Human factors root causes of accidents in inland navigation: Organisational Aspects

Phase 2b – Report

INTERGO

International Centre for Safety Ergonomics & Human Factors

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Preface

Incidents in Inland Waterway Transport (IWT) change and are experienced to increase in severity & cost of claims. Human factors account for about 70-80% of all incidents, according to databases and literature. Also changes in IWT itself develop like increasing automation, other business models, etc. The European IWT sector wants to learn from accidents aiming for prevention in the future by defining risks and future measures. Policy makers and insurers are challenged to counter this trend and to anticipate on technology push. They realize interaction between human, organisation and technology is becoming more crucial when systems are becoming more complex. They are asking for recommendations on organisational factors as a steppingstone to the future development of European evidence-based guidelines or preventive measures in the sector.

Human factors root causes in European IWT have not been researched on sector level before but are necessary for developing effective mitigating measures. To feed the framework aimed for the sector agreed to learn from human factors root causes of accidents

As information about causes from accident databases is limited, additional information from the field, sciences, other sectors, and human factors experts have been added. Researchers, specialized in human factors and safety, have analysed multiple sources to reveal human factors root causes. Based on triangulation approach, real world information from questionnaires, interviews and on-board-observations helped to reveal context of human factors root causes. They have integrated knowledge and state of the art expertise from other transport sectors. Stakeholders' decision making about execution of recommendations still must take place.

This study could not have been conducted without the enthusiasm, critical interest, openness, hospitality, and expertise of all the experts we met.

Table of Contents

Abbreviations

ADN	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
AIS	Automatic identification system
AMSA	Australian Maritime Safety Agency
CCNR	Central Commission for Navigation on the Rhine
CCTV	Closed-circuit television
CEMT	Classification of European Inland Waterways
CESNI	European committee for drawing up standards in the field of inland navigation
CESNI-PT	European committee for drawing up standards in the field of inland navigation - Technical requirements
EBU	European Barge Union
ECDIS	Electronic Chart Display and Information System
EEMUA	Engineering Equipment and Materials Users' Association
EN	European Standard
ENC	Electronic navigational chart
ESO	European Skipper's Organisation
ES-RIS	European Standard River Information Services
ES-TRIN	European Standard laying down Technical Requirements for Inland Navigation vessels
ETA	Estimated time of arrival
HF	Human factors
HMI	Human-machine interface (= MMI)
HSI	Human systems integration
GSM-R	Global System for Mobile communications for Railways
GUI	Graphical User Interface
IACS	International Association of Classification Societies
ISO	International Organization for Standardization
IT	Information technology
IVR	International Association for the representation of the mutual interests of the inland shipping and the insurance and for keeping the register of inland vessels in Europe
IWT	Inland Waterway Transport
IWT Platform	European Inland Waterway Transport Platform
MMI	Man-machine interface (= HMI)
RIS	River Information Services
SHEQ	Safety, health, environment, quality
SOLAS	Safety of Life at Sea
SMART	Specific, Measurable, Achievable, Realistic, and Timely
SMNV	Standard Marine Navigational Vocabulary
TASCS	Towards a sustainable crewing system
UIC	International Union of Railways
VHF	Very high frequency (marine 2-way radio communication)

Management Summary

Background of this study

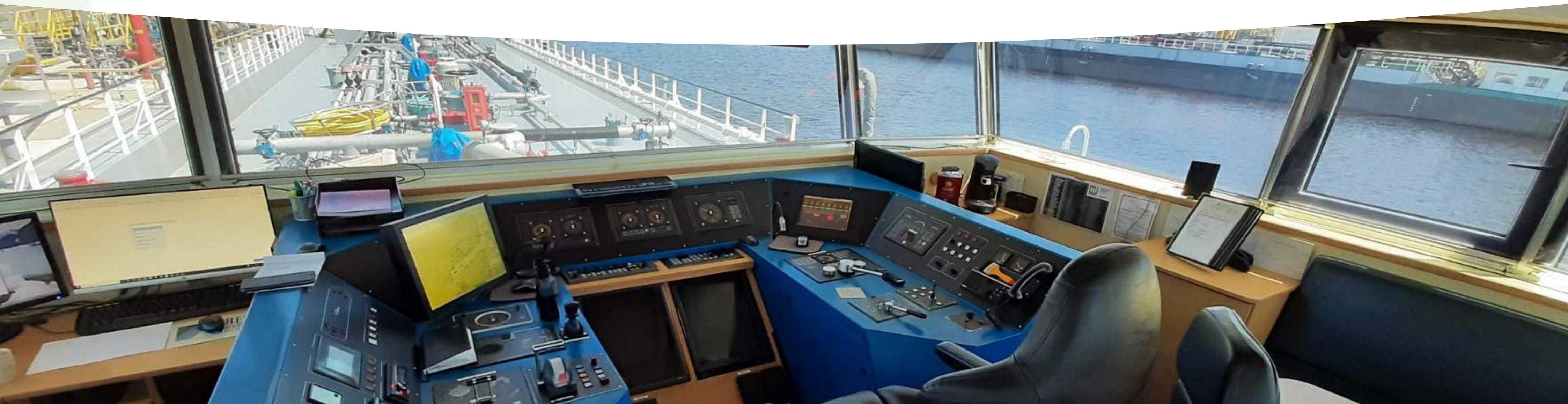
The European inland shipping industry (united in the European IWT Platform), insurers represented in the IVR and the Dutch Ministry of Infrastructure and Water Management, experienced an increase in the number of accidents and claims related to inland navigation every year since 2014, just like the amount of the claims. Therefore, they commissioned a study on the human factors root causes of accidents in Inland Navigation.

An additional motivation for the study was expressed by Paul Goris, president of the IWT Platform: "The Inland Waterway Transport sector is on the eve of a major transition in terms of sustainability and digitalisation. This requires further development of standards and certain safety requirements."

Research programme

This study has been commissioned in two phases. In phase 1 of this study in 2020 – based on data and expert analysis - it was concluded that in 70-80% of these incidents human factors are involved. Most databases do not contain a uniform format or contextual information that allows for understanding factors that contribute to accidents. Despite of that, several contributing factors were identified.

As a follow-up two separate studies were defined: phase 2a and phase 2b. This report covers in depth study phase 2b: the organisational factors *communication*, *fatigue and stress*, *specific waterway situations* and *qualifications of the crew members.* In a separate report (phase 2a) the Human-System-Integration is addressed. Both studies in phase 2 consisted of an international questionnaire for skippers and barging companies (85 respondents), followed by 10 selected vessel visits with interviews and observations to obtain insights in four selected accident causes: communication, qualification of crew members, fatigue & stress and specific waterways or situations. Both older and the newer vessels of different sizes have been visited. Also, a comparison with other (transport) sectors like rail and aviation was made to see how standards, regulations, and guidelines are used to create effective and safe work environments.



Results

The result of the questionnaire showed that the majority of the respondents think that ship-ship communication is an important cause of accidents. Observations and interviews learned it is not common to use standard communication protocols with standard phraseology. Also, limited command of a shared language is considered to be an important cause of accidents, which is related to the increasing internationalisation of personnel. As learned from observations, interviews, and state of the art science, the combination of these communication problems with a high adoption of automation like AIS-positions on ECDIS may contribute to overtrust and a false sense of safety resulting in (potential) errors.

Second, lifelong personal development including periodically retraining is not the convention across the sector. Almost equally large proportion of the respondents think limited skills on board are an important cause of accidents, especially mentioning lack of experience and craftmanship of new boatmasters. Various individual preferences exist for acceptable clearances above the vessel or under the keel, leading to more or less risk taking. Route competence is considered as very important. Unlike other transport sectors, no criteria exist for periodical retraining of technical and non-technical skills. Company culture and on-board culture, which are related to resilient strategic and operational management across stakeholders in the IWT ecosystem, are influencing communication, planning, experienced stress and fatigue on board and thus influence operational risks and safety.

Third, boat masters are end responsible for safe operation and safe navigation, but they have limited options in closing the supply chain loop, facing delays, or changed plans. This puts financial pressure on the crew often leading to concessions in operational risks including safety, like proper journey planning, sailing under challenging conditions or suboptimal work-rest schemes.

Fourth, specific waterway situations are believed to contribute to a lesser extent to accidents. In practice, boatmasters experience difficulties in easy access to reliable information like actual water levels.

Recommendations

The **first recommendation** is to update and improve protocols and guidelines on VHF communication in inland navigation, incorporating a shift to one shared nautical language across the IWT ecosystem and location and IT support of communication devices as is common in other transport modalities.

The **second recommendation** is to develop an integral vision on appealing lifelong personal development on especially mastering management/entrepreneuring and non-technical skills before setting out measures like guidelines to provide staff and crew with a proper safe profitable 'operation zone'. Manning, decision-making in critical situations like during commercial pressure and planning/work-rest schemes will be optimized, leading to better nautical safety and less stress and fatigue. Successful peers might function as role models. Apprentices should be supervised more while sailing, integrating more practice in education. The **third recommendation** is to explore possibilities to distribute responsibility of time-bound operations across the IWT ecosystem in a more closed supply chain loop. This distributed responsibility may support risk-averse production across the sector and reduction of fatigue and stress.

The **fourth recommendation** is to develop a shared vision on minimum requirements on availability, reliability, usability and integration of information and automation on the helmsman's position before setting out a strategy or developing measures like policies or guidelines on: route planning including minimum safe clearance conventions, use of non-task related systems like personal social media including TV, easy and valid registration means like tachographs and in-vehicle fatigue related decrements.

Finally, the **fifth and last recommendation** is resonating from phase 1 of this research: to develop a central detailed database in European inland navigation including clear definitions, formats, and instructions for registration, permitting to learn from incidents and to prevent them from happening again in the future.

Recommendations may be combined. Also, synchronisation with recommendations from Phase 2a (about HMI and wheelhouse design) is important because technical and organisational issues are interrelated. A roadmap should first be developed, involving all stakeholders in the ecosystem of inland navigation, because new guidelines should first of all be appealing to use for all parties involved.

1. Introduction

The number of accidents and claims related to inland navigation has risen every year since 2014, just like the amount of the claims. Depending on the source analysed 44-92% of these accidents are related to human factors as a primary cause. The International Association for the representation of the mutual interests of the inland shipping and the insurance and for keeping the register of inland vessels in Europe (IVR), the European Barge Union (EBU) / European Skipper's Organisation (ESO), European Inland Waterway Transport Platform (IWT Platform), and Dutch Ministry of Infrastructure and Water Management are looking for ways to prevent such accidents and initiated research in two phases, starting from January 2020. Phase 1 consisted of a data and expert analysis of human factors root causes and was finalised in November 2020. In phase 2 the highest risk activities as defined by phase 1 will be subjected to in-depth analysis. This phase 2 focuses on verification and enriching of results from phase 1 on two main areas: 'nautical technical factors' and 'organisational factors' contributions. We unravel these factors that influence human behaviour.

The steering group suggested splitting phase 2 into two lots: 2a. Focus on the human-machine interface in the wheelhouse, also seen in the light of current and future levels of information provision and automation, and 2b: Focus on organisational aspects as plausible root causes, being communication, fatigue and stress, specific waterway situations, qualification of the crew members. Both phases were executed separately with their own steering group. Parts of the implementation however were carried out simultaneously in order not to unnecessarily burden skippers.

This report is about the results of phase 2b: organisational factors.

The main question from the steering group in phase 2b is:

"How to improve in future training content for both young trainees and for already experienced crew members?"

Sub-questions from the steering committee are:

1) What are priorities and most plausible root causes of four selected accident causes:
   - Communication?
   - Qualification of the crew member?
   - Fatigue and stress?
   - Specific waterways or situations?
2) What measures could be taken to reduce the respective four root causes?
3) With regard to communication in particular: what effective measures to improve communication among crew members and communication to third parties can be defined?

In addition, the steering committee stresses the importance of proper and reliable data collection, verification, and validation in European IWT in order to help develop an evidence-based technical and safety policy as is the case in other transport modalities. This research question now is not part of the scope of this assignment.

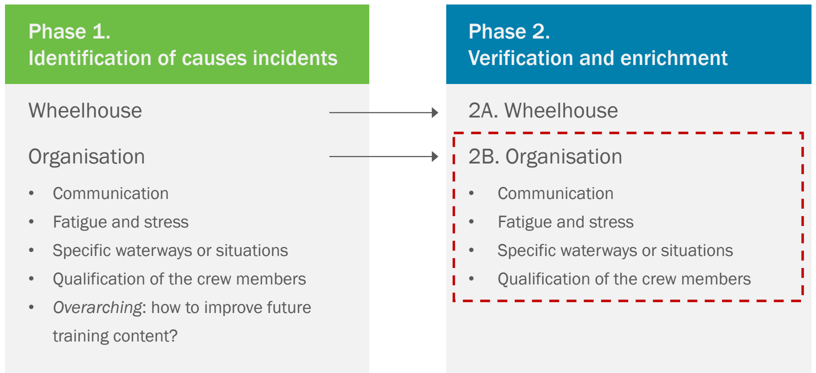


Figure 1: Schedule of part 1 and part 2 topics for this study and report

Our proposal is to develop a guide with recommendations on organisational factors based on human factors principles from science, expert judgement, field research and best practices, in order to answers the questions above. The recommendations from this research phase might serve as a supported steppingstone to the future development of European evidence-based Guidelines or preventive measures in the sector.

To solve problems structurally, it is necessary to look at the underlying root causes (*Figure 2*). Symptoms, experienced as causes of accidents, are caused by problems in a certain context, which in turn have been provoked by root causes. Focussing on symptoms will not lead to lasting improvements. Focus on root causes will.

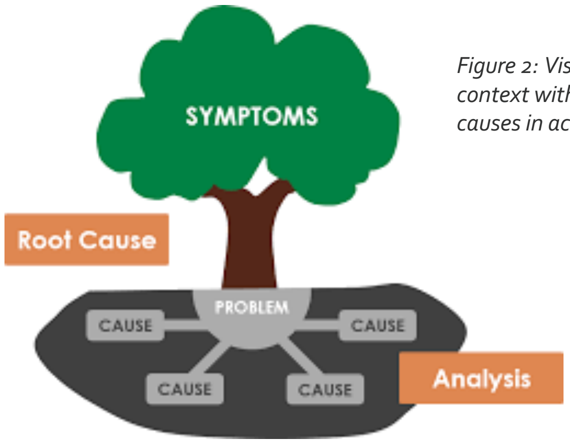


Figure 2: Visualisation of symptoms, context with problems and root causes in accidents

It should be noted that wheelhouse and HMI design, on the one hand, and organisational factors, on the other, both determine human behaviour. A perfectly designed wheelhouse alone is therefore no guarantee of safe sailing, as organisational influences can still trigger unsafe behaviour. This report covers the organisational human factors root causes. Wheelhouse design and HMI (Human Machine Interface) as plausible root causes are reported separately on request of client (*Human factors root causes of accidents in inland navigation: HMI and wheelhouse design, Intergo 2021*).

Guide to the reader

The report is structured as follows. The approach is presented in *Chapter 2*. In *Chapter 3* some general results regarding the questionnaire and vessel visits can be found. Then, the four main topics of this part of the study are covered: Communication (*Chapter 4*), Qualification of the crew members (*Chapter 5*), Fatigue and stress (*Chapter 6)* and Specific Waterway situations (*Chapter 7*). We end this report by providing a summary of root causes and recommendations in *Chapter 8*.

In the annexes an overview of vessel characteristics is given in *Annex 1*, detailed results from the questionnaire in *Annex 2* and selected references in *Annex 3*.

This report is directed at several stakeholders in IWT: for instance, Policy makers, Insurers, Shipbuilders, System integrators, Ship owners, Crew IWT, Operational management IWT, SHEQ/ HF professionals, Authorities, Education organisations, Classification organisations, IWT industry organisations.

2. Approach

We first analysed the nautical-technical aspects in-depth during field research (questionnaire and observations/interviews) focusing on the most plausible root causes. Second, we combined these results with knowledge from science and our extensive experience in organisational factors from other transport modalities (rail, road, maritime & aviation). This triangulation approach is a powerful and scientific method for valid results (*Figure 3)*. Based on these results we defined recommendations for optimal organisational factors.

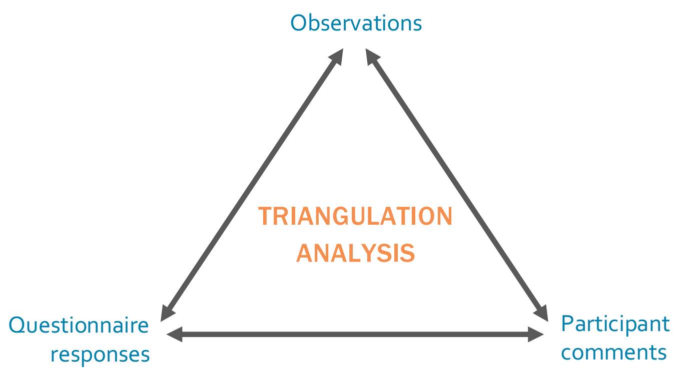


Figure 3: Triangulation approach, combines data from questionnaires, facts from observations in real world and verification by participants, leading to valid results.

More in detail, we used 3 major steps, apart from preparation, feedback loops and reporting:

1) Preparation of collection of best practices.
2) Collection and evaluation of cases in HMI and wheelhouse design.
3) Evidence based recommendations for safe HMI and wheelhouse design.

Scope

The scope for this study is incidents in professional inland waterway transport while navigating in Europe (i.e., the ship is moving). This scope excludes recreational traffic unless involved in an incident with a professional vessel. Also, incidents while loading/unloading, being moored, etcetera are excluded. We do acknowledge however that processes besides the actual sailing of a vessel may influence the quality of navigating by having an effect on planning, workload, rest/fatigue, and environmental circumstances.

To illustrate the scope of this study, the tasks that apply during incidents studied in this project are highlighted in a list of all tasks. See Table 1, as derived from the TASCS study (2019) based on the directive with harmonised competences of boat masters and boat men. As mentioned, the other tasks may contribute to the causation of incidents during sailing & manoeuvring (by simultaneous task performance or by influencing those tasks), which is considered in this study.

Navigation	Operation of the craft	Cargo handling, stowage, passengers
Voyage planning, org. crew change **Sailing & manoeuvring,** **Mooring & unmooring,** Organize and control work	Bunkering, Ballast water & waste management	e.g., Handling hoses, cleaning tank, freight document, control checking strength & stability; Passengers
Inspection	**Maintenance & repair**	**Communication**
Periodic inspections (vessel / hardware / software etc.)	Maintenance (preparation & coordination), Planning maintenance by external parties	Crew management & shift handover, Organisation & execution of training
HSE, Emergencies & calamities	**Entrepreneuring**	**Other tasks**
Control work & rest time (shifts), Developing safety plans, Instruct the crew in safety drill	Acquisition (follow-up cargo), Commercial accounting, Personnel administration, Vessel account, (Port duties etc.)	Studying, waiting, Housekeeping (cooking, cleaning accommodation) Teaching apprentices
Recovery & free time	**Travel**	
Pause, leisure, sleep, standby	Commuting to/from vessel	

*Table 1. Overview of tasks in IWT (source: TASCS, 2019). In **bold** and highlighted in the orange block are the tasks that apply during incidents studied in this project.*

Categorization of vessels

To be able to compare databases, the reported vessel types had to be categorised in four major subsets. Additionally, the steering group requested to specify container vessels as special subtype in this research phase:

- Containers;
- Dry cargo (including barges);
- Tankers;
- Passengers.

2.1 Step 1 | Preparation of collection with experts' input

The main goal of this step was to obtain further insight in the multifaceted categories communication, fatigue & stress, specific waterways or situations, qualification of crew. Although these categories were identified in phase 1 as root causes, their exact causal paths could not be distilled from the databases. Therefore, in preparation for step 2 we gathered information about possible causal paths from a workshop with experts in (internal and external) communication and qualifications/education. Additionally, we performed a gap analysis to explore what scientific knowledge or standards from other transport sectors, like rail, road or maritime can be used. Finally, a questionnaire was constructed that included the four organisational aspects that we focus on. The questionnaire also included themes regarding the wheelhouse and used instruments in the wheelhouse, as these are important topics in phase 2A.

The following activities haven been performed:

- Kick off session in NL with stakeholders' project team for planning & organization.
- Inventory of relevant, existing IWT regulation standards and possible causal paths and future developments in these topics by means of an online Sailing for Excellence II workshop with experts in communication and education.
- Gap analysis based on science and literature on actual relevant guidance like in rail, road, maritime.
- Development of a questionnaire. This was reviewed by the steering group and translated into Dutch, English and German. The questionnaire was open for response via an online survey tool for two weeks. Themes of the questionnaire included:
    - General information on the participant, e.g., employment function, nationality, years of sailing experience, stretch they sailed;
    - General information on the vessel e.g. type of vessel, dimensions, weight;
    - Contact information of the participant, used to arrange vessel visits or answer follow-up questions.
- Members of the steering group invited captains via their supporters to fill out the questionnaire. After one week during the collection phase, one reminder was sent to participate in the questionnaire.
- Development of a (online) vessel visit evaluation tool for step 2.

2.2 Step 2 | Collection and evaluation of data by questionnaires and vessel visits

During step 2 we collected data through questionnaires and (online) vessel visits. First, we used the network of all stakeholders to send out a digital questionnaire to as many crew members as possible. In this questionnaire all issues identified in step 1 were addressed. In total the questionnaire was filled in by 85 participants.

From the 85 participants we selected 10 exemplary cases on specific aspects with learning potential for a more in-depth understanding reflecting IWT as inclusive as possible. See Appendix 1 for an overview of the vessels involved. We performed the in-depth study by observations and interviews with boat masters during a vessel visit while sailing or incidentally alternatively by an online interview due to COVID-19 measures. This selection of cases was made on (diversity in) the following criteria:

- Type of vessel (container, tanker, dry bulk or passengers);
- Form of employment (self-employed or organisation);
- Nationality of participant;
- Experience;
- Conventional stretch sailed (within the boundary that the vessel's current position was within 3 hours travel time from Utrecht);
- Order of reported importance of organisational factors;
- Use of guidance systems (used for phase 2A);
- (Dis)satisfaction about instruments (used for phase 2A);
- Being involved in an incident: ship-ship, ship-infra, grounding or no accident);
- Skippers vision on the importance of social media in regard to accidents;
- Photos of the wheelhouse were used to include both 'new' and older wheelhouse designs (used for phase 2A).

We prepared the in-depth understanding observations and interviews by detailed semi-structured questionnaires, observation lists and a data-processing model.

We evaluated the cases in relation to science, actual human factors standards and best practices from other transport modalities with help of a gap analysis (maritime, rail, aviation, and road transport). The gap analysis with other sectors comprised of an inventory of existing standards in communication, qualification, fatigue/ rest, and environmental factors.

2.3 Step 3 | Evidence-based recommendations for preventive organisational measures based on human factors principles

This last step included formulating evidence-based recommendations for preventive organisational measures based on the field research and human factors science and best practices in other transport modalities, mainly aimed at the target population of regulators, barge operators/ vessel owners, insurance companies and education parties. The recommendations from this research phase might serve as a supported steppingstone to the future development of European evidence-based guidelines or preventive measures in the sector. Recommendations are indicating the level of evidence and prioritised for safety impact. The level of evidence of a recommendation is indicated as follows:

- ***[Evidence: H – High]*** Recommendation proven by scientific research and published in international literature or standards.
- ***[Evidence: M – Moderate]*** Expert judgement of HF Professionals (registered human factors experts) with extensive experience in mission critical design).
- ***[Evidence: L – Low]*** Literature, standards, and common practice, however without traceable or sufficient evidence.

We performed the following activities:

- On 20 July 2021 we shared the draft results with the steering group for feedback.
- Presentation of draft guide with recommendations per topic to stakeholders on September 13, 2021.
- Delivering end report with a description of work, results, conclusions, and recommendations.
- Presentation of study in CESNI-QP December meeting.

3. General results

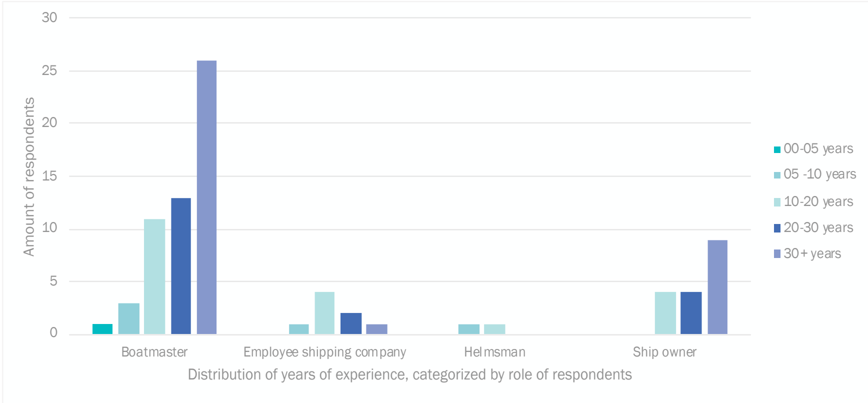
Characteristics of respondents to the questionnaire

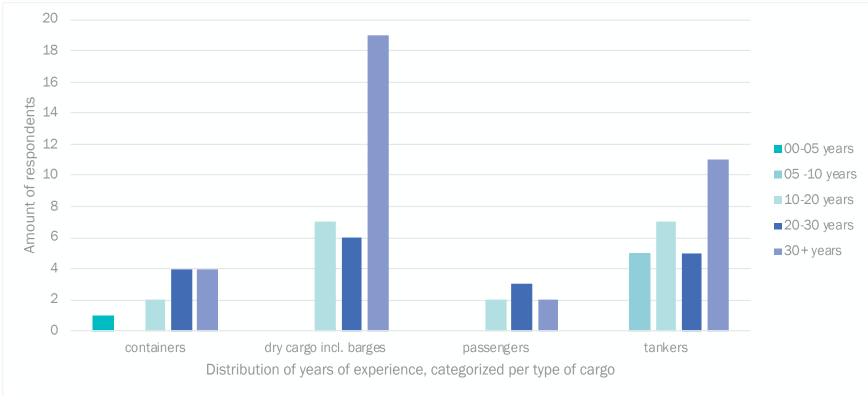
In two weeks, 85 respondents filled in the questionnaire. Majority of the respondents have Dutch or German nationality.

Category cargo	#	%	NL	DE	BE	FR	CZ	PL	SK	Other
Containers	*11*	13	8	1	1	1				
Dry cargo incl. barges	*32*	38	19	11		1				1
Passengers	*7*	8	2	4						1
Tankers	*29*	34	19	6	1		1	1	1	
(Blank)	*6*	7	3	2	1					
TOTAL	*85*	100%	60%	28%	4%	2%	1%	1%	1%	2%

The purpose of the survey was to question experienced skippers of different types and sizes of vessels. That goal has been achieved (see *Figure 4*).

- 64% of respondents was a boat master.
- 70% of the respondents has over 20 years of experience in inland navigation. Also, less experienced respondents are also represented in the research.
- 60% of the respondents was willing to provide additional information.
- 37% of the vessels is 2051-4000 tons (CEMT-class Va); 17% of the vessels was <1251 tons (CEMT-class I to III) and 14% was over 4000 tons (CEMT-class VIa).





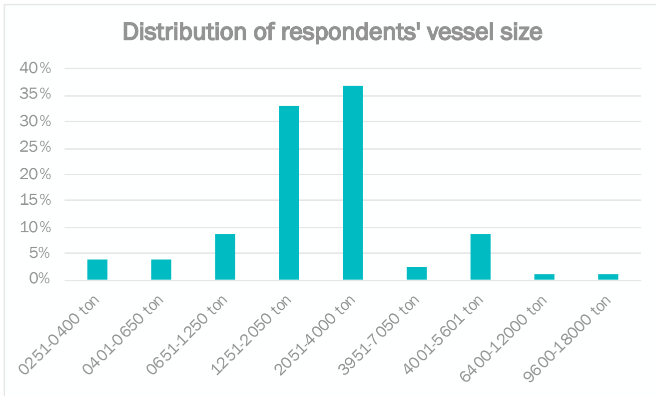
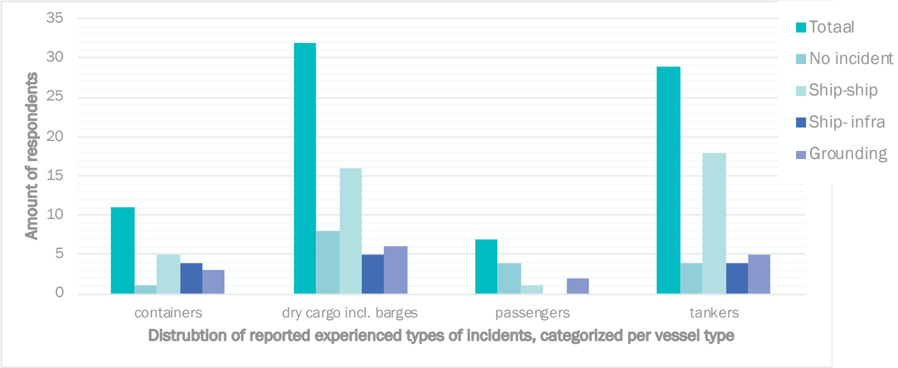


Figure 4. Experience in role of respondents (top), per vessel type (middle), and vessel size (bottom)

Most respondents have at least once experienced an incident. Most reported incidents belong to the operation mode A1 (*Figure 5*):

- 52% of the respondents reported a ship-ship incident
- 18% of the respondents reported a ship-infra allision
- 21% of the respondents reported a grounding.

In research phase 1 it was concluded that no specific focus on certain types of incidents is necessary in this phase 2.



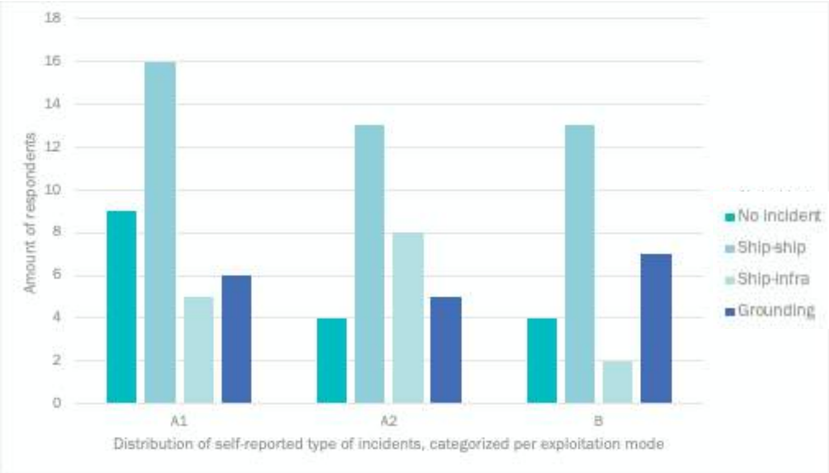


Figure 5. Experienced incidents per vessel type (top) and per exploitation mode (bottom).

Organisational issues

The respondents rated the importance of the four organisational issues that were the focus of this study. *Table 2* shows the percentage of respondents that rated the issue as most important (1st) to least important (4th) cause of accidents. The table shows that communication and qualification of crew members are rated as about equally most important by the respondents.

Table 2. Percentage of respondents that rated the organisational issue as most important (1st) to least important (4th) cause of accidents.

Organisational issue	1st	2nd	3rd	4th
Communication	34%	34%	24%	8%
Qualification of crew members	35%	26%	18%	21%
Fatigue and stress	24%	19%	26%	31%
Specific waterway situations	8%	21%	33%	40%

Vessel visits

Based on the criteria mentioned in paragraph 2.2 a selection of 10 small to large vessels including different types of cargo was made for further investigation. Detailed characteristics of these vessels are summarized in Appendix 1.

Gap analysis

Results from the gap analysis are incorporated in the next chapters.

In the next chapters the results from the questionnaire, the vessel visits, and the gap analysis are presented for each of the four main topics:

- Communication (Chapter 4);
- Qualification of the crew members (Chapter 5);
- Fatigue and stress (Chapter 6);
- Specific waterway situations (Chapter 7).

Per topic recommendations are formulated.

4. Communication

4.1 Context from the data and expert analysis

Phase I of this research identified communication as a major root cause from the SOS-database (NL): 49% of all root causes. This was recognised by Sailing for Excellence focus group (*Figure 6*). Communication issues are primarily associated with ship-ship collisions.

Communication is not limited to the wheelhouse/vessel, but is also related to other vessels, traffic management, terminals, and onshore organisation (e.g., planning). The issue of communication has multiple dimensions: miscommunication, no communication when required, wrong VHF channel, language skills, etcetera. Here, the lack of implementation of 'riverspeak' (elaboration of EU-directive 2017/2397) and training & testing of language skills were mentioned as underlying factors. Also, cultural issues of not speaking up, old vessels/radio systems, old infrastructure, and inadequate navigation signs and markings were mentioned as influencing factors.

In this chapter we will focus on communication. The next chapters will cover the qualification, fatigue/ stress, and specific waterway situations.

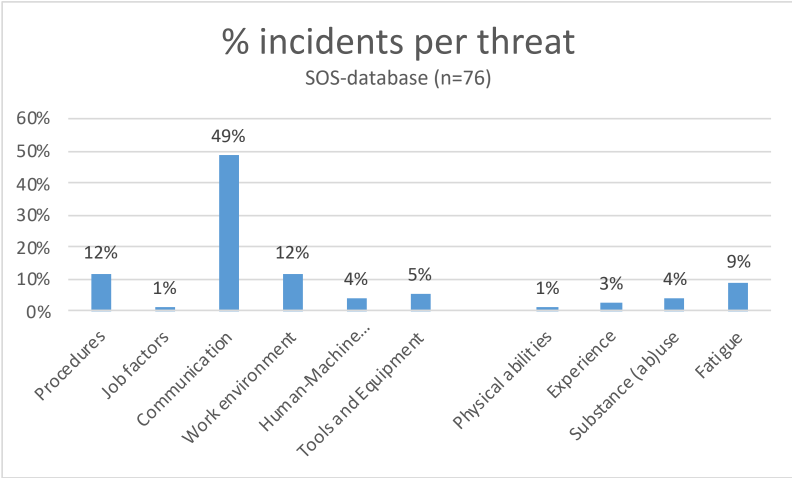


Figure 6. Initial root cause analysis, based on 76 out of 1353 cases from the Dutch SOS-database. Source: Figure 13 Report phase 1.

4.2 In-depth understanding

Table 3 shows the results of the closed questions concerning communication. The respondents rated the importance of the item as a cause of accidents (very unimportant, unimportant, important, or very important). The table shows the percentage of respondents that rated the item as important or very important; results are highly in line with the conclusions from phase I.

Below we will discuss the issues more thoroughly. Appendix 2 contains detailed responses.

Table 3. Percentage of respondents that rated the specific communication subitem as an important or very important cause of accidents in the questionnaire

Items communication	%
1) Too little or poor-quality communication with other waterway users	96%
2) Limited command of a shared language	87%
3) Too little or poor-quality communication with the crew on board	84%
4) Wrong use of the VHF channel	80%
5) Too little or poor-quality communication with traffic management or bridge and lock operations	74%
6) Company culture	69%
7) On board culture/ atmosphere	63%
8) Too much communication with the office or terminals	36%

Ship-ship communication

Almost all respondents who rated communication as most important cause (96%) indicate too little or poor-quality communication with other water way users (ship-ship communication) to be an important or very important cause of accidents (*Table 3*). The respondents added that in some cases there is a lack or absence of communication (See Appendix 2).

- One major cause is the drift from the VHF protocol. This is supported by item 4 in *Table 3*. It seems that boatmasters don't use the prescribed VHF protocols or use it for other purposes than it is meant to. This confirmed by what we learned from the vessel visits:
- Boatmasters stress the importance to keep VHF communication short and to the point to keep the VHF open for others. They experience the protocol as too long, including unnecessary repetitions and ending clauses. Observations learned none of the visited skippers follows the common VHF protocol. If a single pleasure boat captain does follow the VHF protocol, the reactions among professional skippers are pitying, as confessed by the skippers interviewed.
- In this drift there is no clear alternative standard VHF communication convention amongst boatmasters in practice. The drift from the formal protocol implies free interpretation of the practical convention leading to possible risks due to miscommunication or misunderstanding. We have observed too short messages during the visits, not fully making clear skipper's intention. In this case, skippers interpret the message themselves using ECDIS and AIS. Interpreting messages themselves, instead of exchanging an unambiguous message, contributes to possible misunderstandings and the occurrence of accidents. Also, crew explained during the visits that for longer communication between skippers there is a gradual trend for communication by GSM. Possible useful details for surrounding vessels now may get lost on the VHF channel.
- Skippers use electronic support systems like ECDIS/AIS to build an internal picture of the environment (situation awareness). Skippers experience this technology as so supportive that VHF communication has become less critical for them. At the same time, not every vessel on the waterway has the same equipment and vessels depend on the communication with other ships. If

other ships don't communicate, their internal picture of the external situation might be incomplete. Besides that, we noticed support systems sometimes result in an incomplete 'picture' only based on ECDIS/ AIS, which is not always 100% reliable (see Report 2a paragraph 6.2 for complaints about lagging and incorrect ECDIS information). Skippers may think their picture is correct, but it actually is not. They should communicate to confirm whether their information is complete. In addition, developing new technology like supportive systems like steering assistance and partial automation are likely to increase this risk of incomplete situation awareness if not properly mitigated.

Most vessels still operate at automation level 0, no automation for dynamic navigation, considering the degree of automation as defined by the CCNR (2018) (*Figure* 7).The actual introduction of automation varying from steering support (level 1), decision support systems (level 2) to automated execution sometimes under human supervision (level 3-5) leads to a shift in the helmsman's focus from continuously looking outside to an almost full focus inside on displays during full automation (level 3) during local direct control of navigation. When not all waterway users cannot be represented on systems (like pleasure boats), risks due to limited communication are likely to increase.

	Level	Designation	Vessel command (steering, propulsion, wheelhouse, …)	Monitoring of and responding to navigational environment	Fallback performance of dynamic navigation tasks	Remote control
BOATMASTER PERFORMS PART OR ALL OF THE DYNAMIC NAVIGATION TASKS	0	**NO AUTOMATION** the full-time performance by the human boatmaster of all aspects of the dynamic navigation tasks, even when supported by warning or intervention systems *E.g. navigation with support of radar installation*				No
	1	**STEERING ASSISTANCE** the context-specific performance by a steering automation system using certain information about the navigational environment and with the expectation that the human boatmaster performs all remaining aspects of the dynamic navigation tasks *E.g. rate-of-turn regulator* *E.g. trackpilot (track-keeping system for inland vessels along pre-defined guiding lines)*				
	2	**PARTIAL AUTOMATION** the context-specific performance by a navigation automation system of both steering and propulsion using certain information about the navigational environment and with the expectation that the human boatmaster performs all remaining aspects of the dynamic navigation tasks				Subject to context specific execution, remote control is possible (vessel command, monitoring of and responding to navigational environment and fallback performance). It may have an influence on crew requirements (number or qualification).
SYSTEM PERFORMS THE ENTIRE DYNAMIC NAVIGATION TASKS (WHEN ENGAGED)	3	**CONDITIONAL AUTOMATION** the sustained context-specific performance by a navigation automation system of all dynamic navigation tasks, including collision avoidance, with the expectation that the human boatmaster will be receptive to requests to intervene and to system failures and will respond appropriately				
	4	**HIGH AUTOMATION** the sustained context-specific performance by a navigation automation system of all dynamic navigation tasks and fallback performance, without expecting a human boatmaster responding to a request to intervene[1] *E.g. vessel operating on a canal section between two successive locks (environment well known), but the automation system is not able to manage alone the passage through the lock (requiring human intervention)*				
	5	**AUTONOMOUS = FULL AUTOMATION** the sustained and unconditional performance by a navigation automation system of all dynamic navigation tasks and fallback performance, without expecting a human boatmaster responding to a request to intervene				

[1] This level introduces two different functionalities: the ability of "normal" operation without expecting human intervention and the exhaustive fallback performance. Two sub-levels could be envisaged.

Figure 7. Definition of levels of automation in inland navigation, by CCNR (2018)

- Besides communication procedures and protocols there are also technical issues that lead to wrong use of VHF. Boatmasters indicate that selecting the right VHF channel is currently done through personal experience / route competence of the boatmaster, combined with information from direct sight at the proper moment (landmarks) possibly added by looking at onboard ECDIS-displays. Crew indicated during the interviews from the vessel visits that forgetting to switch between VHF channels happens. There is no assistive technology to alert the skipper of the approach to an area with different VHF-channel. Integration of VHF and AIS could help this. For instance, whenever the AIS notices that the VHF channel from the area the ship is currently sailing is not switched on, it could give a warning or automatically change to the channel needed.
- Mostly the position of the VHF controls, including the display indicating the actual channel, is positioned outside the primary or secondary field of view, requiring the helmsman to actively turn his head and look for the visual feedback to check selection of the proper channel. Such a spatial position in relation to the skipper makes is easier to forget to check or adjust.

To sum up, there is a need for improving the VHF protocols that overcome the drift to the contemporary way of shipping, in which there is a hybrid use of technical support systems and direct communication.

Shared language

Most of the respondents (87%) think limited command of a shared language is a (very) important cause of accidents (*Table 3*). In the remarks of the questionnaire, we find that skippers don't speak the language of the country where they are sailing, or don't speak German or English (Appendix 2). During the vessel visits this was confirmed.

- Riverspeak, the ESTRIN standardised communication phrases or the app Le SINCP with standard communication phrases are barely known and not used in practice.
- The current language that is spoken between helmsmen during ship-ship communication should be the native language of the country the ship is sailing in or German language as regulation requires. From observations we learned that not all 'foreign' skippers master the required languages. Interviewed crew mention difficulties in French speaking area, where colleague waterway users, authorities or suppliers do not always master German.
- Most interviewed crew members think English might be a better common shared language in IWT as in daily life there is a natural drift to English in Europe and other partners in the ecosystem of IWT like on sea going terminals are already used to English as shared language.

In conclusion, there is a need and acceptance for one common language in European inland navigation that everybody knows and uses.

Communication with crew on board and culture

About 82% of the respondents indicate that too little or poor quality of communication with the crew on board is a (very) important cause of accidents (*Table 3*). One of the reasons may be the culture onboard, as shown in issue 7 in *Table 3*.

During our visits crew members told us that it takes some time to learn to know each other and to work as a team. Sometimes crews are multilingual, which makes it more difficult. Ship crews change frequently. Once a crew has found its way it changes again. Especially respondents from tanker and passenger vessels reported too little/ bad communication and culture on board as a (very) important cause of accidents (*Figure 8).* On tankers and often in passenger vessels crew is larger than on e.g., dry bulk.

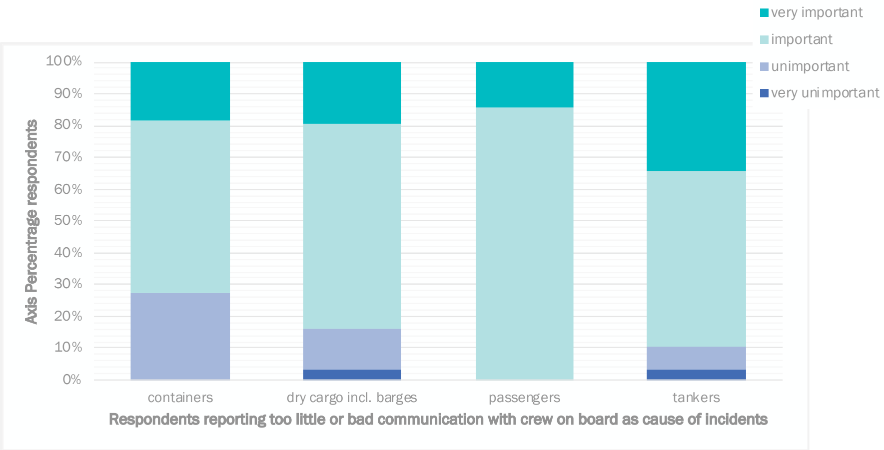
From observations we learned that on some vessels there was a daily meet-up and open logbook for the complete crew where relevant information like maintenance visits, status information of journey is actively shared and administrated in the wheelhouse. However, changes in plans, such as destinations, were usually not always actively shared with the crew during the operation, but only when the crew accidentally entered the wheelhouse.

To sum up, communication on board can be a problem and a cause of accidents. The multilingual character of the nautical world, fast crew changes and a lack of regular team meetings seem to be the cause of this.

Ship-shore communication (office/terminal/suppliers)

36% of the respondents think that too much communication with the office or terminals is an important cause of accidents. It seems that the respondents don't see this as a major issue. Communication via phone between ship and shore can be distractive. However, during the observations and interviews crew explained that an experienced helmsman turns down calls when situations on the waterway require their full attention. In practice, we have seen skippers who assess risks differently from this conservative view and continue to use the mobile phone during manoeuvres.

In conclusion, although skippers use their phone during navigation, they don't experience ship-shore communication as a major cause of accidents.



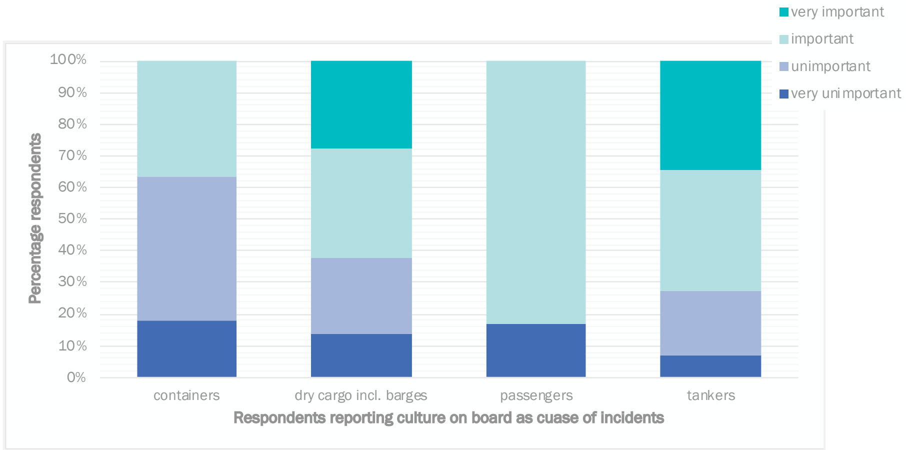


Figure 8: Percentage of respondents categorised per type of cargo identifying too little/ bad communication with on board crew and culture on board as (very) important cause of accidents in inland navigation

Lessons learned from other sectors in communication

- In aviation the standard ICAO standard phraseology is in operation. Standard phraseology reduces the risk that a message will be misunderstood and aids the rad-back/ hear-back process. Errors are quickly detected this way. Ambiguous or non-standard phraseology is mentioned as a frequent causal or contributory factor in aircraft accidents and incidents. International standards of phraseology are laid down in ICAO Annex 10 Volume II Chapter 5, ICAO Doc 4444 Chapter 12 and in ICAO Doc 9432 - Manual of Radiotelephony. Many national authorities also publish radiotelephony manuals which amplify ICAO provisions, and in some cases modify them to suit local conditions. As of 2008 all aviation personnel must pass an English proficiency test; at least level 4 is required and agreed in ICAO standards.
- Additionally for air traffic control (ATC) the dedicated SID/STAR phraseology allows ATC and aircrew to communicate and understand detailed clearance information that would otherwise require long and potentially complex transmissions. Like the drifted VHF use in IWT (and possibly maritime industry also) in aviation drift towards non-harmonised practices also came up. Since 2016 revision of this phraseology is implemented.
- IMO standard 918(22) Marine Communication Phrases contains standardized phrased in English. In 1973, the Maritime Safety Committee agreed, at its twenty-seventh session that where language difficulties arise a common language should be used for navigational purposes, and that language should be English. In consequence the Standard Marine Navigational Vocabulary (SMNV) was developed, adopted in 1977 and amended in 1985."
- European regulation for train operation TSI OPE (2019) offers advice on standardisation on some situations that are common in communication within the railway domain. For safety related communication they use the international NATO alphabet code and numbers to be spoken digit-by-digit ('11' as 'one-one'). In addition, there is not one common language in European rail yet. Drivers are required to speak the language of the country they are driving in at a predefined level. For example, in The Netherlands language proficiency at B1 level is required for train drivers getting their permit to drive (Common European Framework of Reference (CEFR). Where the operating language used by the infrastructure manager differs from that habitually used by the railway undertaking's staff, such linguistic and communications training shall form a critical part of the railway undertaking's overall competence management system.
- We know from other safety critical sectors that there is a strong relationship between culture on board, the quality of teamwork and subsequent communication with crew. This is influencing the mutual understanding of messages and subsequent possible risks during operation. From the questionnaire and the interviews during visits, especially crew from tankers and passenger vessels confirm this cause. This is logical as these crews are usually larger than on, for example self-employed, family-owned dry bulk vessels. But even there, in case of 'foreign' crew, the team approach is crucial in communication and culture (Stanton, 1996).
- In contrast to inland navigation or road transport train drivers in Europe need to periodically demonstrate route competence. This means that the driver has sufficient competence of a particular section of track to be allowed to drive there: location of signals, speed limits, stops, level crossings, signs, (movable) and so on. The driver must learn the route by riding in a cabin or watching an instruction video several times and then take an exam. In order to maintain familiarity, the driver must travel the track regularly (at least once a year) and be aware of any changes, mostly posted and acknowledged via his personal smartphone. Centrally driver's permissions for tracks are logged and combined with manning planning tools (Intergo, 2014).
- In rail, communication by GSM-R is equally important as VHF in inland navigation. GSM-R is a secure platform for voice and data communication between railway operational staff, including drivers, dispatchers, shunting team members, train engineers, and station controllers. It delivers features such as group calls, voice broadcast, location-based connections, and call pre-emption in case of an emergency. The train is automatically connected to the proper GSM-R base station mast. If the modem connection is lost, the train will automatically stop. The train driver has no active interaction or supervision with GSM-R during the journey. In addition, in The Netherlands it is regulated that no communication by GSM-R or any other mobile phone, is allowed while driving with a speed <40 km/h (except for alarm calls) because of limitations in the automatic train protection systems below this speed.

- Like in all sectors, management characteristics and leaders set and determine the safety culture on the workplace (Broadhurst 2017). Employee's perception of leaders' commitment to safety predicts employees' attitude to discuss operational risk issues in the workplace. Reflecting on IWT this would not only affect the boatmaster, being the leader on board. In case of larger companies, we also distinguish leaders onshore.
- High reliability organisations, effectively handle the enduring tension between commercial production and protection:
  - *production*, making profit, makes money and is easy to measure;
  - *protection* of operational risks costs money and is difficult to measure.

  Business pressure can put organisations to adjust financial management: to cut costs and corners and a catastrophe/ accident is often followed by more protection like tighter procedures, compliance, and regulation. James Reason (1997) explains that organisations with a chronic sense of unease, which is typical for high reliability organisations, are more successful in production as they are constantly aware of (financial) risks. Low reliability organisations focus more on past success rather than on future failure. By balancing financial and operational risk management, one can confine the operation within the safe profitable operation zone between.

Commercial and financial pressure on a company is likely to be a key reason for perceived on board pressure, confirms Broadhurst et al. (2017).
Since 2013, ICAO and in rail from EG directive it is required all states to establish a state safety program, suggests that all service providers in the ecosystem must formulate their own safety management system.
In 2010 the International Maritime Organization (IMO) made significant changes to the International Standards for Training, Certification and Watch keeping (STCW) requirements. These included the introduction of mandatory training at an operational and management level in human factors/ human element, leadership, and management (HELM) in 2012.
Seen from another communication perspective Puisa et al. (2018) revealed from an analysis of 188 maritime incident and accident reports that deficiencies in design and manufacturing - where safety hazards are overlooked - are an important systemic root cause in combination with inadequate communication by designers of those design limitations to the company, subsequently leaving unattended in the company's safety management system. Especially in combination with inadequate regulatory function by classification societies these situations will lead to different operation of the ship as was assumed during design.

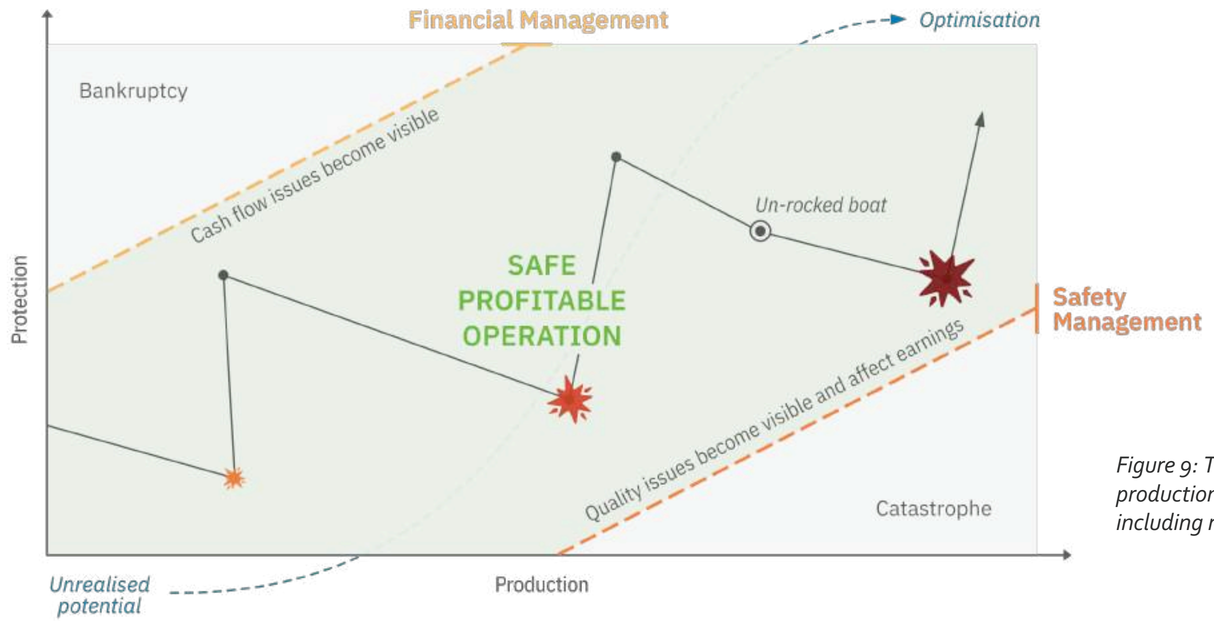


Figure 9: The safety space zone, balancing between production implying risks of bankruptcy and protection including risks of catastrophes (after J. Reason 1997)

4.3 Evidence based recommendations

The results of the study verify that communication is seen as an important cause of accidents. Specifically, the poor ship-ship communication, the lack of a shared language, culture in company and on board and the wrong use of the VHF channel are rated of high importance and confirmed during the observations and interviews. Organisational elements that determine on board communication also influence the other main risks qualification and fatigue/ stress.

1) There are ample indications that lifelong personal development has advantages from safety, health, and operational perspective. Mastering management and entrepreneuring is critical for controlled/ robust and resilient operations. Emphasize the importance of team cooperation in ship crews during education and training for optimal communication. For example, develop short training methods for crews to learn to know each other or develop daily crew start-up meetings to discuss the journey and the daily work. ***[Level of evidence: H]***
2) Update communication protocols with proper standard phraseology. Additionally, develop training for its use and make sure feedback on quality of communication will soon be part of periodic retraining and coaching of all crew and involved communication partners.
   Consider the use of supportive systems and possible risks of (over) reliance on ECDIS and AIS information. At the same time protocols should be sufficient for vessels with minimum or defect equipment. ***[Level of evidence: H]***
3) Shift to one shared European nautical language that is obligatory in European interconnected waterways in order to meet internationalisation effects in multilingual and frequent changing crew. Partners in the ecosystem of inland navigation like for example terminals, traffic management, maintenance support, or lock and bridge operators shall be considered too in determining the proper language in order to understand each other's goals and risks. Additionally, set an adequate proficiency level including possible periodically refreshment trainings and certification. ***[Level of evidence: H]***
4) Incorporate ergonomics and human factors knowledge in design guidelines for wheelhouses design and HMI (human machine interface) considering viewing areas. Provide technical support in optimal interaction, like automated position-based support of VHF-selection. ***[Level of evidence: H]***

5. Root causes qualification of the crew members

5.1 Context from the data and expert analysis

The Sailing for Excellence focus group stressed the importance of competence, training, and experience in phase 1 (Intergo, 2019). Although progress has been made on determining and harmonising required competences onboard depending on exploitation, quality (and sometimes quantity) of personnel is mentioned as a factor involved in incidents. This factor may be a manifestation of recruiting problems for the entire IWT sector and or organisational/ safety culture referring to manning rule breaking behaviour. In this chapter we will focus on qualification. The next chapters will cover fatigue/ stress and specific waterway situations.

5.2 In depth understanding

Table 4 shows the results of the closed questions concerning qualification of crew members. The respondents rated the importance of the item as a cause of accidents (very unimportant, unimportant, important, or very important). The table shows the percentage of respondents that rated the item as important or very important. Appendix 2 contains detailed responses.

Table 4. Percentage of respondents that rated the specific qualification subitems as an important or very important cause of accidents

Items qualification	%
1) Limited skills on board	94%
2) Bad attitude and behaviour	93%
3) Limited knowledge about navigation	89%
4) Limited knowledge about tasks to be performed other than navigation	89%
5) Violation of the rules on board	72%
6) Limited retention training	63%
7) On-board systems	60%

Limited skills and knowledge about navigation

Item 1 (94%) and 3 (89%) confirm that the lack of skills and knowledge on board are rated as important causes of accidents. The respondents note that a lack of experience and craftmanship is seen in other boatmasters. Fresh crew members with limited experience have to perform responsible tasks before they have enough experience. During the visits experienced skippers often mention that crew members have too little practical experience.

Bad behaviour and violation of rules

93% mentioned bad attitude and behaviour as an important cause of accidents, 72% rated violation of rules as in important cause. During the visits, boatmasters mention that people do not go for craftsmanship but work for the highest wages. In this cases work ethic becomes very low and staff is getting careless, not interested. This is also related to aspects of communication and business management (see *Chapter 3*).

Lack of retention training

60% of the respondents rated limited retention training as a possible cause of accidents. From observations and interviews we learned that periodical (re)training and re-examinations are generally regarded as something positive by the visited boatmasters. However, this is mainly done by shipping companies and not by self-employed ship owners. Self-employed mostly only focus on required certificates like ADN. Skippers mention as reason the lack of time and financial resources.

Unavailability of affordable crew members

Respondents and boatmasters during the visits mentioned that it is hard to find qualified personnel and that good personnel are expensive, especially substitute boatmasters. It is hard to find affordable staff. These findings have been confirmed by the thematic CCNR report (2021). This might be a reason that available crew members on board in practice not always have the right qualification. On the other hand, we also interviewed successful entrepreneurs only hiring all round boatmasters irrespective of the task on board or entrepreneurs hiring additional young crew with development forecasts.

On-board systems

More specifically, 60% think that a major cause of accidents is the limited knowledge about working with automation. During the visits experienced boatmasters mentioned that young boatmasters tend to rely too much on on-board systems. In phase 2a of this research we concluded that for on board crew, regardless the degree of experience, there is a risk of over-trust due to a false sense of safety using new technology (Intergo, 2021). This is related to the (believed) reliability of information, knowledge of systems and possibilities to calibrate automation information on real world (see also *Chapter 7*).

5.3 Lessons learned from other domains

Training and retention training

- Puisa et al. (2018) revealed from an analysis of 188 maritime incident and accident reports that deficiencies in the safety management systems, such as insufficient training or inadequate feedback to the company etc. were the most frequent contributing causes behind analysed accidents and incidents. OCIMF (2018) published a guide to best practice for navigational assessments and audits. This initiative is a good example of a first step for future obligatory certification requirements in inland navigation.
- In rail, the competencies are defined at European level, permitting member states to fill in their education programs. Train drivers have to practice scenario's every year in a simulator and are coached by an instructor. In some cases, train drivers' performance is assessed and judged. Managing mental underload is part of retraining.
- The same goes for pilots, who must practice flying manoeuvres in a simulator.

Team training and leadership

Among the various studies on Leadership, Zaccaro et al. (2001) reported that the leadership aspects that affect group performance are: active participation of the team leader and of all the other team members, definition of group's direction and the attempt to organize the team as to maximize team development, respect from other team members; awareness of one's own strengths and the willingness to respect the other team members and their role, encouraging open communication, including the discussion on the team's goals and on expectations about performances, which lead to commitment and consensus within the team. As a matter of fact, it was demonstrated that good leadership is important for safe performance in the workplace (e.g., Hofmann and Morgenson, 2004; Glendon et al., 2006). Some studies found that team skills are identifiable and can be trained (e.g., Cannon-Bowers and Salas, 1998). Flin et al. (2003) showed that cooperation does not refer to job characteristics, such as quality or quantity of job outcomes, but that good cooperation originates from an open and active communication among the team members.

Crew Resource Management (CRM) Training can help to enhance team performance. CRM training is common in the aviation domain. The objectives of CRM training are:

- To enhance crew and management awareness of human factors that could cause or exacerbate incidents that affect the safe conduct of (air) operations.
- To enhance knowledge of human factors and develop CRM skills and attitudes that, when applied appropriately, could extricate an aircraft/ship operation from incipient accidents and incidents, whether perpetrated by technical or human factor failings.
- To use CRM knowledge, skills, and attitudes to conduct and manage aircraft/ship operations, and fully integrate these techniques throughout every facet of the organization's culture to prevent the onset of incidents and potential accidents.
- To use these skills to integrate commercially efficient aircraft/ship operations with safety.
- To improve the working environment for crews and all those associated with aircraft/ship operations.
- Finally, the main goal of CRM is establishing a common "corporate safety culture" within the company.

Safety awareness training

Safety Culture is the way safety is perceived, valued, and prioritised in an organisation. It reflects the real commitment to safety at all levels in the organisation. It has also been described as "how an organisation behaves when no one is watching".

One way to improve safety culture is to create safety awareness among crew members by changing attitude, behaviour, and communication. This can be accomplished by doing safety awareness trainings.

5.4 Evidence based recommendations

The results of the study verify that lack of qualification is seen as an important cause of accidents. The respondents rate poor skills and knowledge about navigation as important causes. Additionally, poor knowledge about automation tools is seen as another cause. To sum up, underlying causes are:

- A lack of retention training and experience.
- Qualified personnel are not available.
- Qualified personnel are not affordable.

As a result, ship owners often choose for less qualified and experienced personnel. This might be the reason of the rule braking behaviour (because they don't know the rules) and less sense of safety and urgency that respondents experience. Safety awareness and team coherence training may also be an underlying cause of bad attitude and rule braking behaviour.

We recommend the following to improve the qualification of crew members.

1) Develop a shared vision on lifelong development including management and entrepreneuring, which are critical for robust and safe business at the same time.
2) Investigate whether, and to what extent, incentives are desirable so that all crew members, irrespective their experience, engage in continuous development in a structured and periodic manner on the topics listed in these recommendations. The apprentice should be supervised more while sailing and more practice should be integrated into the standard education. In the best case, the minimum number of practical hours should be harmonised across Europe.***[Level of evidence: M]***
3) Periodically Retention training e.g., in simulator environments learn boatmasters to deal with complex or unexpected conditions or production related challenges like energy efficient sailing. Therefore, we recommend encouraging or oblige (experienced) crew members to perform periodically retention trainings.
   - Encourage ship owners and staff to periodically organize a CRM (crew resource management) training to improve the team coherence and the importance of safety on board and in the organisation. This should include themes as safety awareness and business operations. Also involve partners in the ecosystem into trainings of safety awareness and business operations including human factors organisational aspects. ***[Level of evidence: H]***
   - Explore quantification of developing and maintaining route competence. ***[Level of evidence: H]***
4) Safety awareness training should be emphasized during education and be part of the team training when preparing a partly new crew for a journey. Therefore, we recommend performing safety awareness trainings. ***[Level of evidence: M]***
5) Qualification for entrepreneurship. This can be achieved by encouraging ship owners to maximize their business operations by periodically doing additional masterclasses necessary to rise above the minimum level, preferably by successful peers. ***[Level of evidence: H]***

6. Fatigue and stress

6.1 Context from the data and expert analysis

In this chapter we focus on fatigue and stress. From the data and expert analysis (Part 1 of this study) we concluded that fatigue in itself or as contributory factor is involved in many incidents. Based on one rich database (the SOS-database) fatigue was identified as root cause in 9% of all incidents. Fatigue was also mentioned by the Sailing for Excellence focus group as an important factor. It may be the result of rostering and workload.

Also, the Sailing for Excellence focus group explicitly demanded attention for organisational culture. The role of barging operators, planning, the situation at terminals, administrative processes, and journey preparation may cause a high operational pressure that increases workload, distraction and possibly fatigue of boatsmen.

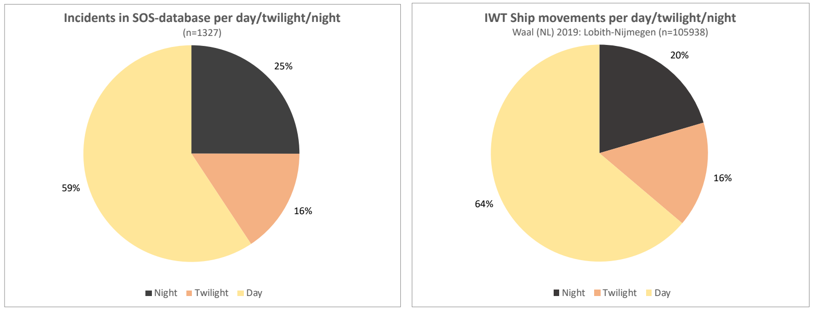


Figure 10: Incidents during day, twilight and night left shows the proportion of incidents; right shows the number of IWT traffic on river Waal. (Source: Intergo 2020).

Time of day is associated with incident risk (*Figure 10*). Analysis of the SOS-database (NL) showed higher risk in the early morning, after lunch, evening, and around midnight. These risky hours are not unique for inland navigation. They are associated with biological and social (evening hours) factors and are thus related to fatigue and distraction and even related to safety awareness.

The next chapters will cover specific waterway situations.

6.2 In-depth understanding

Table 5 shows the results of the closed questions concerning fatigue and stress. The respondents rated the importance of the item as a cause of accidents (very unimportant, unimportant, important, or very important).*Table 5* shows the percentage of respondents that rated the item as important or very important. The questionnaire's results confirm the importance of fatigue and stress. Distraction by media is rated as main cause, followed by a sub-optimal work-sleep rhythm, multitasking, and doing too many tasks by the same person. Besides that, respondents mention the many working hours and external pressure as important causes. Appendix 2 contains detailed responses.

Table 5. Percentage of respondents that rated the specific subitems of fatigue and stress as an important or very important cause of accidents

Items fatigue and stress	%
Distraction by social media (tv, smartphone/ tablet, radio)	80%
Crew fatigue on board due to sub-optimal work-sleep rhythm	77%
Multitasking in the wheelhouse (navigation, administration, planning, etc.)	75%
Too many tasks at the same person	68%
Pressure of barging operators	67%
Administration and paperwork	64%
Waiting times at terminals and ports	49%
Boredom	40%

Distraction by media

Vigilance is a predominant character of sailing, and thus a root cause. Vigilance includes a big risk that concentration drops after a while, or the distraction will take place. In practice several ways for dealing with vigilance exist.

- Most of the questionnaire respondents (80%) mention distraction by social media as (very) important cause for accidents in the category items (*Table 5*). Social media included use of tv/ private use of smartphone/ tablet, radio).
  - 40% of the respondents report no TV in the wheelhouse (*Figure 11*). Also, during the observations and interviews in the field on 4/10 of the vessels we found a TV in the wheelhouse (Appendix 1). Most mentioned reason for not having a TV in the wheelhouse is safety.
  - The improper use of mobile phones/ tablets or laptops during sailing is in practice less manageable but occurs even so like watching TV. Use of social media is mostly more engaging than watching TV
- During interviews all skippers reckon vigilance decrement is a serious issue during navigation in dark, calm areas or during limited sight. Some boatmasters indicate that they watch TV talk shows that they can easily neglect during monotonous stretches. They feel that films require too much attention as a 'side task'.

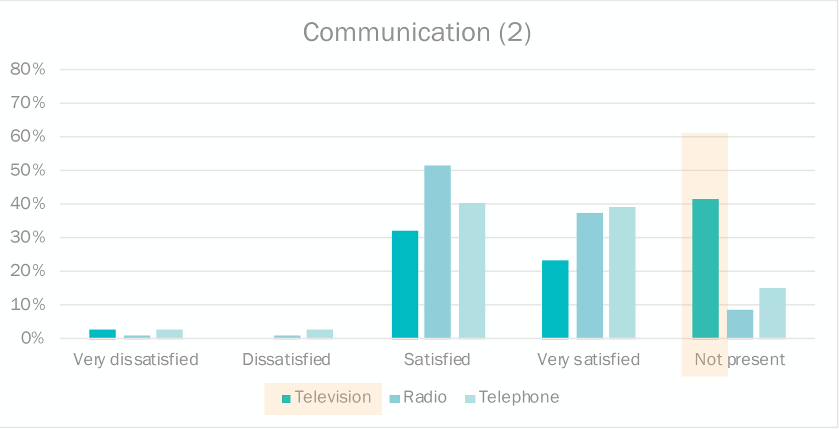


Figure 11: Percentage of respondents indicating (dis)satisfaction about the position of television, radio, and phone in the helmsman stand, also learning that 40% of respondents does not have a television in the wheelhouse

- On hotel vessels it is convention to invite an additional crew member whether from navigation crew or hotel crew in the wheelhouse for small talk during the difficult night hours to overcome vigilance decrement. From other boatmasters – irrespective of cargo type – we learned they also invite a 2nd crew member in the wheelhouse in difficult areas to assist navigation. As a remark, we observed however, most vessel layouts do not facilitate the presence of a 2nd crew member/ an 'assistant' at the helmsman stand (see Report phase 2a).

Exploitation mode and crew fatigue

The majority (77%) of the respondents mention crew fatigue is (very) important as a risk factor for accidents *Table 5*)). From the research we cannot explain the difference between respondent's reaction over countries (*Table 6*).

The questionnaire's result showed a relationship between exploitation mode, type of cargo, number of working hours and quality of rest.

- Crew sailing in A1 exploitation mode report long consecutive hours of navigation at the helm per day of navigation, some of them even longer than regulatory allowed (>14h). According to §3.10 RPN, a vessel operating in A1 mode is entitled to navigate up to 16 hours once per calendar week. About 50% however (18/ 38 respondents) are sailing max 8h consecutively (*Figure 14*).

INTERGO

Country	Communi-cation	Qualification of crew	Specific situations waterways	Fatigue & Stress	Grand total
NL	13	17	4	12	46
• Unknown				1	1
• Boatmaster	9	11	3	8	31
• Employee shipping company	2	2			4
• Helmsman				2	2
• Ship owner	2	4	1	1	8
DE	12	10	1	1	24
• Unknown	2				2
• Boatmaster	6	3	1	1	11
• Employee shipping company	2	1			3
• Helmsman		1			1
• Ship owner	2	5			7
BE	1			2	3
• Boatmaster				2	2
• Employee shipping company	1				1
• FR		1		1	2
• Boatmaster		1		1	2
CZ	1				1
• Boatmaster	1				1
PL				1	1
• Boatmaster				1	1
SK				1	1
• Boatmaster				1	1
Other				1	1
• Boatmaster				1	1
Grand Total	27	28	5	19	79

Table 6. Fatigue ranked by respondents as primary cause of accidents, categorized per country and role of respondents.

- In A1 and A2 exploitation modes 22% of the respondents (14/ 63) report rest periods of max. 6 hours, while in B-mode this is only 9% of the respondents (2/22) *(Figure 14)*.
- In A1 mostly dry cargo is represented and in A2 most dry cargo and containers (*Figure 12*). In dry cargo and to some extent also in container transport, most respondents live on the vessel, where work and private time may overlap (*Figure 13*). In container and tanker sector short, 1-week on/ off turns occur, whereas the majority has 2 weeks on/off turns. From the TASCS-study (Intergo, 2019) we know that most 'foreign crew' is on board for longer periods of time (4-12 weeks). During longer periods of time on board, the risk of recovery from fatigue may be larger.

From the observations and interviews we learned that a good night rest of 8h is regarded by many boatmasters to be essential. The observations confirmed the questionnaire's results. Boatmasters that sail for a shipping company more often report an 8h-9h working day. For self-employed ship owners we noticed that working hours are generally longer, outliers range from 14h to 18h a day.

Earlier during the TASCS-study (Intergo, 2019) we learned that on vessels with smaller crew a much more organic way of starting and ending shift times occur, with – depending on the boatmasters philosophy – more or less flexibility and supervision of the frequency/duration of interrupted sleep. This kind of flexibility is heavily related to pressure.

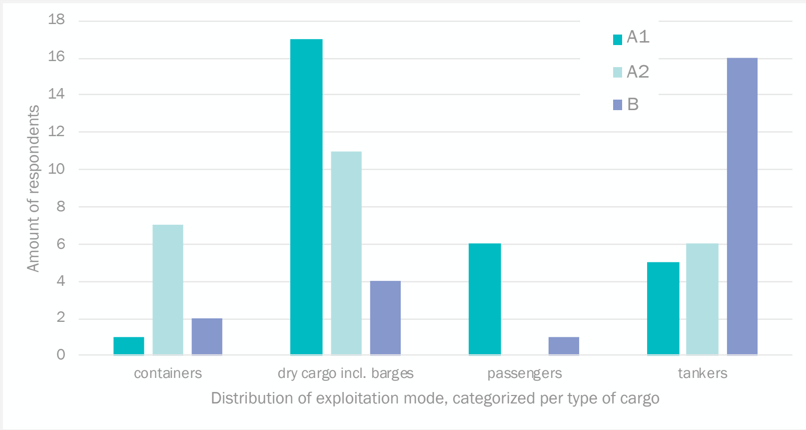


Figure 12: Distribution of respondent's exploitation mode, categorized per type of cargo

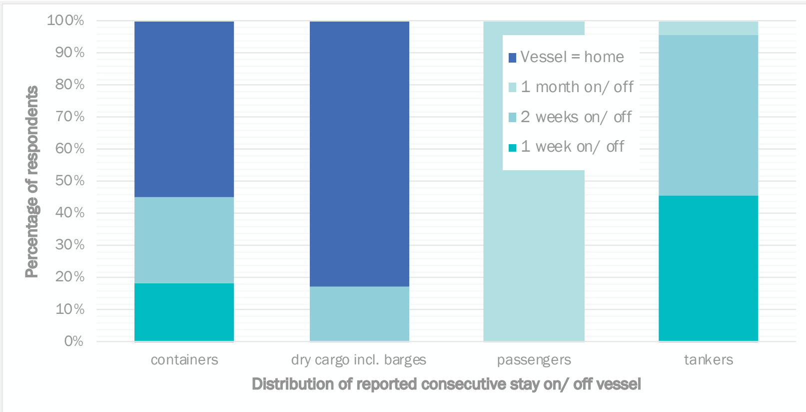
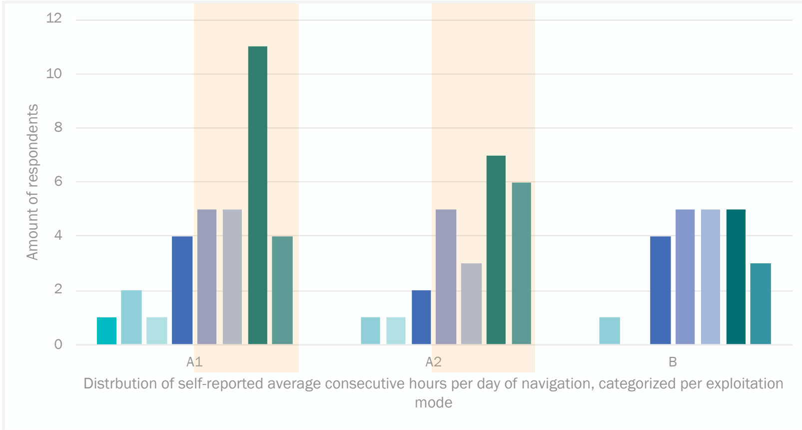


Figure 13: Distribution of respondent's consecutive stay on and off their vessel.



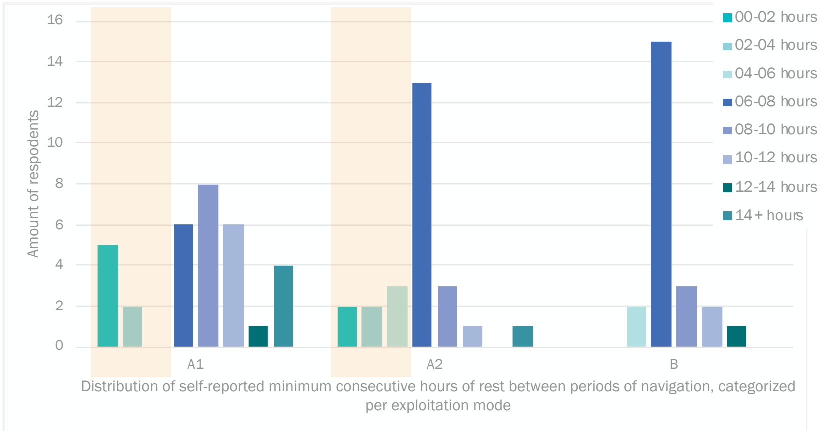
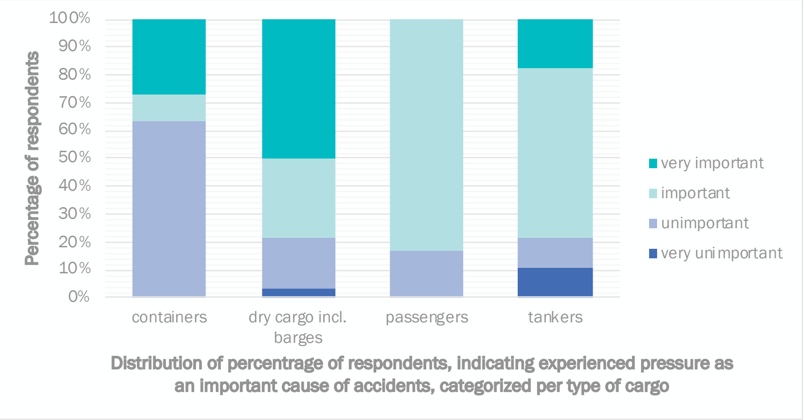


Figure 14: Distribution of self-reported average consecutive hours per day of navigation per exploitation mode (up) and distribution of self-reported minimum consecutive hours of rest between periods of navigation (below), both categorized per exploitation mode

Pressure

Vessels and crew are part of complex ecosystem, including terminals, ports, clients etc. Boat masters are end responsible for safe operation and safe navigation, but the supply chain is not always closed. If the loading or unloading is delayed or the cargo sold to another party, the ship and crew just must wait or adjust to route B. At the same time, the boat master must be on time at the next destination and guard the wellbeing and safety of the crew. This puts pressure on the crew, for example because they have to make extra working hours to be on time or to postpone the rest period outside regulatory boundaries (manning rule breaking). Obviously, this 'flexibility' affects also fatigue and leads to feelings of stress.

- Much of the respondents' experience stress, whether by multitasking (75%), pressure from barging operators (67%) or administrative burden (64%) (*Table 5*). From (*Figure 12*) we learn there is a difference between type of cargo, tankers suffering more from stress by pressure and administration.
- Some of the interviewed self-employed ship owners experience financial stress. If they do not sail, they are not generating income. This pressure causes time problems which can lead to boatmasters not taking enough time to e.g., properly prepare for their next journey in advance. In addition, this stress may cause boatmasters to sail under challenging (weather) conditions in which they normally would not sail. On the other hand, we also interviewed some very successful self-employed ship owners that manage to be in control of planning, finance, their own strategic choices in quality of boatmen recruited, work-rest schemes and facilitating on-board technology. In general, lifelong personal development, like in entrepreneuring and mastering (business) management, is not considered as an opportunity in the sector.



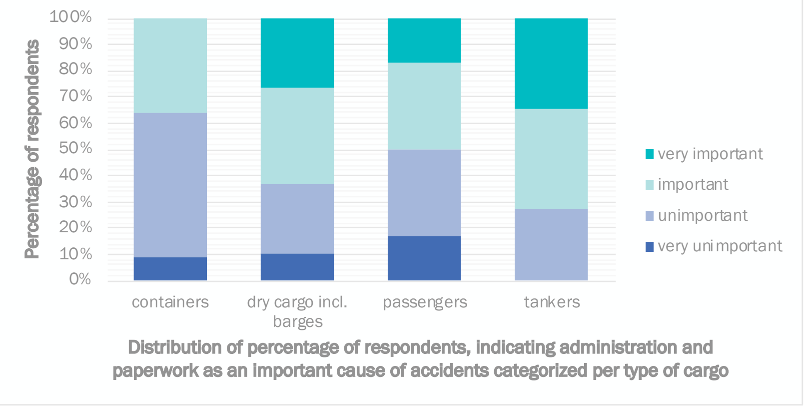


Figure 12 Distribution of respondent's reaction on stress from pressure and administration as an important cause of accidents, categorized per type of cargo.

Lessons learned from other sectors in fatigue and stress

- Commercial pressure/ production pressure has been a causal factor in many catastrophic incidents in various industries. Contributing factors are poorly designed workload policies of the organisation, inadequate staffing, last minute changes in schedules, long work hours and lack of an effective safety culture. External elements like market competition or very demanding performance targets by regulator may put pressure on the organization and its personnel. Safety affecting effects are 'cutting corners' attitude, mistrust between operational personnel and management, loss of staff motivation.
- From amongst others road transport research, it is known that fatigue has the same kind of effects on safety as substance abuse. In general fatigue is not an operational risk that receives much attention in inland navigation.

In general, based on state-of-the-art literature, on a working day everyone needs at least on average 8hr of uninterrupted sleep of sufficient quality on a daily basis to recover from work in order to prevent fatigue-related problems and guarantee proper performance and thus proper navigational safety. The average of 8 hours is the value between the minimum of 7 hours and occurring need for sleep of 9 hours. This variation is based on individual characteristics. Prolonged rhythms with 6h of consecutive rest hardly result in sufficient sleep as also is recognized in literature (e.g., Intergo, 2019; MCA, 2010). Personal, biological differences in sleep needed do exist.

- Fatigue is a major factor in a large proportion of road crashes (10-20%). Fatigue is associated with increased crash risk: driving after being awake for 17 hours results in a risk of crashing equivalent to a 0.05 blood alcohol level (i.e., twice the normal risk).
- Not only work-rest schemes may contribute to fatigue. Driver vigilance decreases during driving on a monotonous stretch is an expression of fatigue.
- People are poor judges of their own level of fatigue, performance, and decision-making (several sources, e.g., SafeNet, 2009).
- Fatigue induced accidents can be recognised from missing corrective actions, witnesses reporting drifting prior to the crash, person alone in the cabin, problems occurring late night/ early morning or mid-afternoon, and absence of other likely causes like mechanical defects, substance abuse or bad weather (several sources, e.g., SafeNet, 2009).
- Minimum requirements in work and rest times differ in European transport *(Table 7)*. IWT is less strict than in rail or road transport.

Table 7: Summary of some work-rest characteristics in regulation for four transport modalities in Europe

	IWT	Maritime	Rail	Road*
Max h of work	• 14h/ 2h4 • Max. 31d consecutively	• 14h/ 2h4 and 72h/ 7d	• ≤9h/ dayshift OR • ≤8h/ nightshift. • 80h/ 2weeks	• ≤4,5u consecutively on route. • 9h/ 24h (twice a week 10h/ 24h) • 56h/ wk. OR 90h/2 wks.
Min h of rest	• ≥10h/24h • ≥77h/ 7d.	• ≥10h/24h • ≥77h/ 7d + hours of rest can be divided into 2 periods, 1 of which ≥6h and interval between rest ≤ 14h.	• ≥12h at home/ 24h or 9h once/ 7d. • ≥8h/24h if away from home.	• 45 min break after 4,5h driving (may be split into 2 pauses of 15+30 min). • 11h/ 24h, may be split in 3+9h (3x/ wk.)

*: Reinforcement via tachograph

- In transport the attention to fatigue differs.
  - In 2018 IMO provided fatigue guidelines and exemplary monitoring tools for maritime industry (MSC1598). IMO acknowledges accident rates rise exponentially after 12 hours of consecutive work, particularly when working at night. The Australian Maritime Safety Agency (AMSA) published fatigue guidelines, classifying amongst others:
    - <9h hours of work per 24h leading as lower risks, 10-12h/ 24h as a significant risk and >12h/24h as a higher risk;
    - >12h rest between duty periods as lower risk, 7-12h as significant risk and <7h as higher risk (AMSA, 2020).
  - A recent study among truck drivers revealed that 25-30% of professional drivers had fallen asleep while driving at least once in the previous twelve months. 88% from the truck drivers and 66% of the bus/ coach drivers reported working more than 40h per week and a significant number of drivers more than 50h/ week (Vitols & Voss, 2021). Unions are asking for measures with impact.
  - In European rail, additional to the minimum work-rest requirements, fatigue management systems, like Fatigue Risk Index (FRI) are known and applied. Especially freight transport with larger unpredictability in its operation than in passengers transport apply this knowledge in rostering. In rail, time spent to additional tasks besides driving are included in the counting of work hours a day.
  - In the rail sector increasing automation may cause mental underload ('boredom') of the train driver. The new European Rail Traffic Management System (ERTMS) provides increased safety, but the risk had been identified that drivers become less vigilant on sections where legacy systems are still in operation. Attention for non-technical skills, e.g., in the form of training, is a way to mitigate this risk (RSSB).
  - Practical measures have been introduced in road, e.g., taking (frequent) breaks causing recovery. roads equipped with edge / centre lines that provide audio-tactile feedback when crossed over. However, studies on education on driving fatigue have shown that failing to address the real underlying causes of driver fatigue is a reason why education on this does not necessarily improve alertness of drivers. (SafetyNet, 2009). Optimal business management is key.
- For maritime sector, the British Nautical Institute stresses that the shipowner can make a difference by keeping process issues off the ship. A 'singe point data entry' like at onshore departments in barging companies can reduce workload onboard.
  - Crew should not only be educated in technical aspects but also ethical and managerial aspects.
  - Onboard crew should have the 'right' to make decisions in potentially high-cost scenarios supported in those decisions by knowledgeable staff ashore. Good decisions reflect a right organisations culture.
- Current legislation and reinforcement in European transport may not be enough. Neither road, air, water, or rail transport legislation fully takes fatigue relevant criteria into account yet. Besides prescriptive legislation and strict enforcement of proper crew manning rules needed competences and technical aspects for adequate rest on board, other elements are necessary to obtain the best counter fatigue strategy. Examples are easy/ valid registration means (e.g., tachographs), non-prescriptive guidelines on e.g., organisational measures, education, fatigue management systems and additionally in-vehicle devices that detect fatigue-related decrements in driving (SafetyNet 2009; Vitols & Voss, 2021).
- As also confirmed by the British Nautical Institute (Broadhurst, 2017) for the maritime industry the absence of adequate control from regulators and the natural management pressure towards cost effective operation, can – when occurring simultaneously – lead to less safe operation on the vessel. However, the impact of company policy is larger than the regulator's impact because the communication frequency from company to vessel is higher than the communication frequency between company and regulator (Broadhurst e.a. 2017).

6.3 Evidence-based recommendations

- Develop an integral perspective on navigation and crew manning, taking care of human factors aspects that aim for optimal system's performance (including operational risk and safety) and wellbeing. Fatigue should be an integral part. ***[Level of evidence: H]***
- More up to date regulation could prevent that the burden of delays will be on the shoulders of the carrier. There should be a distributed responsibility in a more closed supply chain loop. This distributed responsibility might help speeding up the development of smart supportive systems that relieve the administrative burden. ***[Level of evidence: M]***
- Continuous, lifelong personal development of boatmasters is not considered as an opportunity for operational risk and business management. Masterclasses e.g. by successful peers, for learning to master management and entrepreneuring including non-technical skills training and inland navigation business will lead to more robust management implying less operational risks and better safety. ***[Level of evidence: M]***
- Develop a shared vision on the use of social media and tv during safety critical tasks like navigation. Non-task related systems, like social media including TV may distract from the tasks and their related systems at the helmsman's position. Take vigilance decrement into account during monotonous stretches or future monotony in case of technology assisted sailing and remote operation. Captains and ship owners should be aware of this and take this into account when forming a competent crew. During a shift on board crew members should be able to alternate the navigation task. This requires a competent crew, acquired during sustainable business management. ***[Level of evidence: H]***

7. Specific waterway situations

7.1 Context from the data and expert analysis

Specific waterways situation refers to aspects in the infrastructure and sailing area and navigating in weather/ cruising conditions that might create a risk for accidents in inland navigation.

In Phase 1 of the research the Sailing for Excellence focus group indicated that the quality of infrastructure in Europe differs and is often not up to date. This may lead to insufficient situation awareness: the skipper is not fully aware of a risk because s/he does not have adequate information. For instance, water level gauges are not uniform, and they are often missing skippers have to deal with different indications of the same information depending on the country they are navigating in or have lack of information.

The Sailing for Excellence focus group thought that navigating in fog was the riskiest circumstance. Data analysis on this is impossible with the supplied databases and documents. Also, a relation with organisational/safety culture was mentioned: perhaps navigating in certain heavy weather circumstances isn't a good idea at all, despite all electronic assisting devices.

7.2 In-depth understanding

Table 8 shows the results of the closed questions concerning specific waterway situations. The respondents rated the importance of the subitems as a cause of accidents (very unimportant, unimportant, important, or very important). The table shows the percentage of respondents that rated the item as important or very important.

Table 8. Percentage of respondents that rated the specific subitems on waterway situations as an important or very important cause of accidents

Items specific situations	%
Limited familiarity with the sailing area and infrastructure 'en route' (ignorance)	91%
Pressure to sail in bad weather/cruising conditions	76%
High complexity waterway infrastructure	70%
Limited quality and visibility of information outside about waterway infrastructure	68%
High pressure on load factor (e.g., draught)	68%
Limited or not user-friendly digital waterway information	62%
High familiarity with the sailing area and infrastructure 'en route'	64%

Route competence

Route competence is considered very important, especially during challenging weather conditions. However, a boatmaster must be aware that this situation awareness can also cause a lack of attention. The other side of the coin from sailing in a very familiar area is sailing on the so called 'mental auto-pilot'. One is not being aware of the circumstances in real world but is (over)trusting in the believed reality based on expectations that are based on day-to-day experience.

From interviews we know route competence is the most important factor in whether the boatmaster creates a route planning. If the stretch has been sailed many times, then there is most often no explicit route planning. The other way around, if it is a new stretch then a proper route planning is key. However, the quality differs from systematically planning with help of e.g., ECDIS to – in most cases - calling colleagues and organically asking for 'what should I look after in that area'? See also paragraphs on ship-ship communication (*Chapter 3*) for the influence of assistive information on performance and risks.

Route planning

When the stretch is known boatmasters do not conduct a route planning. For unknown stretches a route planning they acknowledge is more important. Key factors looked at in practice are bridge heights, water levels, berthing places and sometimes the 'ship messages'. However interviewed skippers do not read published shipping notices and mostly rely on banner at locks for announcements of possible works. We learned that vessels from larger companies often do have an explicit and structured route planning with aids like ECDIS.

Information availability and reliability

Boatmasters complain about water levels not being easy to find. The way water levels need to be found change per stretch and occasionally the website or apps that needs to be used is not up-to-date or not user friendly. Water levels are communicated once per 24h. We know examples from especially ship-infra allisions where within 24h water levels had raised so much that situation awareness was not in sync with real world and the vessel was too high for passing the bridge.

In addition, waterway owners sometimes share unreliable information skippers experience (Dutch safety board, 2018).

Infrastructure

Kooij et al. (2020) learned from their interviews with skippers that crossing several bridges in a row is experienced as risky. The skipper can estimate the height of the first bridge with direct vision. Skippers find it more difficult to estimate the height of the next, lower bridge with direct vision. If there are also scaffolding structures that are difficult to see on the underside of the bridge, which limit the clearance, the risk of a collision is high.

Clearance margins

In practice skippers apply their own clearances e.g., for passing bridges. During vessel visits we heard from some skippers they are applying small marges like 15 cm above the highest vessel point passing bridges, in dry cargo and container transport. If needed, they can pass with less clearance including use of practical tricks like increased propulsion to pull the boat under the bridge while in the meantime paying attention that no other ship is passing at the same time, that produces a higher water level.

Weather conditions

We learned from the interviews that self-employed ship owners are more pressured into sailing during bad weather then boatmasters sailing for a shipping company. On the one hand this is because of financial pressure not allowing the self-employed boatmaster to not sail. On the other hand, the pressure of the supplier to keep the client satisfied results in the supplier pressuring the boatmaster to deliver the goods according to plan. Boat masters are end responsible in the open loop supply chain. If the loading or unloading is delayed, the ship just must wait. On the other hand, the captain is responsible for being on time at the next stop. This puts pressure on the crew to sail under difficult conditions. This is confirmed by questionnaire results indicating that 70% of the respondents experience "pressure to sail in bad weather/ crusing conditions" as an important cause in incidents within this main risk category. Important to note here is that this is an observation from the boatmasters that we visited expressing their view on less experienced boatmasters. The visited boatmasters themselves did not experience this problem because they said they knew when to say 'no' to a journey. At the same time, we know interviewed skippers who said after a storm that they would not take that risk again the next time.

Experiences from other domains

In maritime sector there are clear recommendations with minimum requirements for passage planning. This is also defined in IMO A.893, including aspects as:

1) safe speed,
2) necessary speed alterations en route,
3) minimum clearance required under the keel in critical areas with restricted water depth,
4) positions where a change in machinery status is required,
5) course alteration points,
6) use of ships' routing and reporting systems and vessel traffic services,
7) considerations relating to the protection of the environment; and
8) contingency plans for alternative action in the event of any emergency necessitating abandonment of the plan.

In rail several sources for modelling the 'golden standard' in driving behaviour considering safety or energy efficient driving exist. A few companies are making their own developments in the area of driving monitoring and advice, but there is no national or European trend yet. In addition, individual route competence requirements are defined and monitored (see *Chapter 3*).

Area and infrastructural information are double checked in rail before publishing to and shared with stakeholders. Train drivers get individual messages they have to read and acknowledge before driving. In addition, it should be noted that the number of messages can be high after a weekend/ period of time free implying that drivers do not actually read these messages but just tick-off in their PDA.

In aviation regulation for acknowledging changes is stricter.

7.3 Recommendations specific waterways

The importance of specific waterways is verified by the questionnaire and the observations. Limited familiarity, the pressure to sail and the complexity of the infrastructure are rated as most important. Also, here we notice a higher experienced pressure for self-employed boatmasters because of financial dependency.

- Apprentices should be supervised more while sailing and more practice should be integrated into the standard education. In the best case, the minimum number of practical hours should be harmonised across Europe. ***[Level of evidence: H]***
- Encourage boatmasters to plan their journey carefully, especially when sailing in unknown waters or under bad weather conditions. The quality and accessibility of waterway information should be improved. Besides that, it should be clear to the boat master when information is not reliable (e.g., outdated, incomplete). This should be shown in the way information is presented on the displays (see also report Phase 2a). ***[Level of evidence: H]***
- Develop agreed safe clearance sector conventions, ready to use during operation and for integration in supportive systems, like for above the wheelhouse and under the keel (see also report Phase 2a). ***[Level of evidence: M]***
- There should be rules which prevent that the burden of delays will be on the shoulders of the carrier. There should be a distributed responsibility across supply chain partners. ***[Level of evidence: M]***

8. Conclusions and recommendations

Based on data and expert analysis of accidents in European IWT, combined with in-depth study by questionnaires, interviews, and live observations during sailing we have summarised the organisational root causes for accidents in European IWT and added recommendations for organisational issues in this chapter to mitigate the associated risks in the future. The recommendations are shown in *Table 9*. The next challenge is to translate the recommendations into concrete measures and implementation. This doesn't happen overnight. We recommend an integral approach.

8.1 Summary of recommendations

The detailed findings and recommendations from the previous chapters 4-7 can be summarized into five root causes with associated recommendations. Some are related to technical root casuses which are also included in the Phase 2a report of this study focusing on root causes *HMI & Wheelhouse design*.

Table 9. Recommendations organisational aspects

Root cause	Recommendations
1) Ship-ship communication is not optimal, leading to (potential) errors in transferring, receiving and interpreting information, overtrust in information/ automation and a false sense of safety and to (potential) errors.	***Update and improve protocols and guidelines on VHF communication in inland navigation.*** The following issues may be incorporated: • Shift to one shared nautical language that is obligatory for all communication partners in the IWT ecosystem to meet internationalization effects in the sector. • Update communication protocols with proper standard phraseology, train all partners in the IWT ecosystem and enforce. Take into account the use of supportive systems and possible risks of (over) reliance on ECDIS and AIS information. At the same time protocols should be sufficient for vessels with minimum or defect equipment. Additionally, set an adequate proficiency level including (periodically refreshment) trainings and certification. • Location of VHF communication and supportive IT in the wheelhouse within proper human fields of view and areas of reach, possibly accompanied by automation position-based VHF channel selection (see report Phase 2a).

Root cause	Recommendations

2) Lifelong personal development is not considered as a need for sustainable and safe operation including communication and fatigue & stress.	***Develop an integral vision on appealing lifelong personal development on mastering management/ entrepreneuring and nautical skills before setting out a strategy and developing measures like policies or guidelines.***
	The following issues may be incorporated:
	• Encouragement of ship owners, boat masters, barging operators etc. to maximize sustainable business operations by excelling in entrepreneuring. Operational risk management should be part of it with a.o. advanced safety awareness trainings to provide staff and crew with a proper safe profitable operation zone. Manning, decision-making in critical situations like during commercial pressure and planning/work-rest schemes will be optimized, leading to better nautical safety and less stress and fatigue. Successful peers might function as role models.
	• Crew resource management (re)trainings for crew and staff to facilitate team communication, and to meet vigilance and fatigue effects during monotonous stretches.
	• Periodically retraining of:
	    • route competence for crew members and barging operator's staff;
	    • other non-technical skills like managing mental underload.
	• SMART criteria (Specific, Measurable, Achievable, Realistic, and Timely) for building up and maintaining personal route competence in specific areas and managing mental underload during monotonous/ assisted/ remote stretches.
	• The apprentice should be supervised more while sailing and that more practice should be integrated into the standard education. In the best case, the minimum number of practical hours should be harmonised across Europe. Wheelhouse design guidelines might include requirements for (periodically) coaching/ supervision, including requirements for direct sight and necessary instruments, for the coach/ supervisor (see Report Phase 2a).

Root cause	Recommendations
3) The supply chain is open, and captain is end-responsible with little options in control	***Explore possibilities to distribute responsibility across the ecosystem of IWT of time-bound operations with all stakeholders in the IWT ecosystem in a more closed supply chain loop.*** More up to date regulation supports risk-averse production and contributes to the reduction of fatigue and stress. The distributed responsibility might also help speeding up the development of really smart supportive systems for e.g. planning and administration like single point data entry that relieve the administrative burden.
4) The accessibility, reliability, usability and integration of waterway information at the helmsman's position is not optimal and quality of available information to calibrate systems' information is limited leading to (potential) errors in interpreting information, over-trust in information/ automation, ignoring alerts, distraction and a false sense of safety.	***Develop a vision on minimum requirements on availability, reliability, usability and integration of information and automation on the helmsman's position before setting out a strategy and developing measures like policies or guidelines.*** The following items may be incorporated: • Criteria and systems for route planning including minimum safe clearance conventions ready for operation and assistive systems e.g. above the wheelhouse and under the keel. • Use of non-task related systems, like personal social media including TV. These systems may distract from the tasks and their related systems at the helmsman's position. • Easy and valid registration means like tachographs and in-vehicle devices that detect fatigue-related decrements.
5) Opportunities to learn from incidents are limited in European IWT because of limited availability of contextual information in incident reporting allowing understanding of causes.	***Develop a central detailed database for analysing incidents, allowing for analysis of primary and secondary causes. Additionally provide definitions, formats and instructions for mandatory uniform incident registration and analysis.*** (Report phase 1).

8.2 Recommendations – An integral approach

The next challenge is to translate the recommendations into concrete measures and implementation. This doesn't happen overnight.

A major hurdle in the successful implementation of major changes such as we propose is the human element. Knoster's model of change (1991) offers guidance, containing 5 important success factors in a change process (Figure 16). The model also contains the behavioural effects of those involved when such a factor is missing or insufficiently developed. This model illustrates the psychology behind people's reactions to change and provides insight into directions for improvement.

An integral step-by-step approach must be applied for implementing the recommendations, with attention for technology, organisation (including leadership and strategy) and people. Careful interaction with stakeholders and experts is required and solution packages should be defined. This increases the chance of achieving the objectives in a steady and supported manner. The approach should be described in a roadmap. We recommend developing this roadmap together with the relevant stakeholders within the European nautical field.

LEADERSHIP AND STRATEGY						PEOPLE AND RESOURCES				EMPLOYEE BEHAVIOUR
Vision	+	Incentives	+	Action plan	+	Competences	+	Resources	=	CHANGE
	+	Incentives	+	Action plan	+	Competences	+	Resources	=	Confusion rather than clarity
Vision	+		+	Action plan	+	Competences	+	Resources	=	Resistance instead of commitment
Vision	+	Incentives	+		+	Competences	+	Resources	=	Turning instead of heading
Vision	+	Incentives	+	Action plan	+		+	Resources	=	Anxiety instead of confidence
Vision	+	Incentives	+	Action plan	+	Competences	+		=	Frustration instead of enthusiasm

Figure 16. Five necessary ingredients for successful organisational change, including typical employee behaviour if one ingredient has not been developed fully (Source: Knoster, 1991).

At least the following steps should be described in the roadmap (Figure 17):

- Create a platform with stakeholders to create a roadmap (Steering group) with e.g., waterway owners, vessel owners, barging companies, unions, branche organisations, etc.
- Prioritize the recommendations.
- Make an inventory of possible ways to implement the recommendations:
  - Making skippers aware of and inform them about relevant root causes, e.g., via campaigns with good examples of organisational aspects;
  - Learn working group teams working on solution packages as an outcome of the roadmap how to take relevant subjects into account;
  - Prescribe guidelines and regulation.
- Make a plan with different steps that are necessary to execute the implementation.

For self-employed skippers who also live on their vessels and hardly ever change crew, the need for certain recommendations may be smaller but not necessarily irrelevant when, for example, an existing vessel is acquired or sold.

Making aware	*Inform*	*Learn*	*Prescribe*
• Campaigns	• Seminars • Master classes	• Training • Education	• Guideliness • Regulation

Time →

Figure 17: Step-by-step approach for developing recommendations

Appendix 1 | Overview vessel characteristics

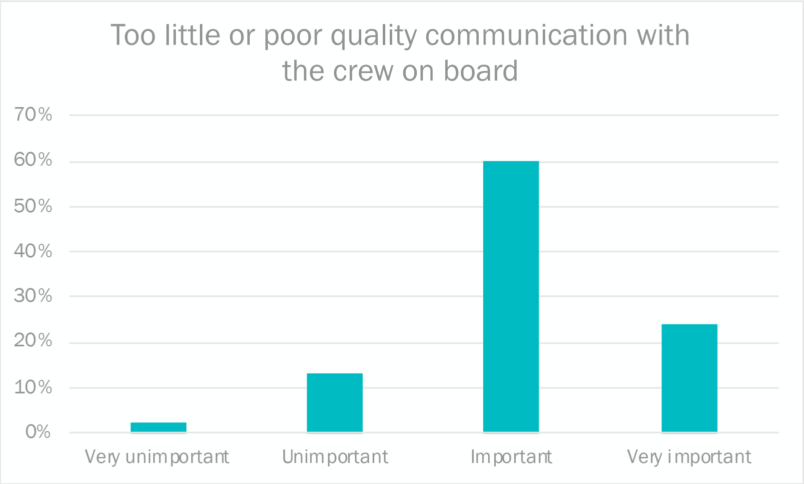
Vessel visits (Random order)	What role do you have on your vessel at this moment?	How long have you been active in inland shipping in total?	Construction year of vessel	In what year did you last adjust the wheelhouse?	What was replaced?	What is your nationality?	What is the type of vessel you sail?	What is the size of your vessel?	What is your ship's tonnage?	What is the vessel' s equipment standard?
1	Shipping company employee	10-20 yrs.	2019	2020	Radar	BE	Tanker	CEMT Va (110-135 x 11,4)	2051-4000 ton	S2
2	Self-employed	< 30 yrs.	2009	Not adjusted		NL	Container vessel	CEMT Va (110-135 x 11,4)	2051-4000 ton	S2
3	Captain/ boatmaster	10-20 yrs.	1949	2016	Pilot, radar, bow thruster alarms and control panel	NL	Dry cargo	CEMT III (55-85 x 8,2m)	651-1250 ton	S1
4	Self-employed	10-20 yrs.	1993	2018		NL	Dry cargo	CEMT Va (110-135 x 11,4)	2051-4000 ton	S2
5	Self-employed	20-30 yrs.	2000	Last couple of years	Tracking pilot, spud poles, ballast pump	DE	Tanker	CEMT IVa (80-105 x 9,5m)	1251-2050 ton	S2
6	Captain/ boatmaster	0-5 yrs.	1956	2019	New pilot complete with instrumentation	FR	Container vessel	CEMT IVa (80-105 x 9,5m)	1251-2050 ton	S1
7	Captain/ boatmaster	20-30 yrs.	2008	Not adjusted		NL	Container vessel	CEMT VIa (110-135 x 13,5-17,0m)	4001-5601 ton	S2
8	Self-employed	10-20 yrs.	1954 (middle section 1982)	2019	Bow thruster control	NL	Dry cargo	CEMT IVa (80-105 x 9,5m)	1251-2050 ton	S2
9	Captain/ boatmaster	20-30 yrs.	2004	2020	The shuttles and the display of the main engines	DE	Passenger vessel	CEMT IVa (80-105 x 9,5m)	1251-2050 ton	S1
10	Captain/ boatmaster	20-30 yrs.	2020	Not adjusted		NL	Passenger vessel	CEMT Va (110-135 x 11,4)	4001-5601 ton	S2

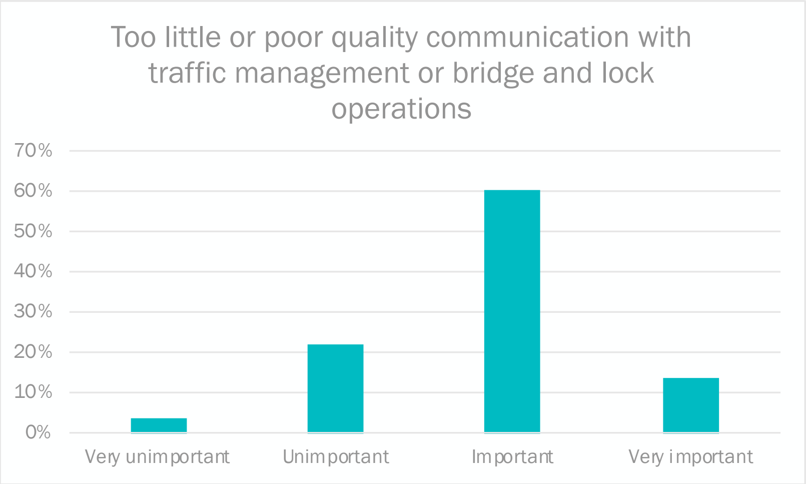
Vessel visits (Random order)	How many crew members are on board?	What are did you regularly sail the last year?	What is the most common mode of operation of the vessel you usually sail on?	What is in practice your average consecutive duration per day for navigating?	What is in practice the minimum number of consecutively rest hours between two navigation periods?	What is the most common consecutive length of stay on board the ship you are sailing on?	Other	TV in wheelhouse?	Does wheelhouse comply with EN1864 layout? (L-large, M= medium, S = small wheelhouse according to EN 1864)
1	4	Lower Rhine, Netherlands	A1	8-10 hrs.	6-8 hrs.		3 weeks on/ off	Yes	**L: Yes**
2	5	Upper Rhine, Netherlands	B	6-8 hrs.	6-8 hrs.	Continuous (ship = house)		Yes	**L: Yes**
3	2	Netherlands, Flanders, Wallonia	A1	12-14 hrs.	6-8 hrs.		Weekend-off	Yes	**M: No** Seating is in the back but with a table in the middle. No cupboards
4	4	Lower Rhine, Middle Rhine, Netherlands, Flanders, Wallonia	A2	>14 hrs. per day	6-8 hrs.	Continuous (ship = house)		Yes	**L: No,** seating is in the back. Left front is desk with pc. Right front is just a desk
5	2	Lower Rhine, Middle Rhine		>14 hrs. per day	>14 hrs. per day			Yes	No pictures available
6	2	France	A2	12-14 hrs.	2-4 hrs.	2 weeks on/ off		No	**M/S: ?** No pictures that can establish this
7	3	ARA-area	A2	4-6 hrs.	6-8 hrs.	2 weeks on/ off		Yes	**L: No,** Lessenaar and cupboards changed. Desk and seating is according to EN1864
8	2	Lower Rhine, Netherlands, Flanders, Wallonia, West Germany	A1	8-10 hrs.			Weekend-off	No	**M: No** Different seating area
9	7	Lower Rhine	A1	10-12 hrs.	0-2 hrs.		Depending on the situation	No	**L: No** Seating in back, two desks: left front & right front
10	>8	Lower Rhine, Upper Rhine, Middle Rhine	A2	8-10 hrs.	>14 hrs. per day	2 weeks on/ off		No	**M: No,** Complete rear is desk, no individual seating area

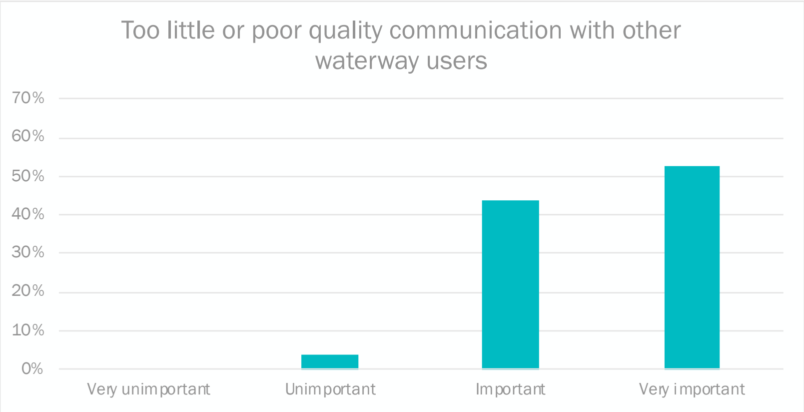
Appendix 2 | Detailed results questionnaire

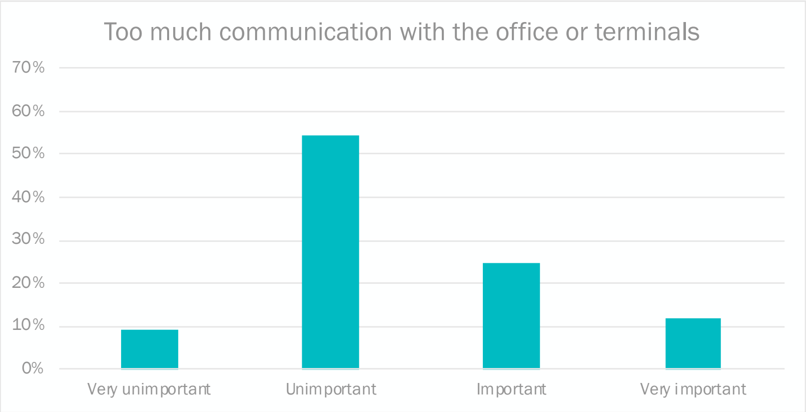
Communication

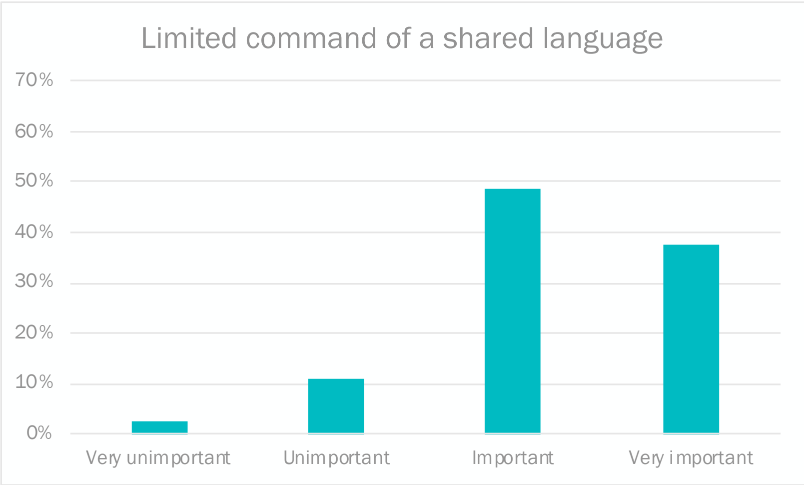
Ratings

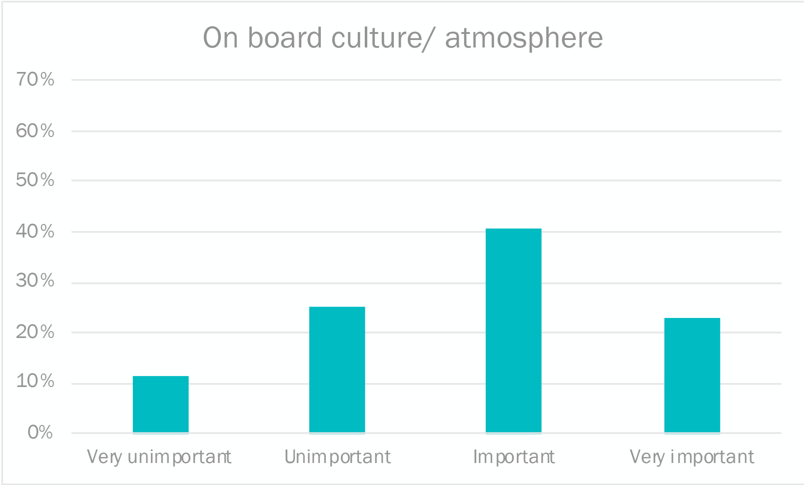


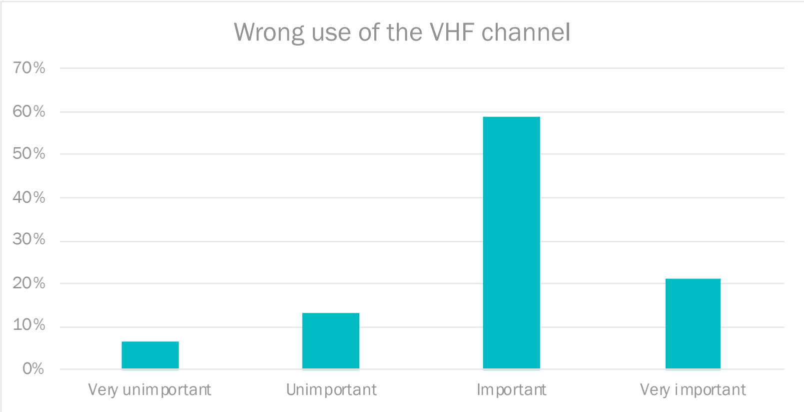


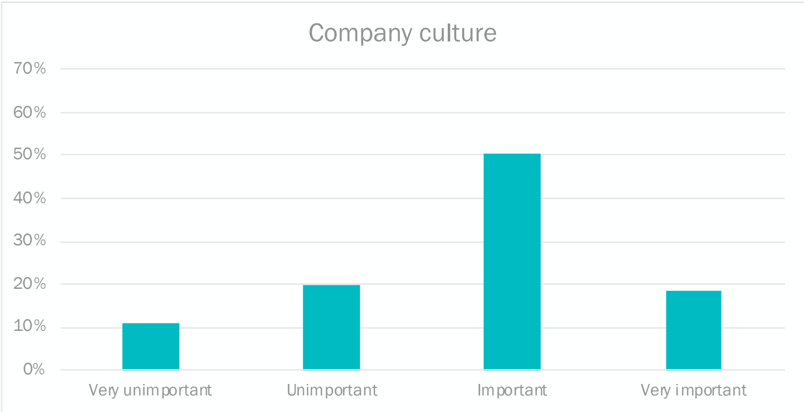





Limited command of a shared language
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

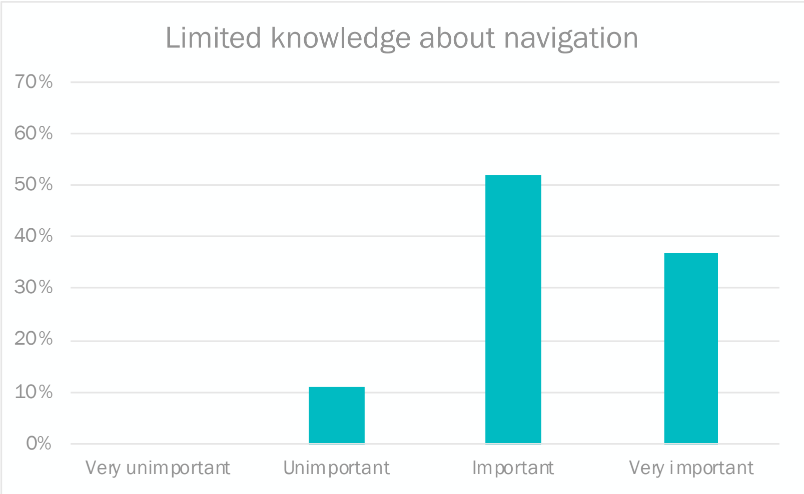

On board culture/ atmosphere
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

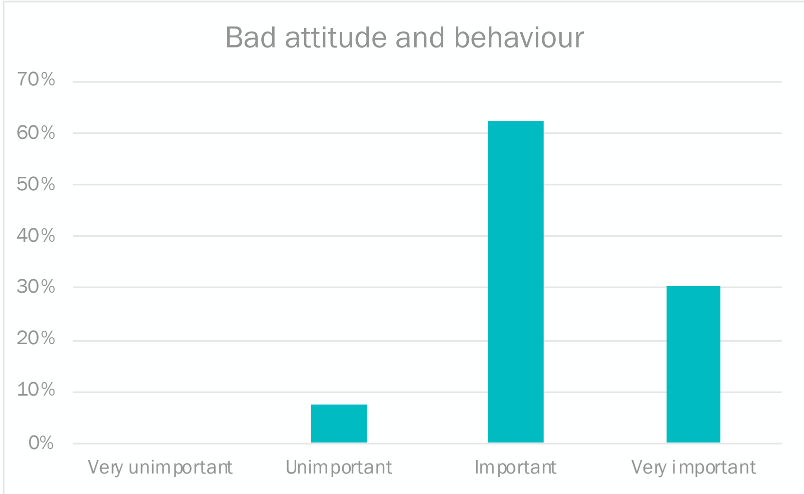

Wrong use of the VHF channel
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

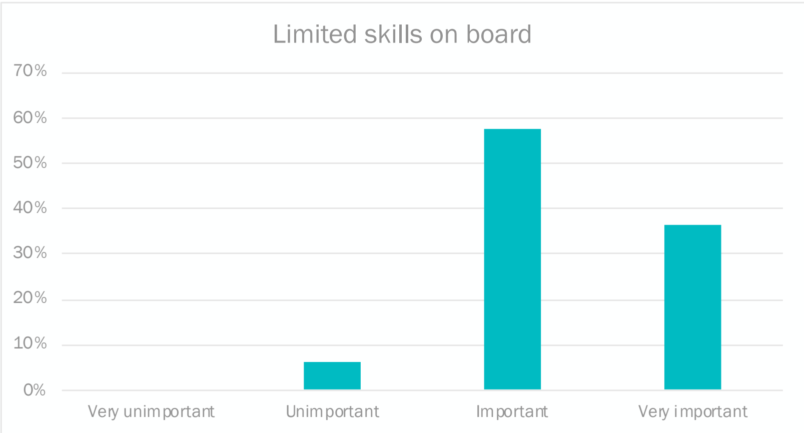

Company culture
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

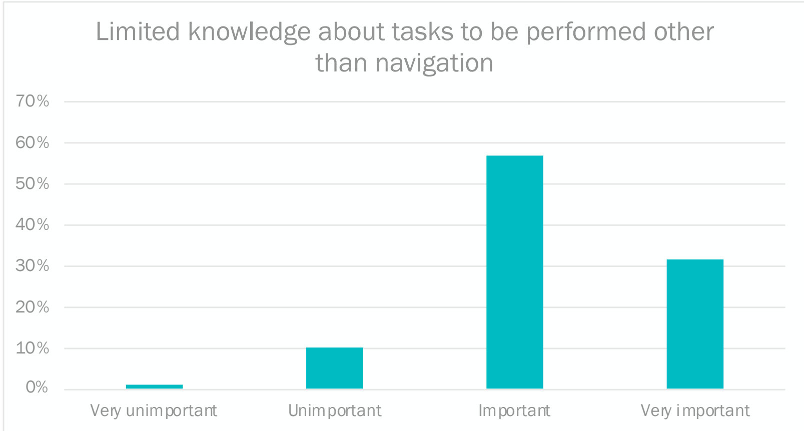
Qualification of crew members

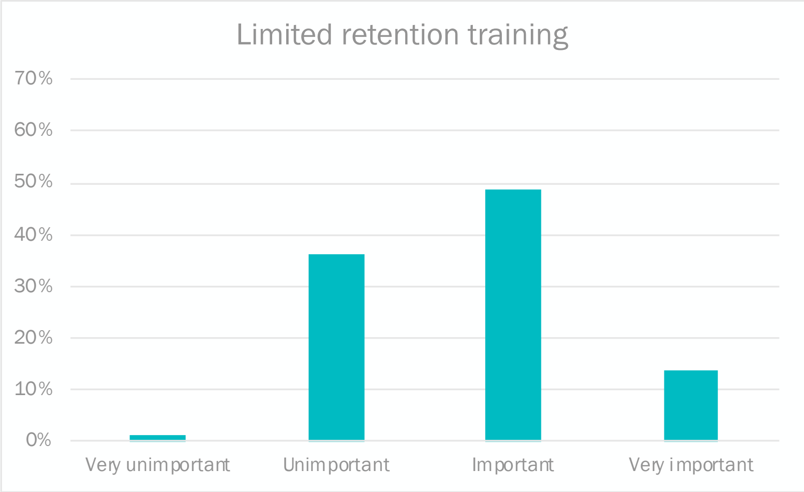
Ratings

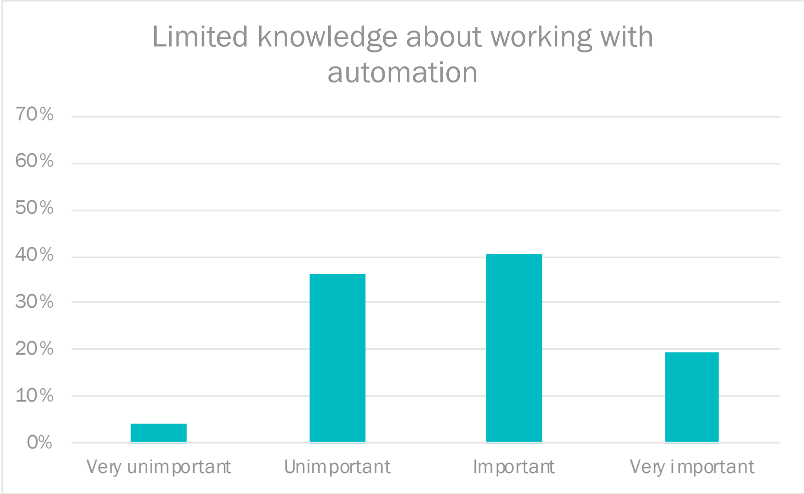


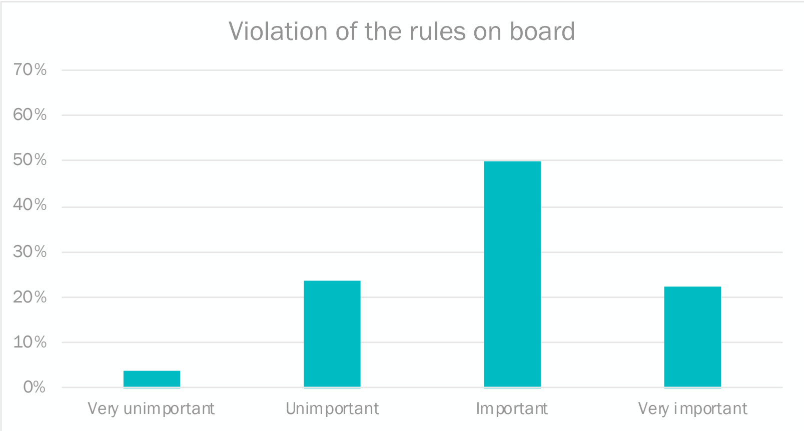






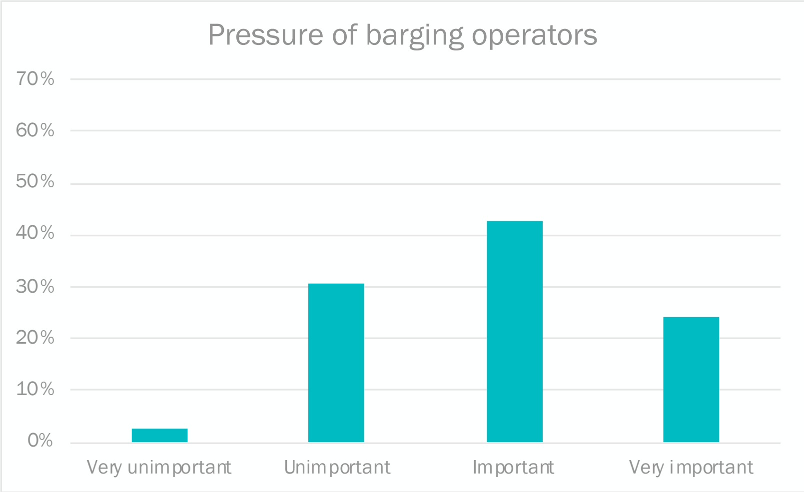

Limited retention training
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

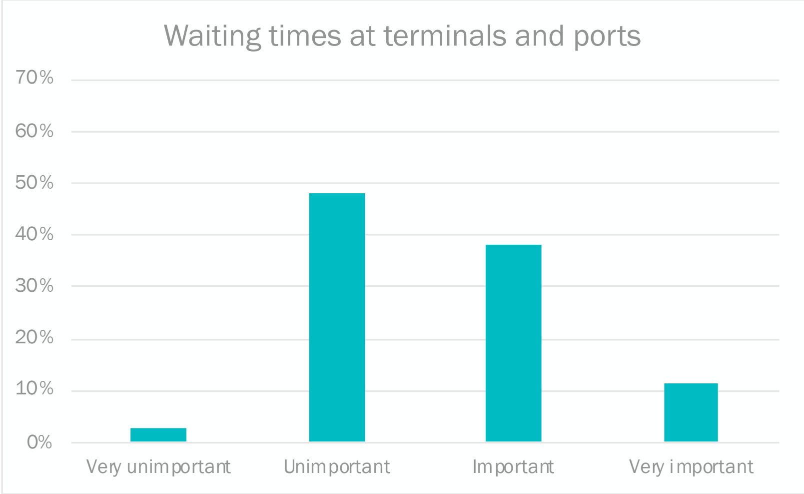

Limited knowledge about working with automation
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

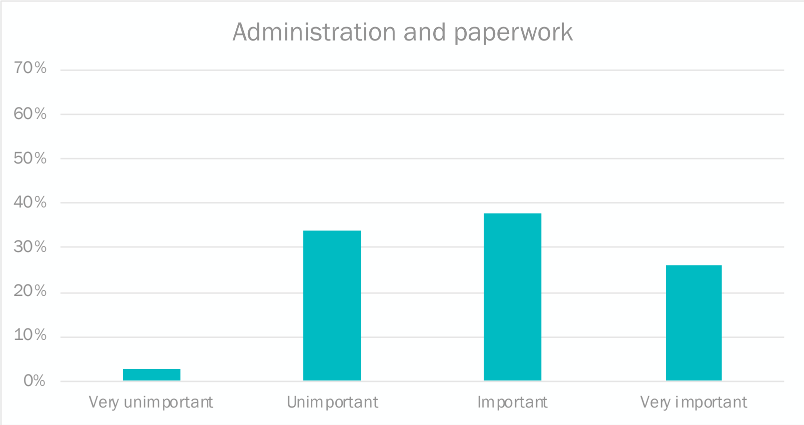

Violation of the rules on board
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

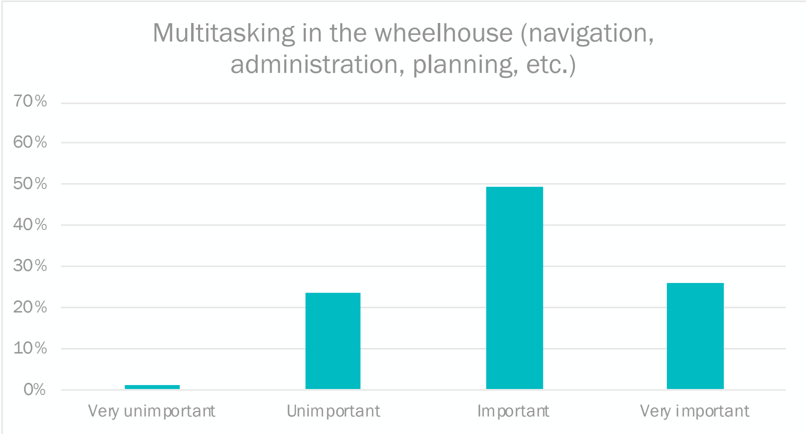
Fatigue and stress

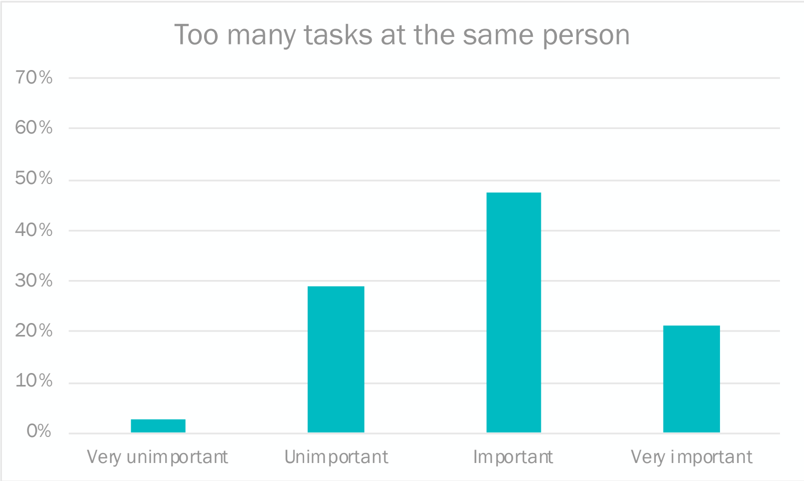
Ratings

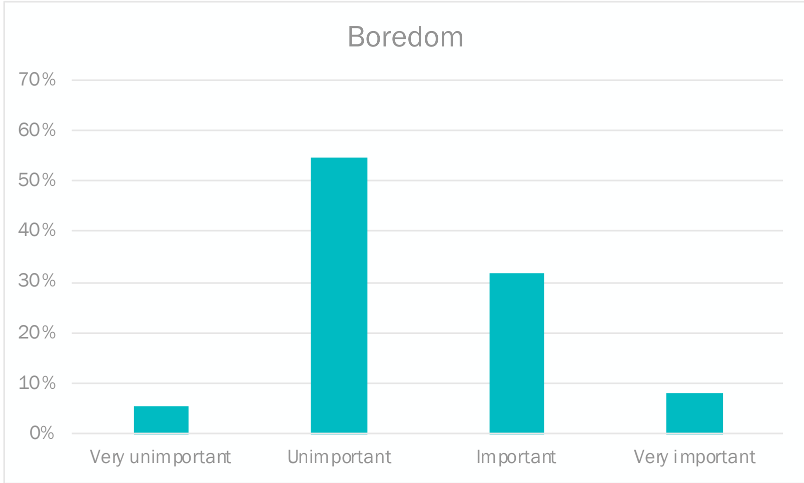


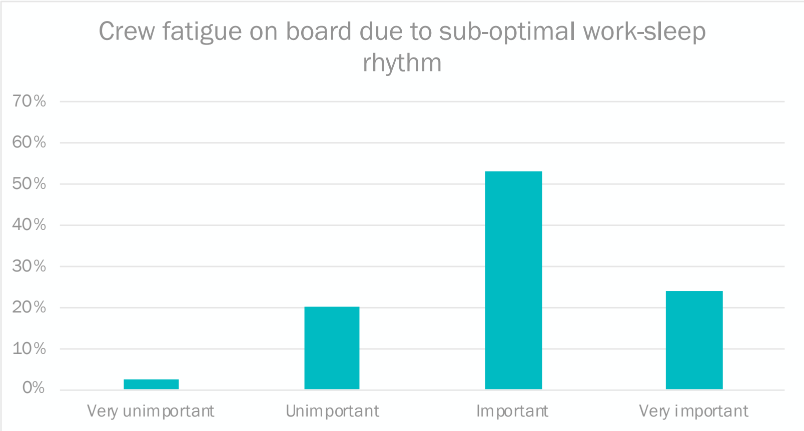


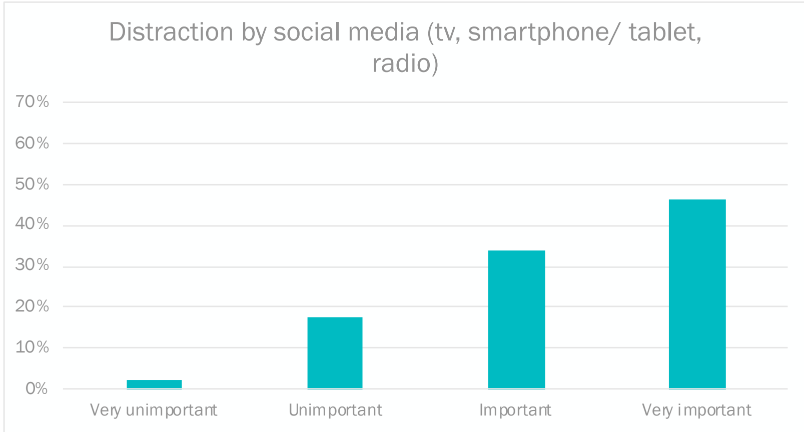





Too many tasks at the same person
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

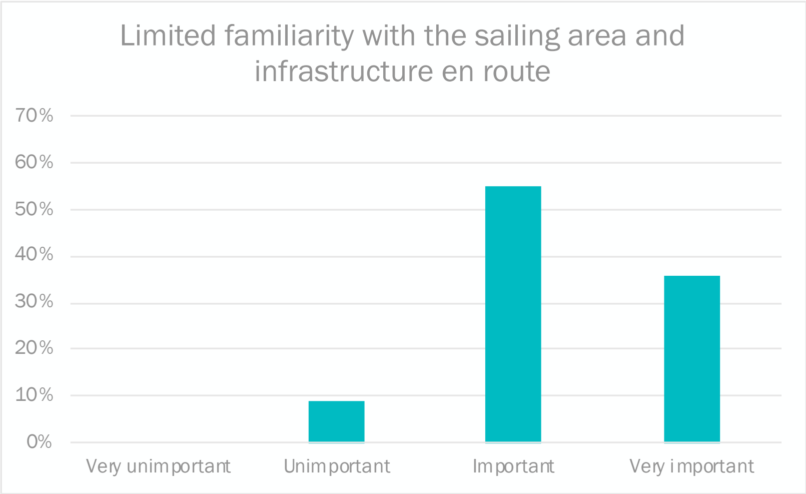

Boredom
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

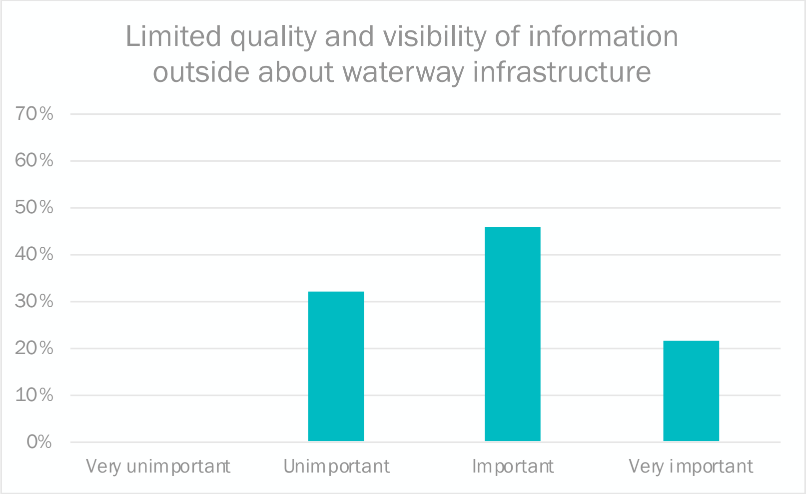

Crew fatigue on board due to sub-optimal work-sleep rhythm
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

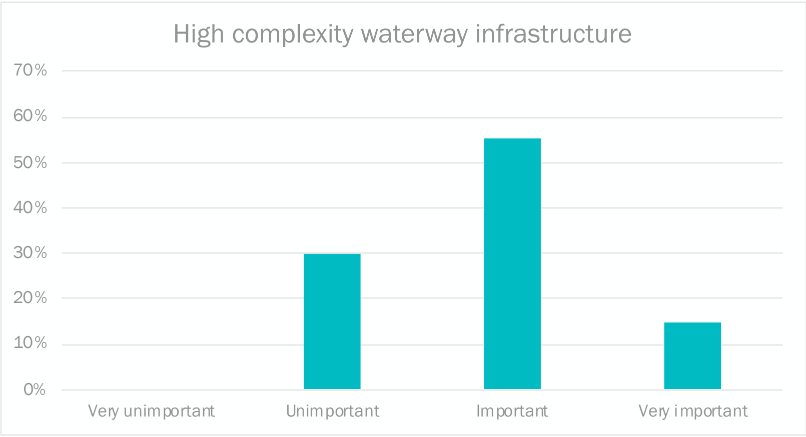

Distraction by social media (tv, smartphone/ tablet, radio)
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

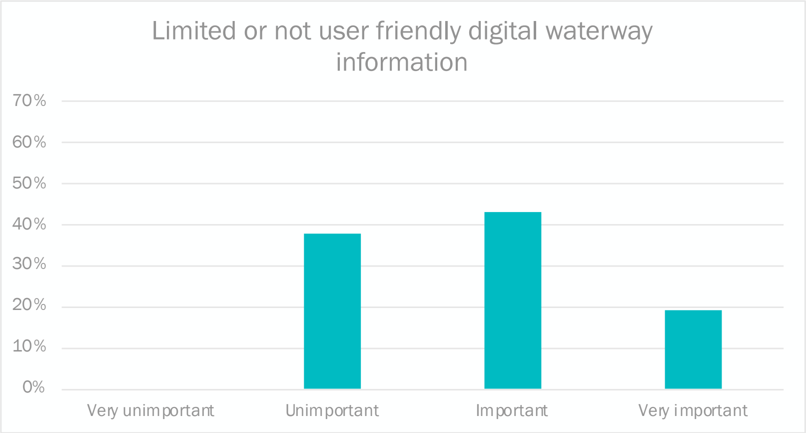
Specific waterway situations

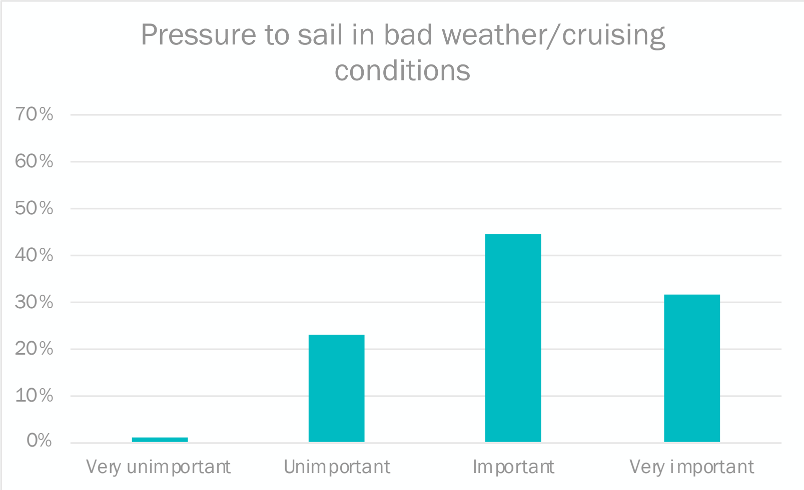
Ratings

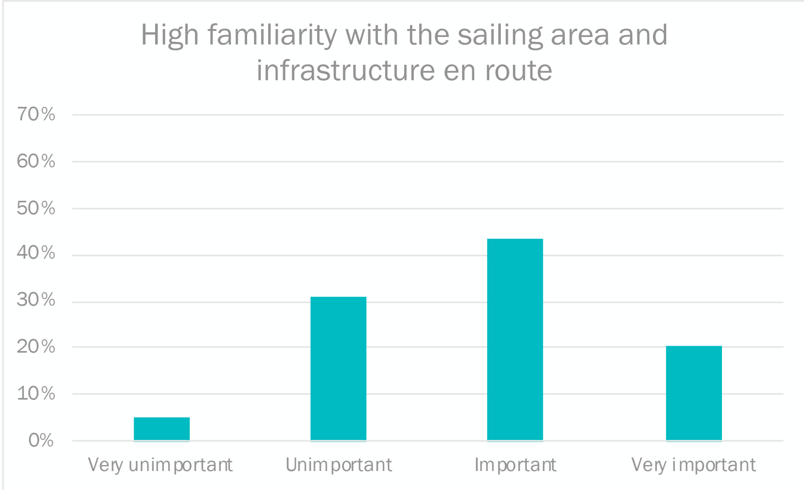


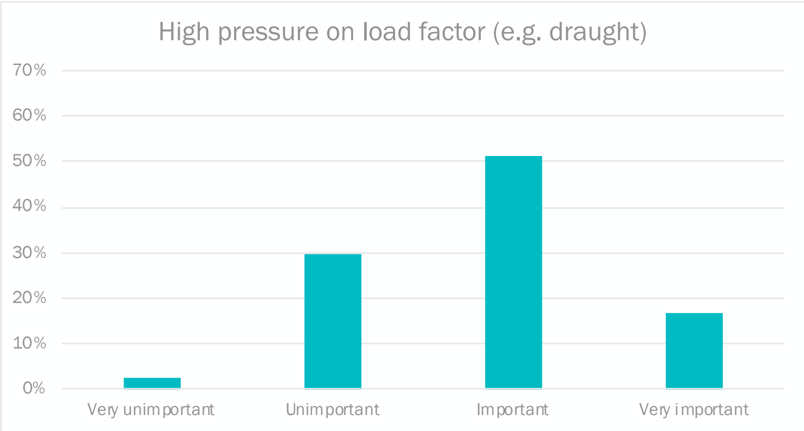







Pressure to sail in bad weather/cruising conditions
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important


High familiarity with the sailing area and infrastructure en route
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important


High pressure on load factor (e.g. draught)
70%
60%
50%
40%
30%
20%
10%
0%
Very unimportant
Unimportant
Important
Very important

Appendix 3 | Selected references

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