very similar to the Command and Control concepts. It is a pyramid with separate specific silo departments. Like C2 from Gold to Silver to Bronze also the hierarchy and information flow is from top to bottom. The underling paradigm is the same that the subject competency is higher at the top management or strategic gold commando than at the simple worker or soldier. This probably was the case in 1900 but changes over the century.

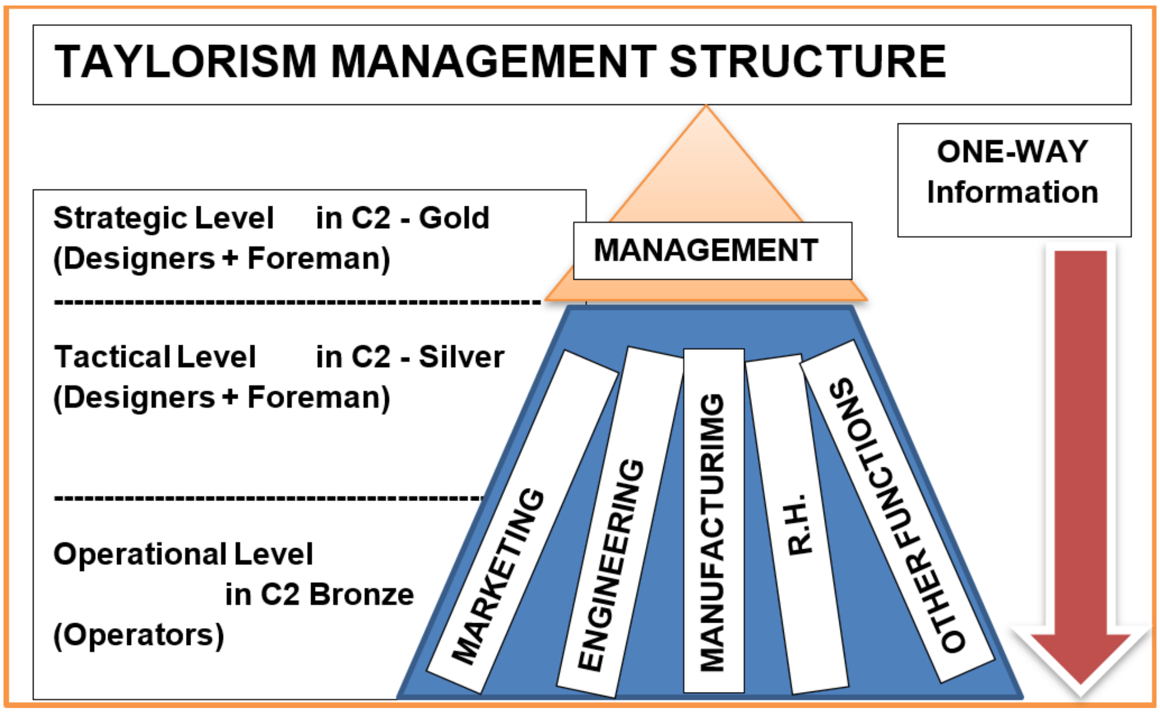

Figure 10 Taylorism Management Structure, adopted from (Zabala, 2019)

There are known and good documented disadvantages at Taylorism influenced systems which is discussed in detail in the next chapter. (Zabala, 2019) Especially in the compatibility to the disaster cycle with its circular information flow even though the basic pyramid structure still influencing todays governmental organizations.

Another interesting aspect in those historical influencing movements is that Mr. Peter Ferdinand Drucker pointing to Mr. Taylor as the pioneering of knowledge management due to Taylors scientific management approach of the systematic knowledge collection to permanently improve processes. (Drucker, 1954) Knowledge management on the other hand is a modern approach like in the Disaster Cycle's a circulation of improvement is the core idea.

Mr. Drucker himself is the pioneer of modern management education and the concept of management by results (MBR) or Management by objectives (MBO). (Drucker, 1954). The results or the objectives in the context of M3C is the mission itself which defines the objective e.g. SAR Search and Rescue or the results like e.g. safe and efficient navigation.

Like the structured background of the various Risk or Disaster management cycles (DMC) or the ICS, SKKM concepts, Peter F. Drucker formulated also:

"To be sure, the fundamental task of management remains the same: to make people capable of joint performance through common goals, common values, the right structure, and the training and development they need to perform and to respond to change."(Drucker, 2007)

This is the citation every modern self-learning organization could be built on, at least an organization which is following the disaster cycle concept of circular respond to change and built back better.

Well known and used until today in project and program management is the Gantt chart named by its originator in 1910. It is the widest known type of control chart designed to show relationship graphically from planned and actual performance. (see Cox et al., Gantt, 1992). Scientific Management principles are used and established in military context since the beginning of the 20th century. Mr Holden address Taylors role and rising scientific management in the U.S. Army and Navy between 1900-1925 in his treatise. (Holden, 2016) Also Yimeng Su addresses Taylors decision not to use early military management structure at his times in factory environment. He expected inefficient and extremely complexity for his idea on specialization of management functions vs. generalists with a variety of quality in parallel. (Su, 2017, p.104.)

Mission Critical Control Centre (M3C) operated or at least are oriented on navy and army structures, they make practical and effective use of main tactics and goals of Scientific Management and Management by Results but not under that name. Single examples are mission briefings where the goals of the missions are presented and afterwards debriefings were the achievements and result are reviewed.

For the motivation in C2 incentives are used by modern military, this incentive is more the skill bonuses for new recruits e.g. Metals of honor, promotion, or similar incentives, other than wage like in commercial companies.

According to American Management Association, growing 80 % in US corporations keep employees under surveillance regularly. The term new digital Taylorism was created for permanent surveillance and constant psychological pressure. (Parenti, 2001). To analyses the introduction of innovation in M3C like e.g.

EWS it is part of this work to consider the human factor (HF). It is needed to take the already mentioned C2 nature of the problem into account, to identify the incentives needed to rise EWS acceptance also on the operators or bronze levels human factor.

Finally, a hindering aspect is within the M3C organizational structure itself

According to the WITORG Guide project to evolve your organizational system by Alex Zabala, for us humans in a group it is normal even natural to be resistant to change. This is due to from our primitive origin, man was organized in groups dealing with the survival. Within those groups of individuals, a hierarchy was necessary to implicitly crate an order and form of governance. When the power is established in a specific way and to certain individuals often, even when change is needed to continue the survival, there is resistance to change by several people within the group. (see Zabala, 2019 p.262)

Everyone can see such effects in all kind of daily teams situations up to political occurrences. E.g. the behavior to act to climatic change.

Others approaches to organize organizations is e.g. Holacracy with decision cycles and rolls without the typical hierarchical structure described before. Holacracy or Sociocracy as nonhierarchical Taylorism systems could be an alternative organizational form to establish innovation in organizations easier in general. To go deeper in the organizational change as such would be too far for this work but interesting enough to mention it as an alternative future to the above described actual C2 structure in M3C.

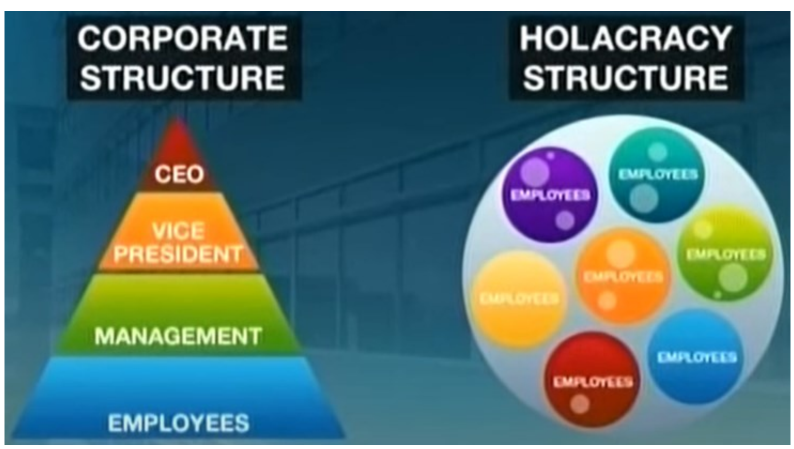

Figure 11 Hierarchy vs. Holacracy organization structure

At least for the civil VTS it could be an alternative for the MRCC or NAVY probably the military context will not allow such fundamental organizational changing.

Nevertheless, the Taylorism itself as it is the identified today existing structure behind those control centers it needs to closer look to the known limitations of the

Taylorism to answer the scientific question on the hindering aspects to EWS innovations.

Taylorism's limitations to identify resistance to change and innovation

"Considering that even today most organizations are structured in a Taylorist way by functional departments, what parts of the… Pyramid does each department assume as their own?" (Zabala, 2019 p.281)

This question as is asked to guide change within such organized organization it sharpens the eye towards the invisible effect the Taylorism has. Translated to the EWS as innovation the effect a new EWS can have need to be analyzed very carefully and with the glasses of every existing department within the VTS MRCC organization. E.g. if the technical department want to establish EWS it does not imply that the operational department has the same enthusiasm may be by internal political reason far beyond the pure EWS topic. It also can simply make them obsolete and workless which can lead to hidden resistance.

"Organizations with Taylorist influence find it difficult to build and communicate/connect a pyramid, since the departments have a partial vision of the organizational system." (Zabala, 2019 p.281)

As EWS will influence several departments within the organization it is not enough to deal with one department with such innovation. At least the EWS project needs to have high level management support next to the detailed impact analyses for each involved department. Finally, to be successful every department need its individual benefit worked out during the EWS project.

Following table are the collection of the known drawbacks of a Taylor influences organization according to the Zabala's Witorg guide:

"Consequences of the Taylorist system - People in any Taylorist organization tend to perceive, to a greater or lesser extent, the following symptoms:

- *Departmental rigidity against change.*
- *Decision-making process not defined when one issue affects two departments at a time.*
- *Bureaucracy.*
- *Lack of compromise.*
- *Endless meetings without efficiency or effectiveness.*
- *Paralysis by analysis.*
- *Politics and particular interests within organizations.*

- *Prioritization of objectives by personal or departmental interests with respect to global objectives.*
- *Lack of transparency between departments.*
- *Lack of direct collaboration between members of different departments."*

(Zabala, 2019 p.244)

This is kind of self-explaining describing experiences a lot of people working in organizations or associations have in their daily work. Nevertheless, researching the task of EWS implementation it is very helpful to have such aspects conscious in mind. Today's operators are not anymore low skilled workers with easy tasks as in Taylor's times. The System of Frederick Taylor of rational work organization was invented when work was less complex than today. High knowledge or training was not required for the workers and the tasks by designer and engineer constructed for the operations were simple to execute. Today a VTS/MRCC operator is a highly skilled navigator often with several years of experience as officer at the Navy or the merchant fleet. They have their own well-educated opinion on the Systems they work with and they are heavily needed to design a functional EWS for the domain there are experts in.

EWS is an innovation which could be a significantly change in operation and does affect more M3C entries, in terms of Taylorism departments. Therefore, several blocking or limiting items from the list can be seen a cumulative effect hindering such innovations like EWS to be introduced in M3C's like MRCC's and VTS.

<u>Competing philosophy on competence hierarchy is the main EWS blocker</u>

The following picture depicts the incompatibility very obviously that the pyramid structure and the cycle are not working together now due to the different information flow.

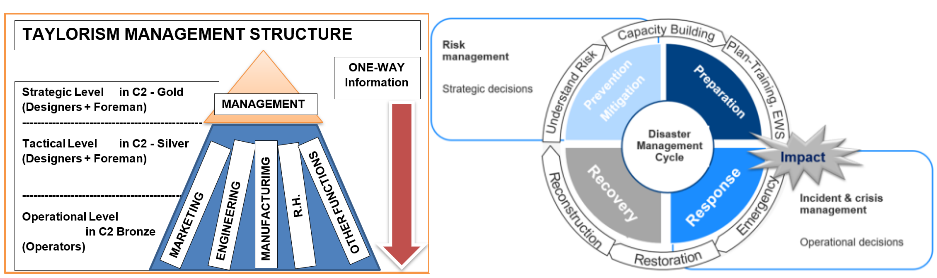

Figure 12 Incompatibility of Taylorism Pyramid vs. Disaster Circle concepts

Taylorism's Pyramid from Strategy top down to Operational is not compatible to the Disaster Risk Cycle and Disaster Management Cycle. The information direction in Taylorism is one-way including the expectation that the competence on the subject is higher in a higher level in the pyramid. In the DRC the information in a cycle and there is no hierarchy in term of subject competence. The Competence in the DRC is by the experts in each field and therefore like described they need to be involved to be successful with EWS independent from organizational structure of the VTS or MRCC.

M3C, Control Centre, Control System, Command & Control C2, C4IS?

Knowing the high lever organization theory, now it is needed to have a closer look to the real existing M3C structures. There are many disambiguation Control definition for several domains. Those domains also overlap sometimes if cooperation is needed. E.g. between civil, police, fire brigade and military in ICM. A control centre in the M3C context is basically a summary of control systems including maritime patrol and human assets, to command manage, invade, record, edit, react or regulate behaviour of other systems mainly the scene defined in the mission including M3C owned assets.

Mission critical in that M3C context is basically a framing of the objectives and the area of responsibility and tasks within the control centre. The mission or sometimes called service is defined by a higher authority's (HighA) legislation and the procedures by the operational organizations (ORG) for the specific missions including defined resources and financing CAPEX/OPEX.

The term Command & Control C2, widely used in defence context refer to the operational part in organization (ORG) operating M3C's. In some context the C2 is used to address the function of a solution of system (TEC&SOL) to support the task of C2 by those technical ICT systems.

In military context these terms are also used in combination, also not clearly defined and dependent to the exact mission but widely used as C4IS. The C2 is expanded by physical systems (TEC&SOL) Computer & Communications and Information System & Sensors or service Intelligence and Surveillance. For the C4ISR even the recognizance is added to this M3C specific Control Centre as part of its mission or ability.

The functions and systems behind that terms are highly relevant to M3C as well in civil context, due to all of them have the objective to increase the Situational Awareness (SA) of the commanders. Intelligence, surveillance and reconnaissance (ISR) is base to build Situational Awareness (SA) in M3C's, it integrates and coordinates the acquisition, processing of various sensors and data.

Key is the relevance, accuracy, timely and coherency of the information to assure intelligence to support operators' activities. Today next to traditional ISR TEC&SOL even intelligence from open source can be used if appropriate, including intelligence on human, signature and measurement intelligence (MASINT), signals intelligence, imagery intelligence, for better decision support (DSS).

C2 a dinosaurian concept ready to be evolved?

I it still a fact that C2 is the most spread concept therefore current reality, and in M3C environment the clocks are slower than in commercial market driven companies. Following some titles are listed dealing with that trend to questioning the C2 concept.

- Command and Control Management Is Failing Business - by Vicky Webster and Martin Webster (Eds.)
- How Command and Control as a Change Leadership Style Causes Transformational Change Efforts to Fail by Dean Anderson and Linda Ackerman Anderson
- Command, control ... and you ultimately fail by Simon Caulkin
- Turn the Ship Around! A True Story of Turning Followers into Leaders
    - Inno-Versity Presents: "Greatness" by David Marquet
    - How I Gave Up Control and Gained Power on a Navy Ship | David Marquet I Freedom at Work Talks

This are Articles and books about a new way to work with people in a control centre environment. Fact is that what is common in commercial companies as modern leadership still is not common in governmental structures like MRCC, VTS or even Navy.

6.2. ACCIDENTS AND EWS FEASIBILITY

6.2.1. Incidents, Crisis, Disasters and Accidents

Accidents are never planned, maybe they are "stage-managed" as history showed by insurance fraud e.g. like M/V Lucona Case (see, ECIL, 1991), or a result of warfare, but incidents, crisis, disasters and accidents commonly are not plannable. Nevertheless, they are hopefully manageable and originated by different reason e.g. natural-, technical- or human factors (HF).

The managing of Incidents, Crisis, Disasters (ICD) is the discipline of Incidents and Crisis Management (ICM) which is the area this work is placed, but it is focusing to another aspect than the traditional focus of ICM which is mainly the response phase of the Disaster Risk Cycle (DRC).

The paper focuses on early warning which basically, if it will work perfect in all aspects of warning, it could avoid all ICM response action within the activities triggered by and started after an impact. But nevertheless, as already said by John Augustus Shedd in *"Salt from My Attic 1928: A ship in harbour is safe, but that is not what ships are built for."* (Shedd, 1928)

Today a lot of vessels are offshore out at sea, as depicted in next figures, also in the meantime knowledge and technologies, has developed it could bring safety aspects on scene at high seas, which formally only known from safe places like harbour areas.

This need to be mentioned here, due to a lot of attention is bound by the single ICD events itself, and still what can be done to harden and make the ships better. The ICD investigation mainly is on accident reasons, cause and response performance, which limits the view of decision makers and distracts from the phase and period the ICD development already could be detected by e.g. an Early Warning System (EWS) of an accident, collision, grounding, nearly miss or even illegal behaviour.

Following picture depicts know positions on maritime wrecks. On every single seagoing vessel in international voyages, there are 2 sunken wracks charted on the ocean's seabed, each one an urgent exhort to disaster evidence.

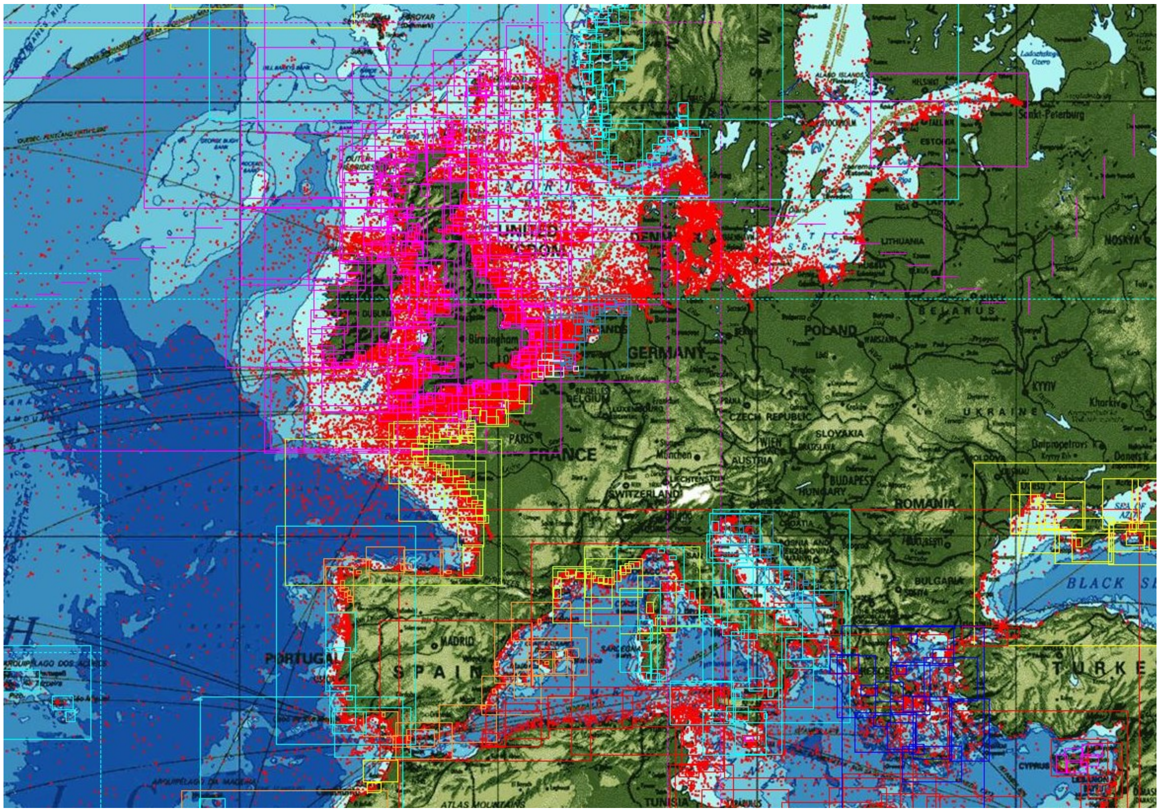

Figure 13 European subset of globally 149.324 hydrographically reported charted wrecks as red dots at the seabed. App. double the number then SOLAS Vessel in todays operation. ((Picture: Wrecksite EU, selected and plotted by 2019-07-23)

As navigational danger and hazard wreck reporting and charting is part of every national hydrographical office at most seagoing nations. This chart aims to underline the evidence of the long documented ICD situation in maritime, which isn't very public known.

Underlaying selected wrecks position data derived from; Croatian Hydrographic Inst., Italian Hydrography, Belgium Hydrography, Dutch Hydrography, SHOM, Greece Hydrography, Mediterranean Hydrography, Kyiv State Hydrographic Inst., British Hydrographic Office, Spanish Hydrographic Inst., Portuguese Hydrographic Inst., Islandic Coastguard, Russia & Black Sea Hydro, Persian Hydrography, -international- United States Hydrographic, South Africa Hydrographic, China Hydrographic, Japan Coast Guard, Philippine Hydrographic Service, Argentina - Servicio Hidro., RAN - Australian Hydro., New Zealand Hydrography, Outer Gabbard - Scheveningen

Accident investigation (AI) are globally established by several governments, this time intensive work mainly results in new Regulations, Standards and Guidelines (R&G) on different aspects to prevent and mitigate ICD consequences, which of course is an important process to gain resilience, but this implicitly needs accidents to trigger and start this process by legal definition. It is commonly known from post safety analyse already set by Herbert William Heinrich in 1931 expanded by Frank E. Bird in a pyramid or triangle depiction and heavily used in safety trainings our days. (Heinrich, 1931)

App. 96% human to 4% technical reasons courses ICD and Accidents. Initiated by app. 300.000 unsafe human circumstances, leads to 3000 small accidents, 300 with medical intervention, 30 serious insures and 1 casually. (see Anderson, et al 2010) Basically, EWS also needs to take this into account by analysing and training its hazard detection algorithm with historical navigation data. E.g. AIS by behaviour recognition (the permanent analyse of todays monitored navigating vessel), need to search or looking for so called nearly misses normally never seen or reported, additional to the analyses of existing accident. This probably also following the same structure app. 300.000 : 3000 : 300 : 30 : 1 disaster as a result. The potential seems high since AIS globally introduced in 2001-2005 next to other sensors produce the basic needed data for that.

The so calls swiss cheese model about accident causation from the late eighties also could be a helpful in evolving EWS for ICM, it depicts layers of cheese as symbolized protection mechanism between hazards and accidents. The symbolic holes in every layer allow a breakthrough of a single hazard. The slices representing every type of measure against the losses. These cheese slices can be e.g. requirements on double hull at oil tankers, safety training of crews also shore based VTS. Following picture shows the metaphor of safety layers with summarizing weakness to lead to the failure. (see Eurocontrol 2006)

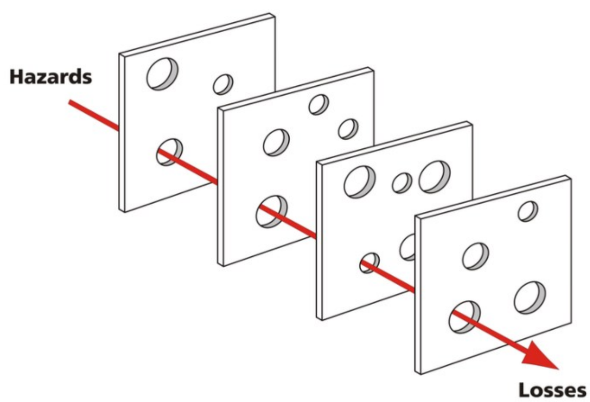

Figure 14 ICD Safety Model “Swiss Cheese” by Dante Orlandella and James T. Reason of the University of Manchester. (Illustration: Davidmack 2014)

Nevertheless, EWS need to address as many of the layers or at least try to identify them and clearly identify the coverage of its selected used layers.

The M3C method later introduced shall be helping to do so in a structured way to balance between R&G, HF and TEC&SOL aspects.

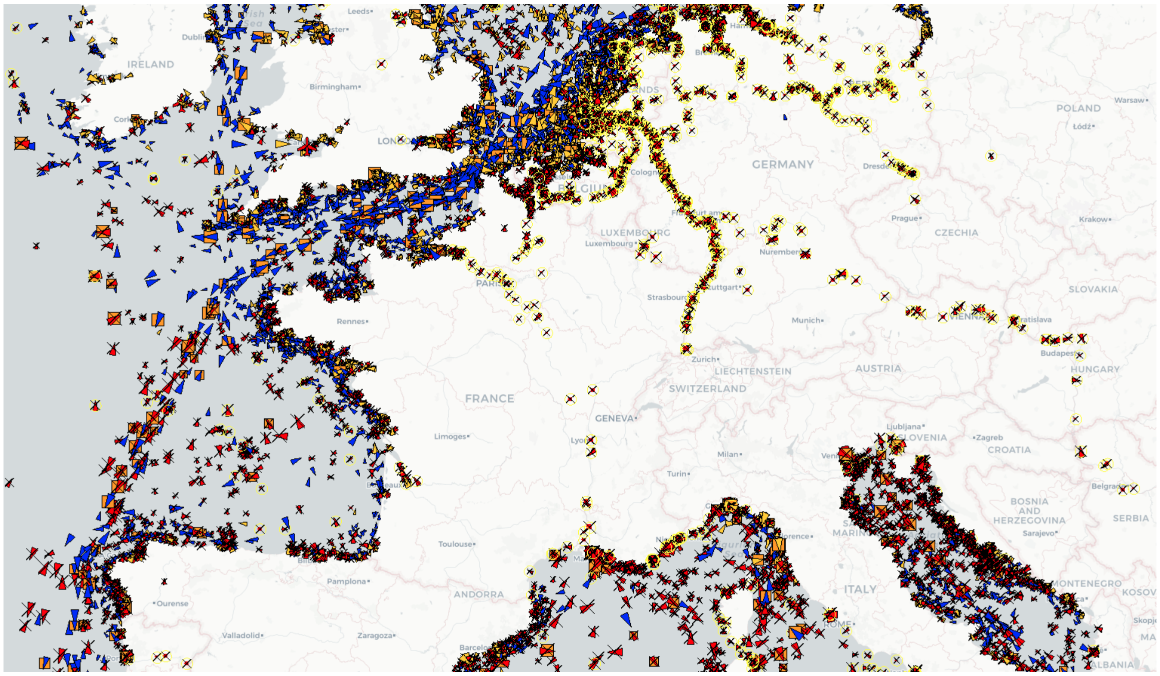

Figure 15 SBAIS based - European live tactical traffic image (TTI) on 2019_0718 UTC 10:10:28 (Picture: 2019 open street map and IHO S57 charts with AIS overly)

The picture shows parts of Europe including North Sea, Atlantic and Mediterranean Sea with satellite based AIS (SBAIS) data of app. 12.000 vessels represented by small triangles in that zoom level in the picture. It is a subset from globally zoom level of app. >100.000 vessels, a combination of tactical traffic Image (TTI) and Strategical Traffic Image (STI) with different position update rates of each object. More details are explained in the TEC&SOL Sensors section at Radar, EO, AIS and LRIT.

Imagine the mentioned ICD situation as accident pyramid or triangle and the swiss cheese model, a single operator or M3C even several M3C's e.g. VTS, MRCC per country could not representable do preventive ICM in today's analogue human context without digital EWS type of decision support systems (DSS). EWS was chosen as example to analyse its ICD feasibility in that area and the circumstances of such innovation implementation and the expected M3C organizational change needed to catch up with TEC&SOL possibilities depicted in the figure and researched later in that paper.

Incident Crisis and Disaster (ICD) handling today a bigger picture

It seems human's need accidents to improve, but why?

In today's process Incident Crisis and Disaster (ICD) accidents unfortunate are needed, to improve or as the UN INDSR propagates to start the process called *"build back better (BBB)"*. (United Nations General Assembly, 2016)

This work presents several EWS aspects to overcome this limitation caused by a todays mainly reactive process for a future's faster and proactive reaction on ICD risks. The underlying background aspects are documented to generalize the findings to be expanded to all innovative aspects which are valuable to be brought into Mission critical Control Centre (M3C) to avoid impacts and mitigate consequences.

EWS needs a comprehensive ICD cause analyses on all, natural-, technical- and human factors (HF) as well as the focus on a todays existing gap between the two periods the preparedness for immediate impact action and the long-term prevention with its political R&G mechanisms. This logical entity will be called and addressed following the M3C Dynamic risk assessment gap (DRAG). This M3C gap includes all aspects of ICD and Accident prevention, which leads beyond the R&G tooling like e.g. offline and paper base risk assessment, chart published traffic regulation, ship classification certification, SOLAS equipment carriage requirements as prevention and tractional response in M3C like VTS, MRCC and similar organizational establishments.

6.2.2. The Dynamic Risk Assessment Gap (DRAG)

The Dynamic Risk Assessment Gap (DRAG) is a term and acronym to address a, within this research observed circumstance in the maritime M3C decision (DSS) context. There is nearly no automatic or in any way ICT based DRM nor EWS based DRM in M3C, VTS, MRCC today. Some indication can be found that CSS use DRA, but due to CSS's military nature, research is limited to unclassified brochures e.g. European Maritime Safety Agency (EMSA) about SafetyNet and the public know involvement of EMSA in MARSUR for FRONTEX. The derived assumption for CSS is based on typical reconnaissance and surveillance mission tasks and the reconnaissance function of the Integrated Maritime Services (IMS) described by EMSA. Automated DRA is heavily needed to handle the amount of military sensor data in a C4ISR especially in surveillance and reconnaissance context.

Why is it easier to sink a Warship with a merchant ship than by Anti-Ship

Missile?

According to Super Sonic Missile. Navy Times, 46, 27 (18 August 1997) a Yakhont, Russian: Яхонт; English: ruby, Anti-Ship Missile (AShM) can travel 860 m/s. That's about 1671 knots vs. most containerships are designed to travel at speeds around 24 knots. Imagine a DRA implemented to risk mitigate a Navy destroyer missile strike technically a simple collision detection. A Missile Detection System, technically also an EWS, would need to detect a potential collision object moving app. 100 times faster than a typical container ship moving at 17 knots in the example ICD below.

Even the 2D vs. 3D aspect and the size and the distance of the two objects are in a very unequal proportion. An additionally, aspect is that the two objects even typically using the same path. The AShM, for being under the radar, is flying close to the sea surface by design to hide and be undetected. In opposite all SOLAS Ship by obligation have AIS and permanently broadcast all navigation, ship static and voyage related data. It also needs to be mentions that Navy ships can be expected to have services available like e.g. COMINT, ELINT, RDF which could deliver EWS relevant sensor data as well.

That leads to the conclusion that it should be significantly easier to detect and avoid a container ship collision that a missile attack.

The following example shall just underline the existence of the maritime Dynamic Risk Assessment Gap - DRAG Problem!

This available intelligence, e.g. used to detect missile attracts on ships, is obviously not for active accident prevention as the ICD event of the USS Fitzgerald and MV ACX Crystal collision in 2017 made evident. No onboard systems, nor Ashore

M3C's as VTS, MRCC, or C4ISR even could provide the developing collision risk to the Officer of the Deck (OOD), ship's responsible for course and manoeuvring who misjudged the course of the Container Ship. (BBC News, 2017)

The following picture is the reconstructed accident bases on AIS Data.

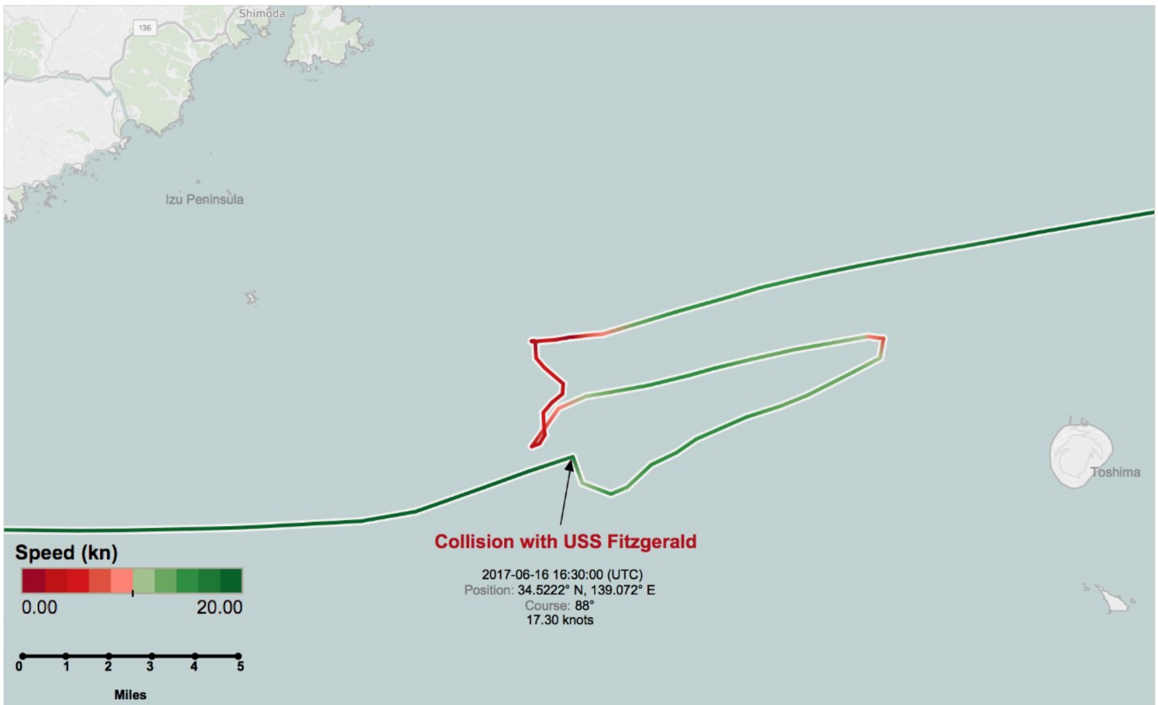

Figure 16 ICD Collision USS Fitzgerald 2017 (Dennis Bratland, CC BY-SA 4.0) "Memorandum for Distribution" (PDF). Office of the Chief of Naval Operations. Department of the Navy. 23 October 2017. Retrieved 9 May 2018.

This picture shall underline the DRAG Problem that the existence of available DRA technology e.g. EWS for AShM detection does not help if the R&G, objective, service or mission is not covering topic the EWS is intended for. Beside that the picture shows an additional challenge in the Maritime Domain Awareness (MDA), the AIS data depicted is only from the SOLAS Vessel ACX Crystal, Warships simply do not use a civil transponder even worse have capacities to spoof and fake AIS (chapter Electronic warfare (EW)), which has to do with a TEC&SOL aspect coming from R&G SOLAS carriage requirements. This is handled later in sensor section and is a very important aspect for EWS coverage.

This example just was chosen due to it depicts the fact of available technology even on the same ship involved is such an accident, does not help to solve the DRAG problem. The fact that it was a Warship or AshM are used to underline the situation but shall not distract from, the civil nature of the problem. This happens of course to less advanced equipped standard vessels as well.

DRAG Basically is a civil topic

Coming back to the civil aspect of calamity abatement, by analysing todays used TEC&SOL and R&G concerning risk management (RM) and dynamic risk assessment (DRA), it was found that mainly the personal analogue human skills, based on subjective, experience measures (the navigational know-how of the dispatcher operator) Human Factor (HF) are used for the dynamic in the risk analyse as part of the DSS. An operator focus is limited to single or only some navigational events, which already depicts the challenge. Technically hundreds of ships are available in the real time tactical traffic Image (TTI) the Situational Awareness (SA) of a Human is very limited. Dynamic Risk Assessment (DRA) is an innovative approach but already know and pushed for some years to be used cross industry. The examples are already stated in the State of the Art chapter with the river vessel bridge collision.

The basic idea of a dynamic approach with real time assessment of hazards is basically already describe. e.g. European Commission – Science for Environmental Policy Risk management:

“a dynamic approach with real-time assessment of new hazards - New research has combined two different techniques for identifying hazards and assessing risks into a single dynamic risk assessment process. The new approach fills a gap in many current risk assessment techniques as it can be applied throughout the lifetime of a process, not just during its design phase, taking into account new information to update risk assessments and calculations systematically.” (Paltrinieri et al., 2013)

US National Transportation Safety Board (NTSB) assessed USCG’s VTS

Another aspect that shows the problem has a well-known civil character is the US Coast Guard (USCG) VTS Situation. The NTSB study was a 4 year’s assessment of the effectiveness of the 12 U.S. Coast Guard Vessel Traffic Service Systems. Following picture shows the location of the 12 VTS in the US. The situation is globally very similar according to IALA but the US due to its free and open information available publish such results while other countries would never let such negative performance evidence go public. This example shall not point to the specific country it is more a great chance to underline the value of EWS for all the VTS in the world were the situation could be expected even worse due to they have much lower budgets for VTS or even no VTS nor a IALA risk analyses in place to establish one.

The following picture shows the location of the USCG VTS centre in Amerika.

Figure 17 US coast guard's 12 VTS in the USA (picture USCG 2021)

The VTS locations in the US have been chosen as a result of a risk analyses and historical accidents in that areas, one trigger of the NTSB study was that the multi billion investments die not lead to a significant decreasing of accidents as expected. The study has details on 14 conclusions and 21 recommendations aiming to reduce the risk of collision, allisions and groundings within the VTS area. Allision is a violent striking (such as in a collision) with a fixed object. From all US reported ICD's 18% occurred inside of a VTS areas resulting between 2010-2014 into two death 179 injuries and more than $69 million in damage to infrastructure, the environment, facilities and the vessels itself. (NTSB, 2016 p.x)

An Assessment of the Effectiveness of the US Coast Guard Vessel Traffic Service System, within that assessment the NTSB examined the VTS to:"

- *"detect and recognize traffic conflicts and other unsafe situations*
- *provide mariners with timely warning of such traffic conflicts and unsafe situations,*
- *control vessel traffic movements in the interest of safety."*

(NTSB, 2016 p. xi)

Following picture shows the VTS New Orleans Mississippi River with the operator positions.

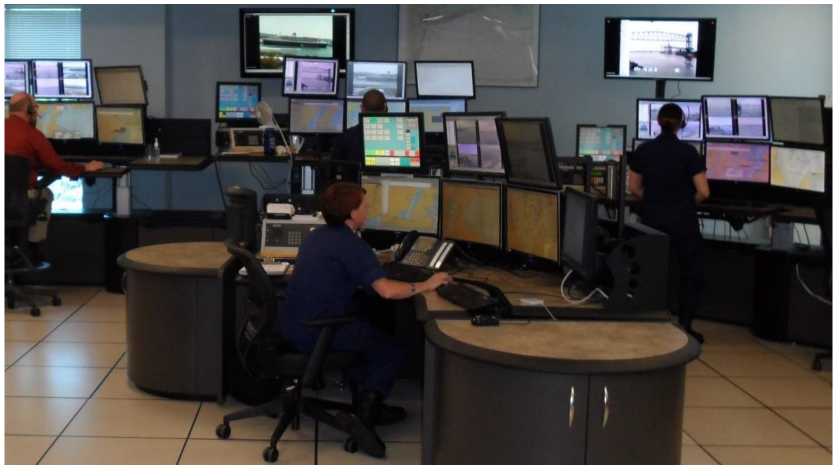

Figure 18 Example of watch floor showing workstations with supervisor and operators

The operators use a VTMIS called the Ports and Waterways Safety System (PAWSS). It integrates radar, AIS data, and other sensor to form a common operational display (COP). The systems are basically the same technical solutions used in Europe which are requested by the already in the State of the Art mentioned EC - VTMIS Directive. So technically there is no difference between the US and Europe even the same products from the same companies are used very often to fulfil the task of, evaluate, collect and disseminate navigation safety information from and to vessels.

Following picture shows the ICD accidents location and numbers for New Orleans VTS. It depicts the 6 geographical locations with 82 incidents for the lower Mississippi river, an area, were next to VTS also pilotage is a compulsory service for classified high risk vessels.

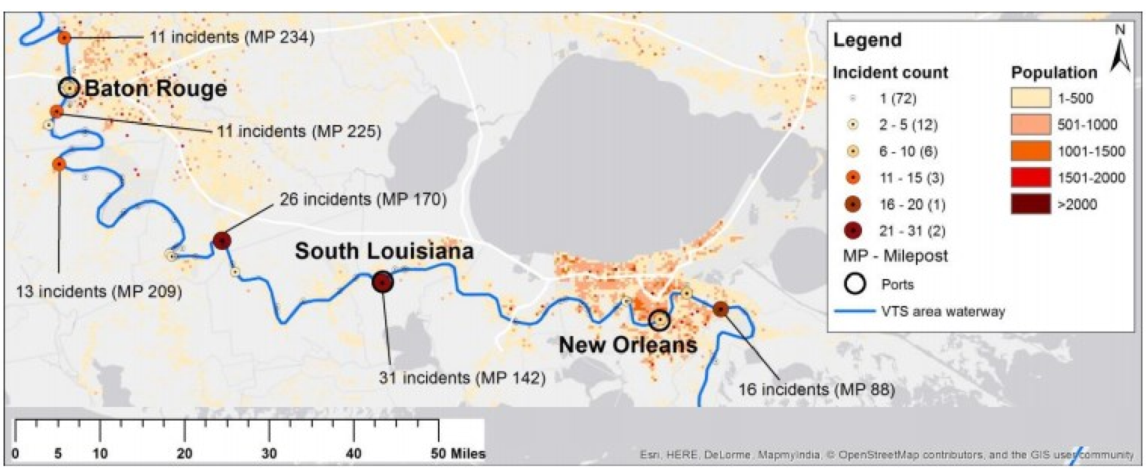

Figure 19 MISLE collision, allision, and grounding incidents 2010-2014 involving VTS

The USCG Marine Information for Safety and Law Enforcement (MISLE) database was used to evaluate maritime activity data and accidents from several sources with that NTSB study (NTSB, 2016 p.8 p.54).

For EWS which does not exist in the current system of all 12 VTS in the US, already before the following NTSB results it can be said that, due to AIS and radar is available and collision, allisions and groundings is the main addressed problem this circumstances are perfect to offer an EWS automated decision support to operators. Also the already described situation that the study was looking to the whole VTS area but only 3 operators and one supervisor shall overlook the whole area points to the mismatching requirement and the limited to the human ability to control manually all the traffic in a VTS area. EWS could multiply the ability of the human limitation already in the setup.

The findings of NTSB: selected points from the report

The following results are selected and cited by its relevance for EWS. Overall summary of the NTSB is that: *“Safety issue areas identified during the study include: (1) variation in the use of Coast Guard VTS authority, (2) inadequate VTS watchstander training and qualification, (3) VTS system limitations, and (4) insufficient safety risk management of VTS areas.”* (NTSB, 2016 p.iii).

Following details are EWS discussed: (NTSB, 2016 pp.58):”

1. *“1. There is widespread variation in the interpretation of US Coast Guard vessel traffic service (VTS) authority within the VTS centers and across the VTS system, which results in inconsistent application of that authority.”* (NTSB, 2016 pp.58)

A national EWS with a basic warning set for all VTS could help in harmonization. E.g. The IMO Convention on the International Regulations for Preventing Collisions at Sea (COLREG) or other international Rules could be the base for all EWS. Local additional needs are of course VTS specific and would need to be configured on top. But it is obvious that if within one organization the interpretation has widespread variation finding a common understanding of EWS setup could be tricky as well.

2. *“2. The US Coast Guard is not using realistic and sufficient vessel traffic service (VTS)simulation training exercises, which would improve competency and proficiency among all watchstanders across the VTS system.”* (NTSB, 2016 pp.58)

And if there are realistic vessel traffic situation available the Ops are deciding every situation individually every time again. Rule based EWS would warn always according the same rules. In case of AI self-learning algorithm EWS behavior recognition even could use daily real time traffic the most realistic situation available to train the AI algorithm.

3. *“3. The quality of on-the-job training (OJT) provided to trainees has been inconsistent because the US Coast Guard does not require a minimum level of vessel traffic service operator work experience or instructor training as a prerequisite for all OJT mentors.“* (NTSB, 2016 pp.58)

That is more a US problem of over aging and that the US flagged ships get less and less to find experienced mariners for the centers. Nevertheless, EWS if it can be seen as automation or digitalization it finally could reduce the people needed to do manual watch standing.

4. *“4. Because the US Coast Guard does not require all of its vessel traffic service (VTS) watch supervisors to achieve a VTS operator qualification or meet a minimum operator work experience requirement prior to selection, the Coast Guard cannot ensure that all of its watch supervisors are proficient in operator knowledge and skills, including detecting and recognizing traffic conflicts and other unsafe situations. “* (NTSB, 2016 pp.58)

EWS could be the warning for at least obvious traffic violations which often lead to more complex danger situation. Referring to the Swiss Cheese safety model. EWS will be one of the protecting layers (slices of cheese) with its own limitation and rest risk.

5. *“5. Because the US Coast Guard gives vessel traffic service watchstanders inconsistent guidance about their responsibility to provide navigational assistance whenever an unsafe situation is detected, watchstanders may be reluctant to provide this service.“* (NTSB, 2016 pp.58)

This is just another Human factor (HF) problem and need to be addressed according the M3C Model introduced in the final section. Nevertheless, also EWS would need a clear definition what would be the role of such a system within the decision support system (DSS) of VTS.

6. *“6. Some US Coast Guard vessel traffic service watchstanders lack confidence applying the navigation rules and regulations when unsafe situations are detected because they do not have sufficient knowledge of or proficiency with the rules and regulations.“* (NTSB, 2016 pp.58)

This is just another Human factor (HF) problem and need to be addressed according the M3C Model introduced in the final section. If the EWS is pointing to an unsafe situation detected of course it will not help if the watchstanders lack confidence applying the navigation rules to the vessels.

7. *“7. The US Coast Guard’s current method of monitoring vessel communications on the bridge-to-bridge radio frequency is inadequate to*

identify unsafe situations in vessel traffic service areas, particularly during periods of low visibility or high traffic volume." (NTSB, 2016 pp.58)

This is just another Human factor (HF) problem, communication on VHF is very limited. To overcome such situation with EWS the detected situations would need to be broadcasted directly to the vessels ECDIS or other warning system. Immediately warn the Ship Master of a situation he is detected in. This is a very controverse topic, but ECDIS onboard anyway could become part of a EWS as they have the potential to perform the same algorithm a shore based VTS can do. The difference and advantage would be that the shore based part of an EWS has more sensor range. E.g. AIS, Radar aso.

8. *"8. Cooperation between pilots and US Coast Guard vessel traffic service (VTS) watchstanders is often adversely affected by a negative perception of VTS expertise because most VTS watchstanders are not licensed mariners with work experience on commercial vessels."* (NTSB, 2016 pp.58)

That's a human factors problem, one is not accepting the others reputation. Pilots organizations are separated from the VTS there are organizational problems as well as addressed in the Taylorism section. See. 6.3.1.

9. *"9. The US Coast Guard is not enforcing its requirement that vessel traffic service (VTS) watchstanders use standardized VTS phrases and message markers from the International Maritime Organization Standard Marine Communication Phrases, which can lead to miscommunication with mariners during safety critical situations."* (NTSB, 2016 pp.58)

That's a human factors problem, if EWS results would be also transmitted over VHF via Text to Speech (TSS) the IMO phrases and message markers can be used.

10. *"10. The US Coast Guard may be limited in its ability to detect the potential for collisions, allisions, and groundings in vessel traffic service (VTS) areas when VTS watchstanders do not have accurate information regarding vessel size, tow size, and tow configuration for VTS users engaged in towing operations."* (NTSB, 2016 pp.58)

Towing information cannot be derived from the systems today available for EWS therefore EWS could not be supportive in that circumstances.

11. *"11. The US Coast Guard is not using its Ports and Waterways Safety Assessment process to conduct continuous risk assessments and mitigate adverse safety trends within Coast Guard vessel traffic service areas."*

Interesting to read furthermore continuous risk assessments is the core of an EWS approach envisioned within that work. Therefore it will improve the NTSB investigated situation. (NTSB, 2016 pp.58)

12. *“12. The US Coast Guard’s collection and quality control of vessel traffic service (VTS) area activity and incident data do not support effective quantitative assessments of risk and safety performance within its VTS areas.”* (NTSB, 2016 pp.58)

Organizational problem not directly related to EWS.

13. *“13. The US Coast Guard’s vessel traffic service (VTS) monthly activity report incident data do not include geographic position information, which prevents the Coast Guard VTS program from using geographic analyses to identify and mitigate locations of high risk in VTS areas.”* (NTSB, 2016 pp.58)

Organizational problem but highly relevant for EWS, due to geographical position is essential to set up geographical oriented alarm and warning for high risk areas. Specially to reduce false alarms for areas which probably are not so dangerous in similar navigational maneuvers.

14. *“14. The US Coast Guard has not widely used regulatory vessel traffic management options, such as routing measures and vessel traffic service (VTS) special areas, to prevent vessel accidents in areas of demonstrated high risk across the VTS system.”*(NTSB, 2016 pp.58)

Regulatory vessel traffic management options like e.g. Traffic separation schemes are essential to manage the safety of traffic. They are also charted in nautical ENC’s, and basically an organizational problem like mounting traffic lights or set up of one-ways. Nevertheless, if regulatory vessel traffic management options are available there are a valid base for an EWS which than can automatically check if vessels are on the right track. Compare with e.g. the Vessel bridge accident in the state-of-the-art section.

6.3. STAKEHOLDER DOMAINS AND CHANCES

Section information

Two main topics were found during that research which could be supportive to implement EWS to sustainable mitigate accidents. First the current R&G standardization process naming the IHO S100 standardization of maritime overall data, which enables a lot of EWS innovation technically to be integrated in a solution TEC&SOL. It eases the technical interfacing and availability of data between different technologies and sensors.

And secondary the here developed M3C Model which structures and visualizes the complex trans domain natures entity of all involved stakeholders in the change process triggered by innovations like EWS. Both aspects are scalable which is important overwhelm national limits in data formats technically as well as in variations of organizational structures and policies in the counties.

6.3.1. The IHO S100 standardization enabling multi hazard EWS

The S100 maritime world

First time in maritime standardization history the IHO S100 expanded with the IALA S200 is a try to cover most of the Maritime Domain Awareness (MDA) topics with one framework standard. Following IHO picture shows the S100 World with selected substandard sorted and depicted by their domain specific occurrence with the MDA.

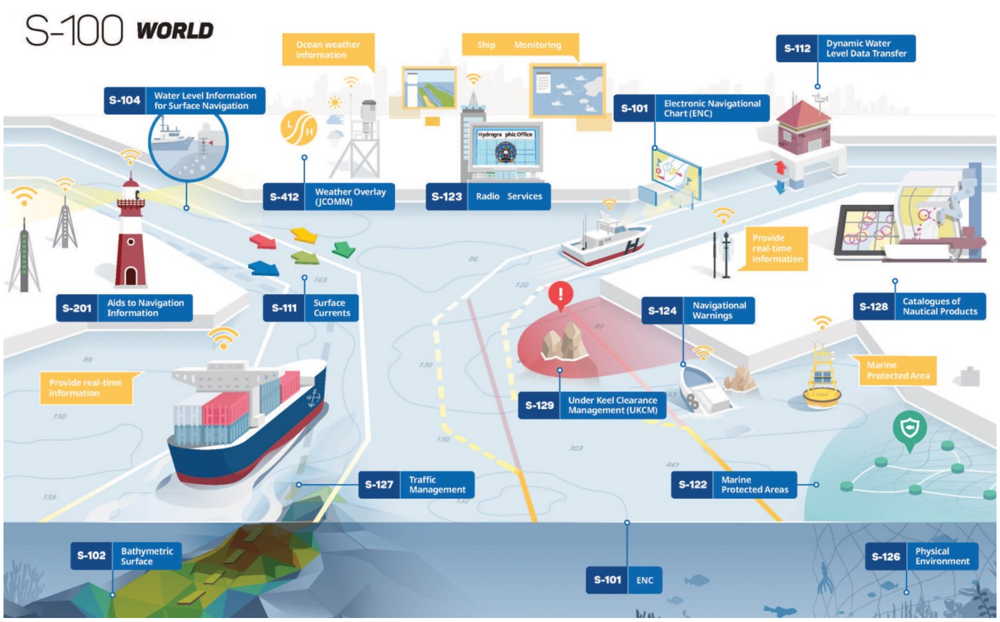

Figure 20 The IHO S100 Maritime Word of standards

The following table shows the comprehensive list of IHO and IALA standards which are a great chance to enable multi-hazard EWS in the maritime field due to the previous domain specific and only proprietary available data now can be accessed via one well defined standard.

Table 3 IHO S-100 and IALA S-200 Standards for MDA

Count	International Hydrographic Organization (IHO) (S-101 to S-199)
1	S-101 Electronic Navigational Chart (ENC)
2	S-102 Bathymetric Surface
3	S-103 Sub-surface Navigation
4	S-104 Water Level Information for Surface Navigation
5	S-111 Surface Currents
6	S-112 Open - (See Decision HSSC9/38)
7	S-121 Maritime Limits and Boundaries
8	S-122 Marine Protected Areas
9	S-123 Marine Radio Services
10	S-124 Navigational Warnings
11	S-125 Marine Navigational Services
12	S-126 Marine Physical Environment
13	S-127 Marine Traffic Management
14	S-128 Catalogue of Nautical Products
15	S-129 Under Keel Clearance Management (UKCM)
16	S-130 Polygonal Demarcations of Global Sea Areas
17	S-131 Marine Harbour Infrastructure
18	S-164 IHO Test Data Sets for S-100 ECDIS
Count	**International Association of Light Authorities (IALA) (S-201 to S-299)**
1	S-201 Aids to Navigation Information
2	S-210 Inter-VTS Exchange Format
3	S-211 Port Call Message Format
4	S-230 Application Specific Messages
5	S-240 DGNSS Station Almanac
6	S-245 eLoran ASF Data
7	S-246 eLoran Station Almanac
8	S-247 Differential eLoran Reference Station Almanac

With such standardization it will be possible to interconnect e.g. a S-122 Marine Protected Areas with an AIS Vessel target and the EWS can find the ship in a protected area. E.g. S-101 Electronic Navigational Chart (ENC) has all the navigational information like fairways river bridges aso. an EWS can compare the Ships AIS Navigational data with the surrounding and detect dangerous grounding situations. Another example would be the S-210 Inter-VTS Exchange Format which could be used to exchange data from EWS detections with sensors from one VTS to other S-210 compliant VTS or MRCC or any other compatible system even the ship's bridges ECDIS system aboard. Adding e.g. the Weather Joint Technical Commission for Oceanography and Marine Meteorology (WMO/IOC JCOMM) (S-411 to S412) S-411 JCOMM Ice Information and S-413 Weather and Wave Conditions EWS could protect ships in collision risk with icebergs or prevent accidents in combination with weather related issues. Like the Ship bridge collision in bad weather example given in the chapter state of the art.

Today the first implementation are like layers on display systems nevertheless, an EWS could start as an Layer with comprehensive backend services doing the multi hazard risk analyse calculations centralized and provide the result may be in a future S-100 standard e.g. future "S-179" EWS Early Warning System.

6.3.2. The Mission Critical Control Centre (M3C) Model

A Mission Critical Control Centre (M3C) simplicity vademecum shows the M3C areas of interest can be categorized by the three main blocks Regulation, Standards & Guidelines (R&G), Human Factor (HF), and Technology & Solution (TEC&SOL). All those three areas are affected and need to be handled to implement successful innovation. Innovation often also needs an organizational change process effecting all three areas.

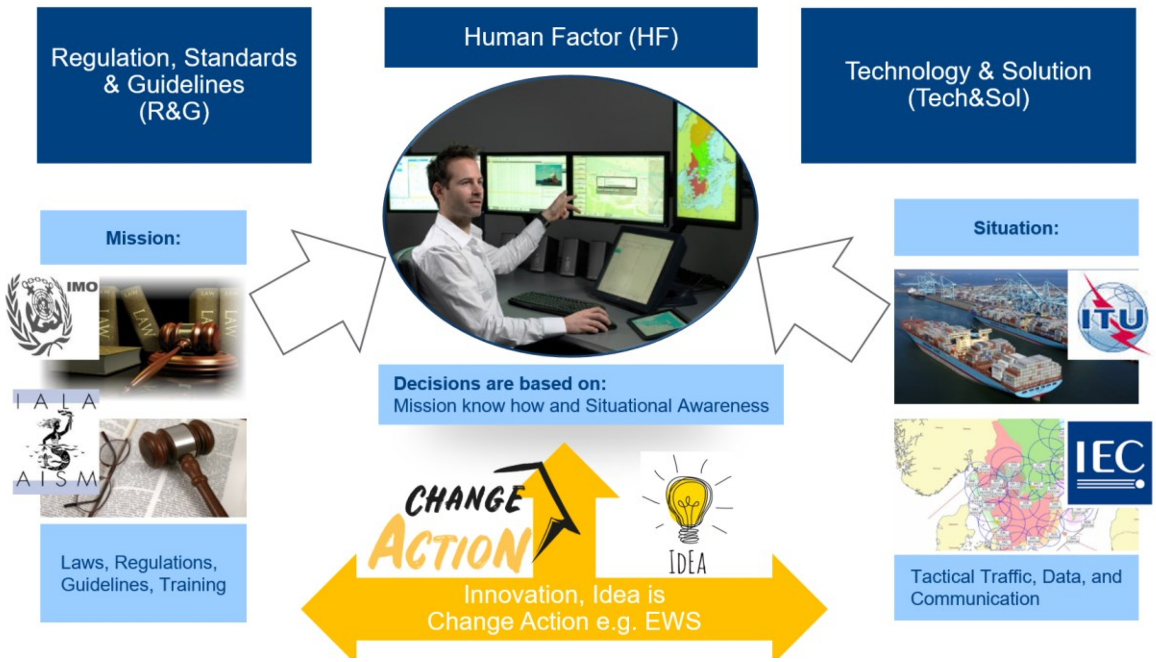

Figure 21 M3C Triangle Blocks in Control Centre reality. simplicity vademecum (2019)

Obviously in M3C VTS or MRCC

The centre of the depicted M3C concept is the operators, an operator often is wearing a uniform with tasks like information gathering, interpretation, decision making, and communication based on individual skills and situational awareness. Following the M3C Model this area is identified as the M3C Human Factor (HF).

In the M3C there is an ICT solution, the operator is placed in front of displays, computers, charts, with mouse and keyboard and communication equipment. Following the M3C Model this area is identified as the M3C Technology & Solution (TEC&SOL).

Behind, beside the operator their missions, sometimes visible on the table, on shelfs in lockers or hanging on the wall, there are navigation books, national and international regulations, laws, standards and guidelines, code of practice and training manuals, vademecums, references of honour and medals. Following the M3C Model it is identified as the M3C Regulations Standards & Guidelines (R&G).

Innovation, Ideas and Change

EWS as Innovation obviously is expected to bring new ways of working and change to this world. Change often goes along with the operators hope and fear and the management of that change increase sustainability of the change an innovation like e.g. EWS contains big potential but also can cause suspicion. As already worked out in the previous answers often only disasters have been the trigger for innovations and new regulations or innovative regulation changes.

M3C support for successful innovations

The initial input could be any idea, a trend, a threat, innovation, Risk towards the M3C, followed by the evaluation according the M3C models systematic. The most official way would be a standardised Risk assessment may be even using the already in State of the Art introduced IALA Risk assessment tools.

Expected result is a comprehensive aspects list to be prepared going into the overall implementation process with best resilience and reduced vulnerability against identified or hidden challenges within the three M3C areas.

The core of the M3C model enables simple and easy communication to all command levels and to receive acceptance for the innovation. Furthermore, the M3C model can be used in building more complex detailed decompositions following the same simple concept levels. The next picture shows a simple 3 entities HF, R&G, TEC&SOL as a triangle decomposition.

The M3C concept and used ontology

The M3C concept involves interaction of processes, technology and the responsible people for using or managing them. First the level of detail needed to be defined, the EWS analyse showed that two levels were needed. One on the control centre itself on Situational Awareness (SA), another for the full maritime domain awareness (MDA) including the M3C environment.

M3C Triangle

The M3C was divided into three entities and areas represented by the dots and organized as the M3C Triangle to easy identify this level of view on the system.

These main categories offered a simple way to sort all upcoming topics to one of them and provide the ability to visualize and analyse the relation between those elements towards its neighbour.

The following schema depicts the M3C ontology.

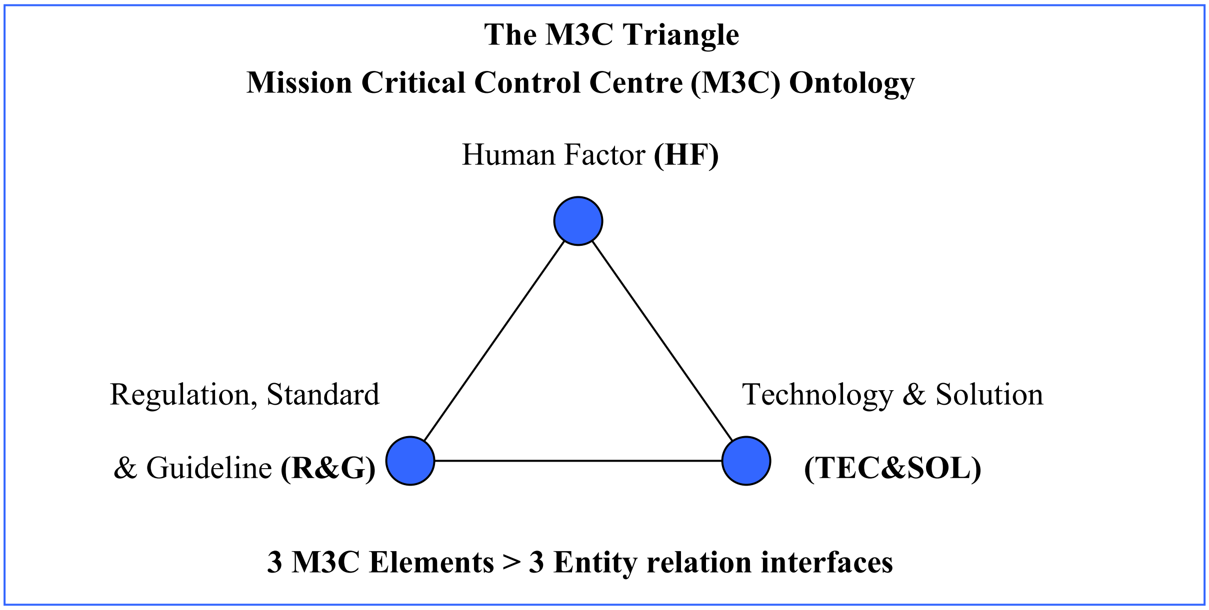

Figure 22 The M3C Triangle

Following figure depicts the relations represented by arrows. With three entities there are only three relation between everybody. It looks simply but nevertheless it already has nine steps to work through to describe a model like this. The three chosen entities and two relations which result in nine information blocks needed. E.g. For HF this would be the definition of the HF itself and then the relation from HF to R&G in expectation, explanation, financing, commanding aso. e.g. mathematic provides several ways to describe relations e.g. order pairs (x,y), mapping input output, table (intersection table), graphing (like on an x/y axis).

In praxis this is that simple than a centre procedure (R&G) exactly defines the language, phrases and wording e.g. SECURITE the operator (HF) need to use by shore ship communication. Another one is Training Certificates (R&G) e.g. on Radar Know Course the operator is supposed to positively attend. Therefore, the R&G side need to provide such courses and the operators (HF) need to consume and built up that knowledge. Similar with e.g. Requirements which may come from (R&G) or (HF) and need to be fulfilled by the Situational Awareness or communication systems (TEC&SOL).

The following schema depicts the M3C ontologies relations.

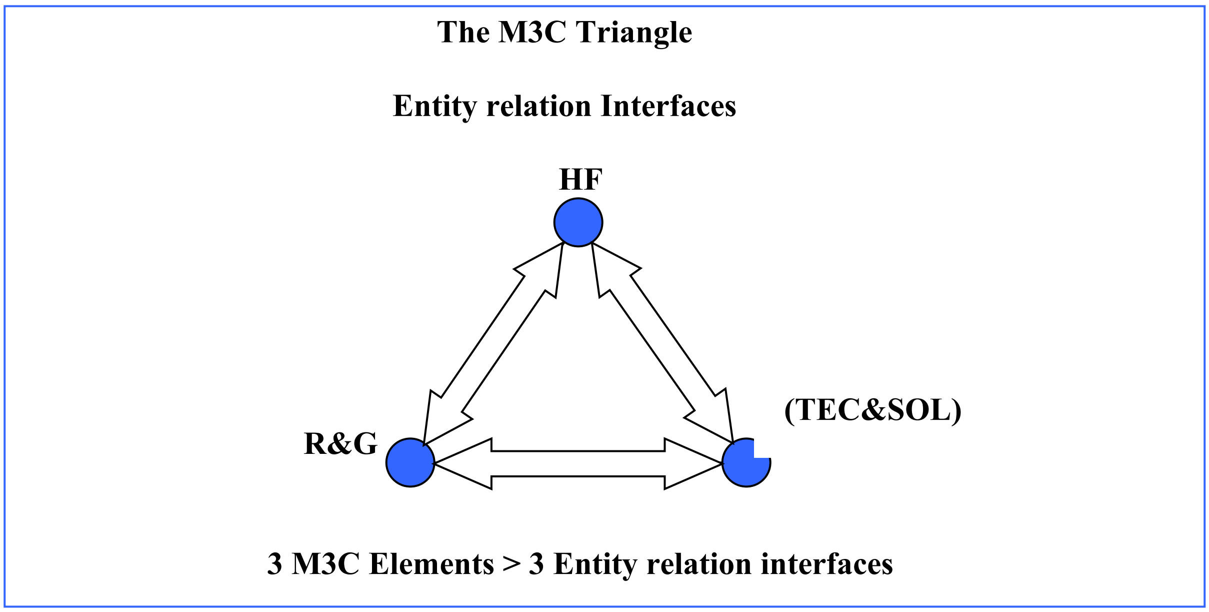

Figure 23 The M3C Triangle - Entity relation interfaces

The arrows in between the entities represent the interface, which simply could be numbered on more complex system decompositions or even be named self-explaining.

M3C Diamond

The following M3C Diamond itself was added to have also the bigger picture of the influencing ecosystem. In the M3C Diamond ontology the mentioned interface naming could be e.g. for the analyse on all issues between the M3C representing the centre (as described in the triangle as a hole) and the Public (Pub) the well know and widely used term Public Relation (PR) Interface. PR itself is a science by its own and would be the one used for the analyse of this interface. Nevertheless, in the M3C method it is also foreseen select and skip interface on their relevance. In this work this identified relation interface is mainly low rated in the analyse due to the DSS aspect here focuses more on the operator than on the also well-known EWS challenge of public warning and alarming. It is important to mention this of course as in another context such interface could be the main enabler or hindering factor. e.g. a big ICD accident with oil spill affecting high density coastal areas.

The following schema depicts the M3C ontologies with 5 entities.

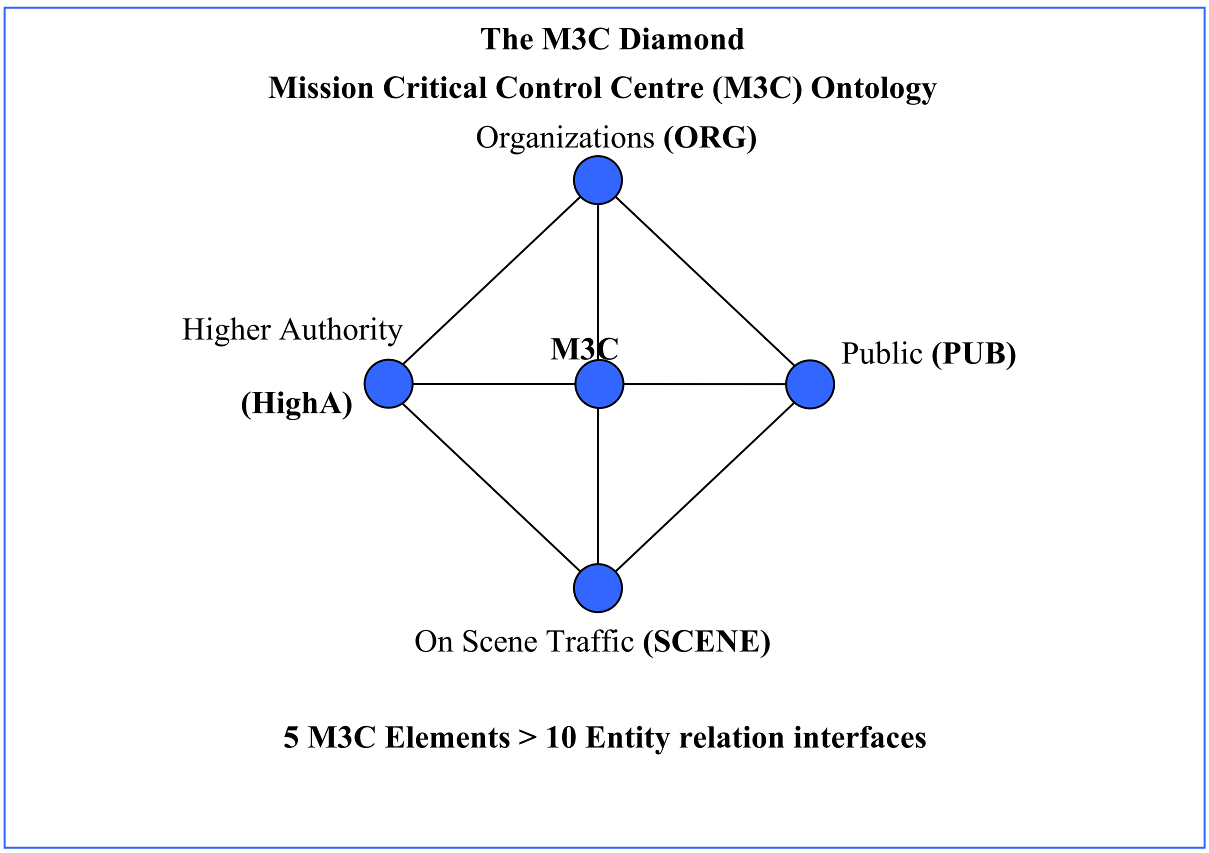

Figure 24 The M3C Diamond

The following schema depicts the M3C ontologies relations with 5 entities.

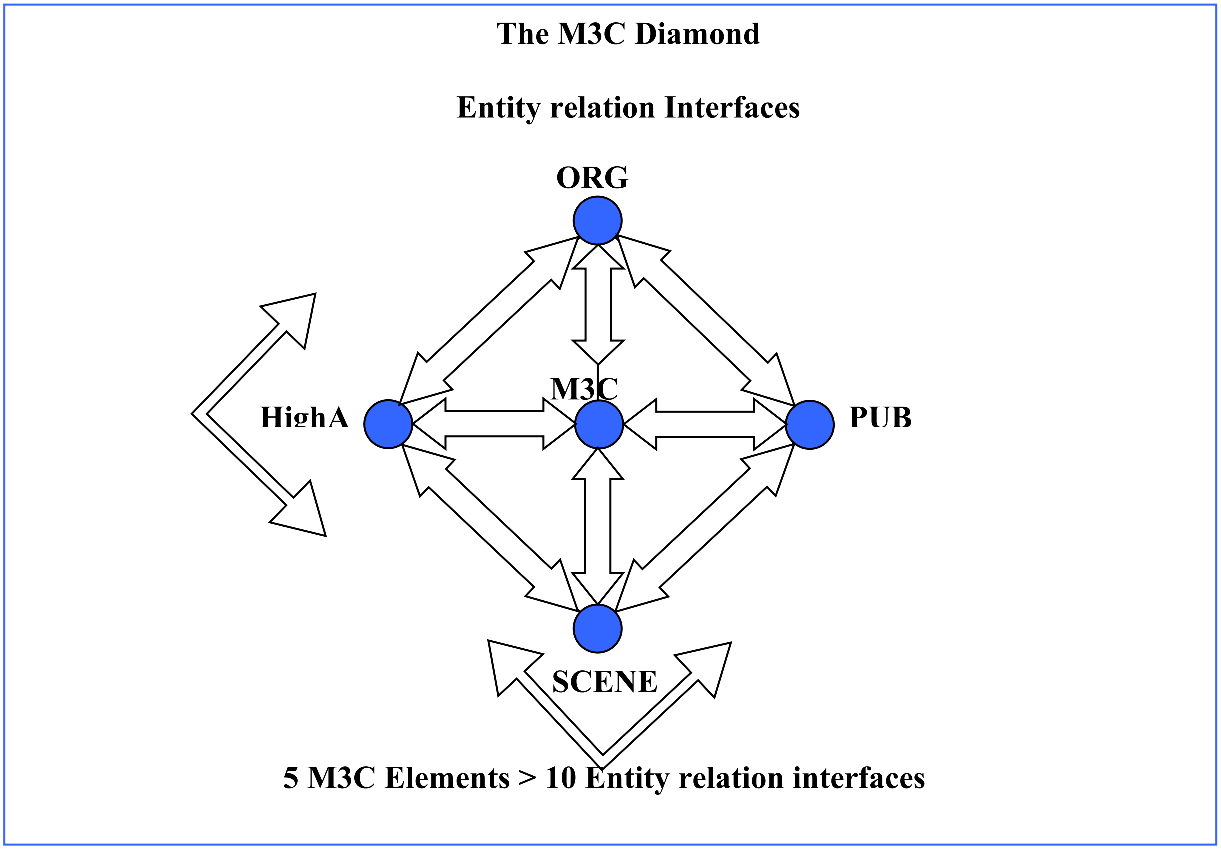

Figure 25 M3C Diamond Entity Relation Interface

The M3C Diamond Entity Relation Interface Model shows with already growing complicatedness in comparisons the triangle model, but still depictable via a graphic showing all relations in a system composition for the chosen 5 maritime domain awareness entities.

As it is complicate in the TEC&SOL context and not complex like HF context, this model can be even expanded to many more relation entities due to the simple mathematic behind it, but the challenge would be to communicate such complicate social meshes to humans.

M3C mathematical basics

The M3C concept is based on the definition and description of a system here e.g. the M3C as an entity and its interfacing to surrounding systems followed by splitting them it into topics to defined logical blocks. The goal is to finally process each of these blocks and resulting interfaces systematically separated. The simple mathematic approach explained will support to easy find the theoretical maximum of those interface.

The M3C system has comprehensive human aspects therefore it is a complex system. In comparison to a complicate engineerable system it cannot be fragmented by pure technical and mathematical methods.

Every theoretical possible M3C interface must be analysed if it really exists and or need to be considered for the specific question e.g. EWS, Decision Support. The main advantage in following that method is that no Interface on the defined system boundaries will be lost, even a description why this specific Interface was skipped is needed. Therefore, the constraint is documented, later traceability is given on such decisions made for the specific analyse. e.g. in That work the relation interface between the Centre (M3C) and the public, which could be a public announcement (PA) or public warning, or alarming is not the focus here and therefore actively skipped.

The formula of the so-called handshake problem, how many handshakes are needed if everyone on a party meets everyone: (Hedegaard, 2000) x = number of people or in the M3C context the number of stakeholders. (e.g. M3C triangle x=3 M3C diamond x=5)

$$\frac{x \cdot (x-1)}{2} \quad \binom{n}{k} = \frac{n!}{k!(n-k)!}.$$

Figure 26 The mathematical “Handshaking problem” behind the M3C model

The intricacy here complicatedness (TEC&SOL) is growing if the party guests or in M3C contest ontological the entity is growing can be obviously seen. The conclusion is to keep them low best less than five (M3C Diamond) with resulting into 20 relationship interfaces if the M3C method is used manually. Nevertheless, due to this structural mathematic a perspective can be given as follow up to research on feasibility and the development of a software tool to support a innovation process in a permanent decision support system (DSS).

Following picture shows higher dimension of the M3C model.

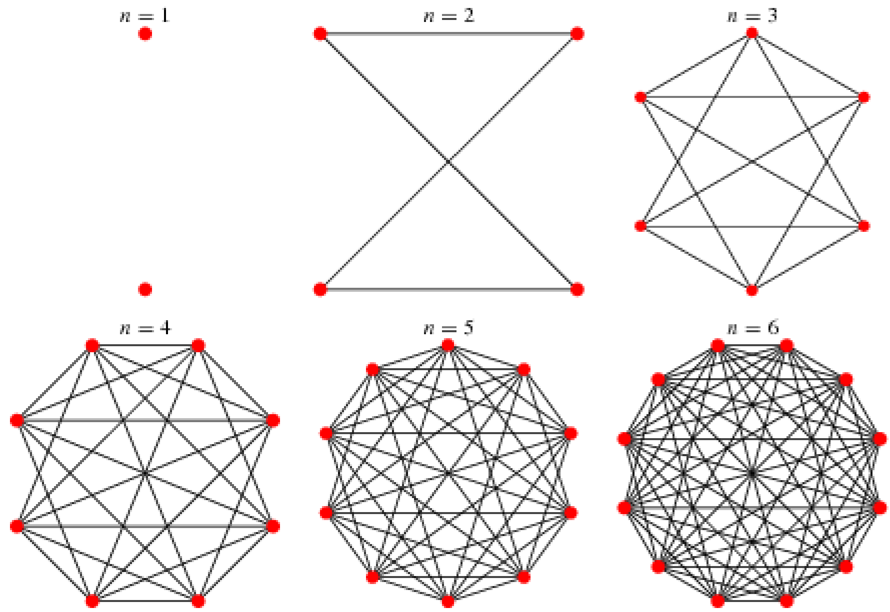

Figure 27 Handshake Problem depiction ((Hedegaard, 2000)

Based on that scalable systematic M3C approach a software can be developed to support that process similar to a Project Management Tool with various depictions of the to solve problem. E.g. as Gant Chart or in the M3C context as Relationship diagram.

7. Chapter: CONCLUSION

7.1. Hypothesis main conclusion

Today maritime vessel accidents can be mitigated even avoided by dynamic decision support innovation like Early Warning Systems (EWS).

Especially the globally availability of transponder technologies like e.g. Automatic Identification System (AIS) in combination with collision detection, behaviour recognition or geo fencing algorithms could mitigate or even ovoid accidents. This is working in the case if the systems are aboard of vessels as well as they would be centralized in Mission critical control rooms.

Nevertheless, this combination leading to an EWS is not in place in today's MRCC and VTS. This is the case due to the regulation studied within that paper showed that only parts of the components are standardized. E.g. AIS or VTS but an EWS as such is not at the notice of today's maritime organizations and standardization bodies.

This work also showed that the expected systematic organizational lack in hindering such innovations is part of the legacy-oriented authority nature of today's control centre structure. Especially the todays still mainly Taylorism influenced organizations and the Command and Control structure in military organization is the main reason for that.

The analysed US Coast Guard study showed in detail the Human Factor problem caused by inadequate and unharmonized training of the watch standers and the inconsistent systems and procedures between the VTS's how to use them.

It figured out that relation management (e.g. the described systematic M3C approach) with focus on authority structures is needed in correlation to public and crowd interests, which are often involved in environmental ICD topics, is needed to answers this analysed maritime situation. The organizations internal positive effect of the relation management is to overcome the Taylorism's silo situation between departments blocking each other. The external effect is improved by better handling the public and political pressure after an environmental or casualty desalter happened as this was the main innovation driver identified in the maritime accident section.

The M3C Model could be supportive to design a transdisciplinary process to visualize and manage cross domain stakeholder relations which supports the implementation of innovations like EWS through organizational change.

7.2. Scientific question main conclusion

What is hindering Mission Critical Control Centre-organizations like Vessel Traffic Services (VTS) and Maritime Rescue Coordination Centres (MRCC) to implement innovations like EWS?

Main reason for such disaster risk reduction -innovation delays are political and economic reason in combination that in the past only disasters lead to new regulations triggering legislation followed by implementation of technical innovation in control centres. This is a very time intensive and only reactive process today. The organizations have Command and Control structures and are still following the Taylorism in their structure, which is incompatible with the iterative process within the Disaster Management Cycle, therefore the hindering aspect of the Taylorism is still present in today's organizations. Furthermore, a structural interdisciplinary problem is making that fact even worse. Accident Investigation departments like the analysed US NTSB start their work triggered by definition on accidents, therefore improvement and innovation can only be initiated through incidents, crisis and disasters (ICD's).

Another more technical hindering aspect was found in the silo domain separation of systems with their proprietary not standardized interfaces.

A great chance to overcome those gaps is the IMO/IHO standardization process. Most promising approach was found it the IHO S100 standardization framework. It is the first time in maritime standardizations that all missions are standardized within on framework which shall guarantee the interoperability of data between the maritime domains.

Within S100, EWS could use data and its combination to find hazardous situation for multi hazard risk analyses first time without complex adaptors and translation between formats. Furthermore, the historical system locks can be opened due to with S100, compulsory requirements can be postulated by the competent authority towards the industry. This avoids vendor lock situations with proprietary interfaces which is also hindering EWS innovations.

Could maritime vessel accidents be mitigated and avoided by todays innovations like EWS?

Clearly yes, the work showed that several aspects of accidents could be detected and therefore mitigated by todays sensor and data. Incidents Crisis and Disasters (ICD) and the negative effect in human's life and environmental damages are well documented and proven including the delay and lack of technical innovation. There is a need for EWS in Vessel Traffic Services and they are effective and supportive, as several examples within that work showed (e.g. Vessel Bridge collision).

The Dynamic Risk Assessment Gap (DRAG)

The Dynamic Risk Assessment Gap was identified and described within that work. Following the example US Navy destroyer USS Fitzgerald collided MV ACX Crystal, the Philippine flagged container ship, collision detection is a technically a well solved problem and available but still not used in the way that this and other similar ICD's could be avoided. One of the most modern Ships with several EWS for other purpose aboard could not avoided a simple Ship-Ship collision.

- Already today algorithm and systems are used for collision avoidance e.g. as shown in anti-ship missel systems but are not used for classical traffic management.
- AIS and other systems designed and supportive for collision risk detection are limited by Human Factor (HF) as final detector and is still a manual interpretation.
- There is no backup organization nor system on MRCC, VTS level similar to Air traffic management in maritime. Furthermore, they do not have EWS or collision avoiding systems beyond the also human task of the wash stander.
- In its todays SOLAS implementation AIS carriage requirement only is availability onboard merchant ships therefore the potential is limited to SOLAS vessels. Navy, Leisure, Fishing Vessels are not included or have proprietary systems for several mission reasons. (e.g. VMS for UN FAO UUI Unreported and Unregulated (IUU) fishing)
- Nevertheless, also the non SOLAS tactical traffic participants, like Fishing, Navy have M3C infrastructure. E.g. Navy obviously the C4ISR centres and Military strategical commands and Fishing Vessels their UN FAO IUU requested, national

MFC and REMO's even imbedded in national Maritime Domain Awareness (MDA) structure joint with Navy. e.g. EU EMSA, AUSTRALIA AMSA, Peru SIMTRAC.

- Obviously this M3C structures have no focus on EWS types of mission focusing on calamity abatement. Especially if it comes to interdomain compatibility. E.g. SOLAS vs. Navy vs. Fishing and Leisure crafts there is no data exchange possible or even wanted today. Mainly for political or commercial reason, like in the Fishing industry as also one important BREXIT topic the Fishing showed.
- Today's answer mainly is in Regulations and Guidelines (R&G) e.g. IMO Convention on the International Regulations for Preventing Collisions at Sea COLREG, IMO's theoretical answer to the topic leading to pure Human Factor (HF) navigational skills solving the problem today, with little technical support for situational awareness in ECDIS on e.g. collisions or automatic behaviour recognition.
- There is only one Sea mainly 2D traffic space but, Maritime Traffic Management isn't harmonized technically between most participants today. Mainly due to political mission reasons. E.g. Fishing, Navy and merchant shipping.

This fact can be named as the Dynamic Risk Assessment Gap (DRAG), summarizing that today the risk assessment still is mainly a human operator task with the potential to be supported with today's available EWS innovations.

Which approach could be supportive to implement EWS in a cross-domain stakeholder driven environment to sustainably mitigate accidents?

There is a need and use for technical innovation in Control Centres as reaction on known accidents as the full potential of EWS is not used today. This was analysed especially in the activities of the UNDRR and the absence of the input of IMO.

Additional there is a structural organisational issue in global governmental purchasing processes hindering an innovative development process like iterative approaches e.g. AGIL, Launching Customer principles. Also, a nature in commercial solutions is to maximize the economical income and to lock the users to one vendor. Requesting a future solution like EWS would need standards equal for all vendors to be compatible like it is today already the case for AIS, ECDIS and several other equipment used in the maritime industry. The IHO S100 Standard was identified within that work as a promising approach to support innovation like EWS du to bridging between domains in technical data formats as well as in interface challenges.

The M3C model can be helpful to identify and clearly visualize all stakeholders and decision participants for EWS. The M3C model can give the process owner a higher awareness to the importance of the relations between the stakeholders and their interested. Most IMO/IALA documents simplifying the stakeholder landscape by the wording “a competent authority” which is not sufficient to address the innovation process needed to implement an EWS. The M3C model can support conscious working on the relations between them and the individual stakeholders due to it visualizations and systematic approach to find and evaluate finally know them. This decomposition of complex systems to simpler entities is helpful to bring innovation forwards in such harsh bureaucratic environment like maritime VTS and MRCC’s control centres.

8. Chapter: PERSPECTIVE

8.1. Section Information

The current VTS MRCC situation is well worked out within that paper. Due to EWS is not established today the situation is to enable the centre organizations to implement the basics EWS's with their advantages. Nevertheless, this work brought up many aspects and ideas which go far beyond the current centre reality but worth to be mentioned as perspective. The following section describe the topic for further research beneficial if the EWS topic gets more mature in the maritime industry and the centres are ready for the next innovation cycle when Artificial intelligence (AI) algorithms need to be accepted for teaming up with operators or even organizing autonomous unmanned seagoing traffic comes in place.

The machine in the team!

Intelligence is individual, artificial Intelligence as well and teams as cooperative individuals make better decisions than a single person.

The basic idea for the perspective is, to melt Risk Assessment and Risk Communication into a new discipline, method or tool, name it Human Machine Cooperation (HMC) or Human Machine Teaming (HMT) for real time decision support, which is following more a risk governance approach in combination with team or group decisions processes, rather than the usual individual decisions by mission leaders or operators today. Today's decisions are based on information and learned interpretation of a situation. Humans are perfect creatures to work and expand their aptitude by tools even create them, but don't want to be replaced by them.

Evolve Human Machine Interface (HMI) to early warning cooperation tools

Due the different durations and latency of various risk processes, they served different disciplines and nature in decision making. Today risk assessment mainly used in long-time political and strategical decisions. Traditional solution to cover risk support in mission control context is, that subject expert's team with the mission leader, but with clear final power on decisions by the mission leader. Decisions are based on predefined procedure and schemata's, from best practice to pre-done risk work and the personal risk type of individual deciders.

Artificial intelligence (AI) and self-learning algorithm today can evaluate in real time uncountable versions of paths of a decision and its effects and most probable result. The human decisions have the competence of creativity and intuition. Setting these two competences in competition, which is often the case today, like machine replacing human decisions, of course gains resistance by today's decision makers and operators. It misses an important team-decision aspect, humans probably cannot think today because of existing paradigm.

The perspective suggestion is to evolve HMI to HMC. Today's Human Machine Interface's need to become Human Machine Cooperation as EWS using todays AI capabilities.

EWS will become a standard decision support system (DSS)

A Tactical Situational Risk Awareness display based on a risk assessment backend service for situational risk communication has the potential to become a powerful AI decision cooperation tool EWS in mission critical control centres.

e.g Navigation by its nature is a complex decision-making domain. Autopiloting in general, by its today's implementation in ships plains or even cars now, have the problem that they work that well that the humans work is replaced totally in standard operation. Sometimes drivers are even artificially designed into the system by other than core navigational reason like e.g. in Vienna's underground trains.

Nevertheless, a human interaction in most systems is still needed to handle unforeseen situations or difficult circumstance. Operators provide creativity, experience and intuition which on the other hand are trained and learned by standard operations. Special situation appears too seldom, and standard operation are mostly done by the autopilots.

Humans involvement gets less and less due to their replacement by machines resulting in decreeing the human competence in the subject itself. The answers today are extra organized operator trainings on simulators, navigation exercise without or reduced technical tooling, which again is a human problem, due to a human need a "Why I am doing it?" A good reason or a creative process for the Training as fundamental base for his individual motivation.

Only answer like "You have to be prepared if the machine fails!" for a human psyche is a less and less attractive motivation, as better the machines gets and less machine errors occur. It can happen that human operators emotional makes the system to their competitive enemies waiting to fail, or even sabotage by job existential reason, which happened several times in history since the industrial revolution e.g. a Luddismus 4.0.

Possible Human, Machine cooperation and Human Machine Teaming implies a radical paradigm change in operators noticing machines and by the engineers designing them. Machines must become part of the group dynamic process like today tools, SAR dogs, some assets and any means of involved supportive resources.

AI machine as mission team member

E.g. following the experimental thinking to imagine an AI machine as mission team member. The mission lead would use each individual strength of every member for in the decision-making process. Experienced mission leaders imply the individual blurred and prejudged ideas of each team member to concentrate and weight each opinion for best mission decisions.

Imagine a SAR dog as team member, it might be the best in smelling and trained interpretation, with individual decision what to do, how to indicate. Probably a mission leader will follow the animal’s nose, which is representing the best available sensor – which became part of the species nature and over thousands of years part of its intuitive decision process.

The AI-machine in imagination as team member, can probably analyse countless sensor data, calculate in extreme speed and follow rational mathematically optimization, with "individual opinion on a best decision", bases on its most trusted skills which is the calculating methods, mathematic accurate and rational results representing the "AI individual decision opinion".

The Human as team member in this cooperate decision making process, has its skills in individual senses like creativity, ecological-, economical-, ethic-, empathic-competence influencing his opinion on a decision.

Next to the human ratio, sanity and the ability to give reason, the mission lead assess and weight all this information to a common operational picture for the Tactical Situational Risk Awareness as fundament to the final decision influencing and managing the situation.

The human ability in giving reason, is mainly implicit given by the mission itself, and can be directly derived from the mission statement the team is trained to. Making the AI-machine to a team member, rather than just a tool, it solves some psychological problems in decision making but opens the door to the well-known physiologically subject of team building.

Humans will team up with machines in near future – consider the human dignity!

9. Chapter: LITERATURE

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