TASCS
TOWARDS A SUSTAINABLE CREWING SYSTEM

DST in cooperation with INTERGO human factors • ergonomics and Professor Peter Turnbull

With the support of the European Commission

IMPRINT

Publisher
European Social Partners Organisations EBU, ESO, ETF

Contact
European Transport Workers' Federation
Galerie Agora
Rue du Marché aux Herbes 105, Boîte 11
B - 1000 Brussels | BELGIUM
Myriam Chaffart, Political Secretary for Inland Waterways, Logistics and EWC's
Tel.: + 32 2 285 46 64
m.chaffart@etf-europe.org | www.etf-europe.org

Author I editor
DST – Development Centre for Ship Technology and Transport Systems [Ed.]
INTERGO human factors & ergonomics
Prof. Dr. Peter Turnbull

Authors
Dr.-Ing. Rupert Henn (DST)
Dipl.-Ing. Berthold Holtmann (DST)
Kirsten Schreibers MSc. Eur.Erg. (Intergo)
Richard van der Weide MSc. Eur.Erg. (Intergo)
Prof. Dr. Peter Turnbull (University of Bristol)

Contents

MOTIVATION
AND OBJECTIVE

1

Motivation and objective

The **Inland Waterways Transport** (IWT) sector is characterised by specific on-board working and living conditions, which cannot be compared with the other modes of transport. In road and rail transport vehicle operators usually work alone. On the other hand, seagoing vessels have a much larger crew on longer transportation routes. Therefore, knowledge of the workload of these modes of transport cannot be directly applied; navigation of inland vessels under the specific conditions of confined waters also requires specific education and qualification.

Further, an appropriate crewing[1] regulation on the one hand has to meet safety criteria (lower limit of crewing) and economic constraints on the other (upper limit). In addition, frequent and ongoing technical developments and improved educational methods leading to a higher education level may reconfigure the workload.

At present, heterogeneous educational as well as crewing standards exist in different European countries and river basins. The EU-wide harmonization of the educational standards is already in progress. A harmonized European crewing framework is also considered desirable in order to contribute to an improved labour mobility and to face general demographic challenges.

The leading IWT crewing regulation in force is the Regulation for Rhine Navigation Personnel (RNP) dating back almost 30 years. The last three decades, however, have witnessed considerable changes that impact on the sector – be it technological or non-technological ones.

Against this background, the Social Partners in 2014 during a Round Table debate jointly agreed on the need for the development of new crewing requirements for vessel crewmembers on the European Inland Waterway Network and initiated the investigation

'Towards A Sustainable Crewing System – TASCS'.

TASCS aims for the development of an in-depth workload assessment that leads to a documented proposal for an easy to use and easy to enforce crewing instrument. Existing regulations need to be updated and a broader perspective incorporated towards a harmonized European crewing framework (which has to allow for modern technical developments, attractiveness of IWT and entrepreneurship, taking operational, cultural, institutional and other differences into account).

WORD OF THANKS
The TASCS-project had not been possible without the support of the European Commission, the hard work and enthousiasm of the Social Partners and their members. We owe many thanks to the vessel crews that have been involved in the research, for their time, expertise and sincerity.

[1] In the frame of this investigation the word 'crewing' instead of 'manning' is used in order to ensure a gender-neutral wording.

GOAL, RESEARCH QUESTIONS AND APPROACH

2

2.1 Goal and research questions of TASCS

The European Social Partners aim for the development of crewing requirements for vessel crewmembers on the European Waterway Network. Besides aspects like working hours, competencies and enforcement, the European Social Partners recognise workload as a relevant dimension in developing a new regulation. This project is in fact a workload assessment and has also investigated whether and how these influences impact on the crewmembers at managerial and operational level. The project has identified and assessed all relevant critical elements and/or influences that have impact on the crewmembers on board of a vessel whilst at work and rest, respectively.

The final ambition of the European Social Partners is a documented proposal with different options, for an easy to use (transparent, flexible, sustainable) and easy to enforce manning instrument for the European waterway network, taking relevant differences into account.

The investigation considered all relevant parameters that impact working conditions. Accordingly, the overall system with its elements that contribute to performance has been studied including the relevant relations and correlations of the various research parameters. This includes:

- crews and their tasks
- vessels and their technical equipment
- waterway infrastructure and nautical as well as traffic conditions
- customer relations
- organization of the company and modes of operation as well as
- port and terminal infrastructures and procedures.

Furthermore, the study considered the relevant European regulations on working time, safety, standardised competencies and current technical, logistic and human factors standards and state of the art knowledge. Scientifically well established models incorporating safety, workload, task effectiveness, fatigue and recuperation – like MARTHA[2], SAFTE[3], FAST[4], FRI[5] – that are used in transport industries, are covered.

VISION
The workload aspects are clustered in three main aspects that determine mental and physical workload: task demands, (working) environment and individual factors and perception. The resulting workload determines system performance in combination with well-being, as depicted in Figure 1.

[2] Jepsen e.a. (2017).MARTHA the final report 2017-01

[3] SAFTE model: Sleep, Activity, Fatigue and task Effectiveness model. Hursh S.R., Raslear T.G., Scott Kaye A., Fanzone J. (2006). Validation and calibration of a fatigue assessment tool for railroad work schedules.

[4] FAST: Fatigue Avoidance Scheduling Tool. Hursh S.R., Raslear T.G., Scott Kaye A., Fanzone J. (2006). Validation and calibration of a fatigue assessment tool for railroad work schedules.

[5] FRI: Fatigue and Risk Index. Spencer M.B., Robertson K.A., Folkard S. (2006). The development of a fatigue/ risk index for shift workers. Health & Safety Executive research report 446/2006, London

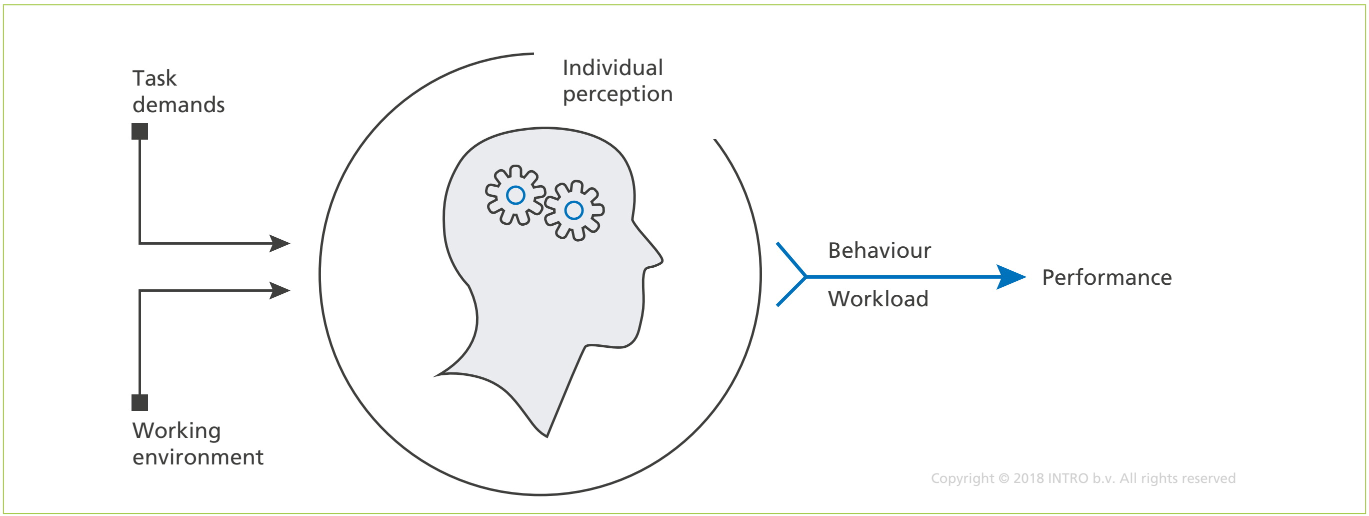


Figure 1: Workload model, based on EN-ISO 10075

An unbalanced workload can be addressed in different ways (underload/excessive load):

- Change in number of crew (part of this project);
- Change in work-rest patterns (work schedules), apart of patterns in sail / standstill pattern of the vessel;
- Change in task allocations (mechanisation, automation or outsourcing).

2.2 Approach of the investigation

The provided approach is characterised as classic Action Research, Illustrated in Figure 2. The foundations of this research seem to fit the context of the research question very well, because they are:

a) Democratic (enabling the participation of all people)
b) Equitable (acknowledging people's true worth)
c) Liberating (providing freedom from oppressive, debilitating conditions)
d) Life enhancing (enabling the expression of people's full human potential)

Besides, a combination of sources has been used:

- Observations in practice on time occupancy and workload
- Collection of objective facts in practice on time occupancy and workload
- Subjective assessments of experienced workload.

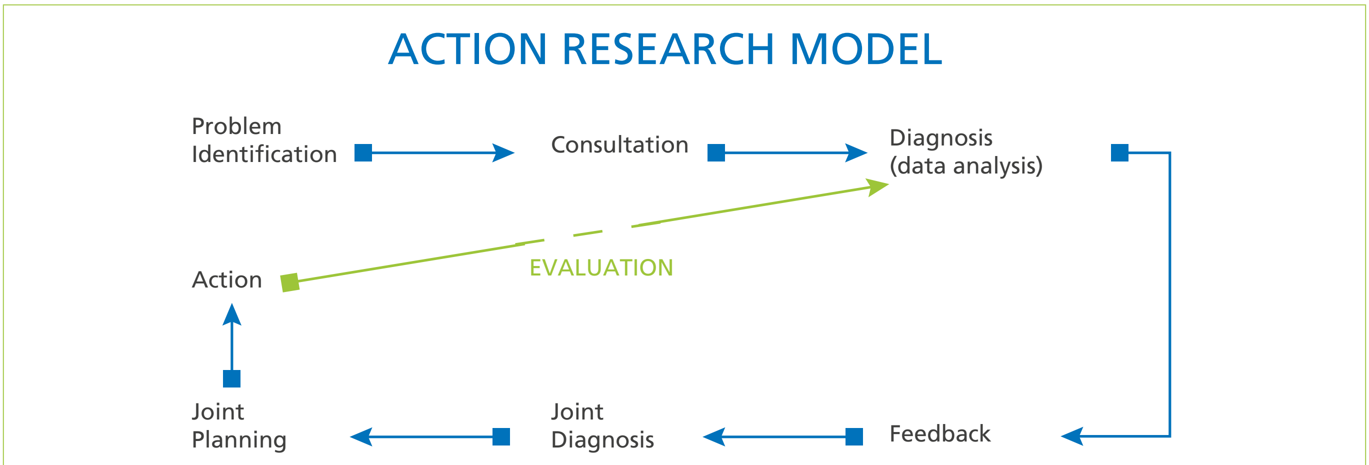


Figure 2: Action research model, making use of different sources for valid and accepted data

2.2.1 Overview

Based on the goal and research questions the following approach has been agreed on and applied for TASCS:

- Analysis of existing structures and IWT system characteristics including literature study.
- **Field study**: observations and interviews on tasks and the corresponding time occupancy as well as physical workload and level of attention on a representative selection of 50 vessels across interconnected inland waterways in Europe, covering all seasons and categorized in 7 types of vessels: (i) dry bulk vessels, (ii) liquid bulk vessels, (iii) container vessels, (iv) pushed/ coupled convoys, (v) daytrip vessels and ferries, (vi) cabin vessels, and (vii) tugs. It was decided to exclude other types of vessels because of relatively low impact in the IWT sector.
- **Future developments**: Identification of expected future (technical and non-technical) developments; consultation of experts from various fields of expertise.
- **Crewing instrument**: Development of a task-based approach; consideration of the outcome of the field study and the workshop on future developments.
- Reflection of all steps including interim results and approach with Steering and Focal Group.

These steps are further elaborated in the next paragraphs (2.2.2–2.2.4).

Timeline of the study

The investigation started in early 2017, has been conducted in 2017 and 2018 and been completed in December 2018. The timeline of the study reflects the milestones as follows:

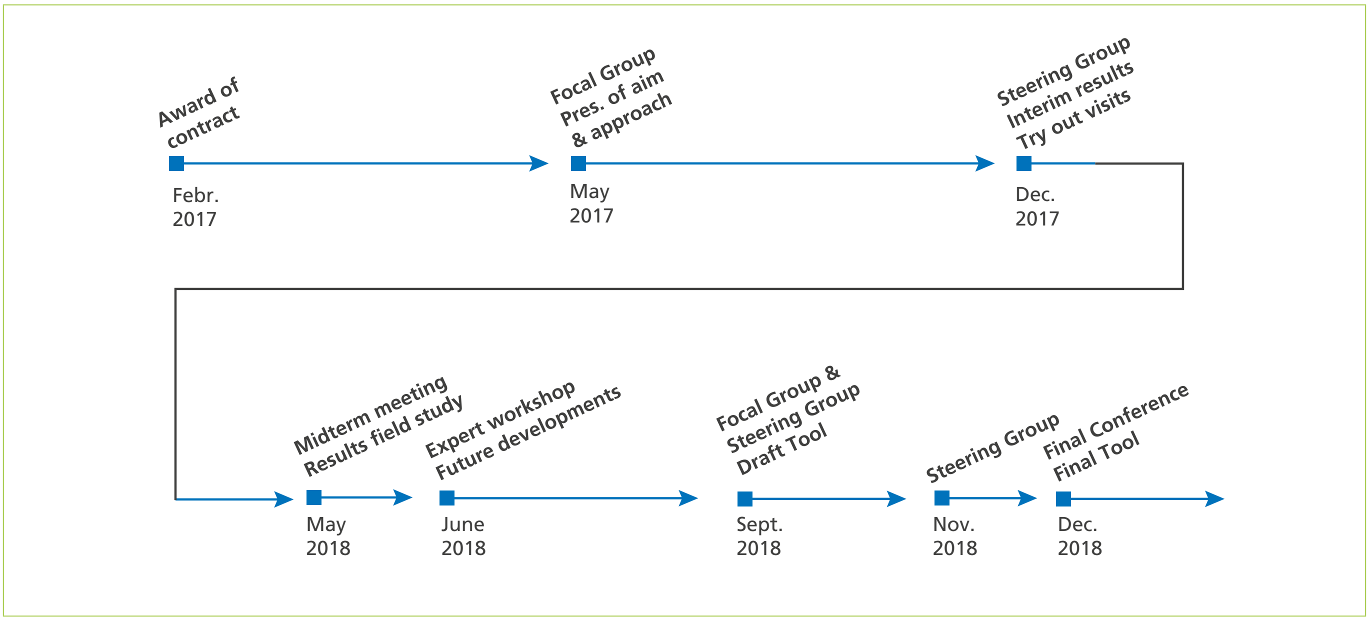


Figure 3: Visual timeline of TASCS milestones

2.2.2 Field study (May 2017 – May 2018)

In the field study, observations and interviews on tasks, time occupancy as well as assessed and experienced physical workload and level of attention were carried out. At the beginning, a standardized task analysis investigation tool including semi-structured interview questions was developed and tested based on the crews of 10 initial vessels. The core study was carried out with crews of 40 additional vessels. The participating vessels were selected in close cooperation and with support from the members of the Steering Group.

Following from the IWT-characteristics and structures on the one hand, and the aim of the investigation and the corresponding requirements on the other, the criteria, parameters and steps as outlined below have been considered.

Based on the different cargo categories (dry bulk, liquid bulk, containers etc.) and the corresponding cargo characteristics and 'requirements' a large variety of vessel types, sizes and equipments results with corresponding specific technical features and a resulting specification of tasks for the crew. Also for passenger vessels, specific requirements, features and corresponding tasks were considered. Correspondingly, a differentiation of the field study into 7 vessel types was choosen. Besides the basic parameters vessel type and characteristics also technical equipment, sailing area and mode of operation were considered.

Work, recovery, travel and commuting, respectively and the corresponding tasks were addressed. Thereby, reference is made to harmonized competences based on ES-QIN[6] (tasks 1-7) including additional tasks that occur in practise (tasks 8-11), which are known to influence workload, level of attention and thus the need for recovery as follows:

1. Navigation
2. Operation of the craft
3. Cargo handling, stowage and passenger transport
4. Periodic inspection of marine engineering equipment
5. Maintenance & repair
6. Communication
7. HSE/emergencies
8. Entrepreneuring
9. Other tasks
10. Recovery/ pause
11. Travel

For each of the tasks the corresponding time occupancy, frequency and (physical and mental) workload was investigated for different crew members; thereby, the main categorisation of boatmaster and boatman has been applied.

In addition, further issues like the simultaneousness of tasks, urgency, need for assistance (2nd person), need for experience and aggravating conditions, such as emergency, difficult nautical conditions (e.g. fog, darkness, high traffic volume etc.) were covered as well.

[6] European Standards for Qualification in Inland Navigation, ES-QIN, Edition 2018; wording and heading as used in TASCS. Slight differences in relation to ES-QIN apply.

Figure 4: Visual illustration of tasks

Besides the different types, the visited vessels also inlcuded all different sizes ranging from small tugs, ferries, daytrip and dry bulk vessels up to large self propelled vessels and coupled as well as pushed convoys. Also, the ages of the addressed vessels varied from 7 up to 83 years. More than 50% of the vessels were owner-operated, especially dry bulk vessels as well as several container and liquid bulk vessels, some coupled convoys, daytrip vessels and tug boats. Nearly 20% of the vessels belonged to shipowning companies, in particular the cabin vessels as well as some pushed convoys and a tanker vessel. Further vessels were municipally owned (some daytrip vessels), port-operated, cooperatively owned or considered company transport.

The following matrix provides an overview of the investigated vessels per type and navigational area (waterway basins).

Type / Area	Dry bulk vessels	Liquid bulk vessels	Container vessels	Pushed/ coupled convoys	Daytrip vessels & ferries	Cabin vessels	Tugs/ Special transports	TOTAL
Rhine & tributaries, incl. canals, France, Weser etc.	12	6	3 (+ 4 sailing ARA-northern France)	4	6	3	3	**37**
Danube (incl. Rhine-Dan.)		1		3		1		**5**
France (besides Rhine)			4		2	2		**8**
TOTAL	**12**	**7**	**7**	**7**	**8**	**6**	**3**	**50**

Table 1: Overview of the investigated vessels per type and waterway basin

2.2.3 Expert workshop "Effects of future developments" (28.6.2018)

Just as the current crewing regulation has been in force for several decades, it is anticipated that the proposed crewing instrument will be in force for several decades to come. Hence, it is regarded of core importance to consider expected future developments as systematically as possible. In order to identify both future technical as well as non-technical developments, experts from various fields of expertise were consulted at an expert workshop on June, 28th 2018 in Duisburg.

Around 40 experts from various fields, thereby reflecting e.g. IWT associations, various companies and administrations had been invided by the Steering Group. Among others, general and dry cargo, liquid bulk, passenger vessels, administration, greening, safety and regulation, suppliers and digitalisation have been addressed. Duing the workshop 12 experts with a focus on associations, cargo vessel operators and administration participated and discussed possible developments with a specific view on corresponding impacts on crewing. Passenger vessel representatives did not participate.

As a result, important insight into various developments was gained and several trends were identified.
The main findings are outlined in chapter 3.2.

2.2.4 Development of a crewing instrument (May 2018 - November 2018)

In accordance with conventional practice in other transport sectors and safety critical industries also for TASCS a task-based approach has been applied. With reference to ES-QIN the approach is based on 11 tasks considering the agreed new profiles for crew competences (boatmaster and boatman). For each task the respective time allocation, level of attention and physical workload has been considered.

In addition, the outcome of both field study and expert workshop has been implemented. Besides, different vessels types, their specific features and impacts on above parameters have been addressed as well.

2.2.5 Project organization and responsibilities

The research took place in close cooperation between the project team, the Steering Group (SG) with European Social Partner delegates and a Focal Group (FG) of dedicated representatives from the IWT sector including skippers, crew members, fleet managers, etc. the Focal Group was established considering different subsegments, e.g. different vessel categories from different countries and the relevant European waterway basins. An overview of the members of the Steering Group is presented in Annex I.

The responsibilities of the Steering Group were to install a Focal Group, consisting of end users like skippers, crew and fleet managers as well as the organization of vessel visits during suggested dates for research partners in selected EU member states on relatively easily reachable locations in cooperation with the research consortium. Furthermore, the Steering Group organized workshops, meetings and milestone events and provided feedback from enforcement bodies.

The responsibilities of the Focal Group were to provide support in terms of determination of critical elements influencing workload and crew manning as well as to verify and to complete findings in the research phase consisting of validation of work load assessment and time occupancy. In addition, the Focal Group commented on and validated the draft crew manning tool.

OUTCOME AND CONCLUSIONS FROM FIELD STUDY AND EXPERT WORKSHOP

3

3.1 Field study

3.1.1 Observations

The Inland Waterway Transport sector is characterised by a large variety of operational and working conditions which result from various parameters. Besides the different cargo categories and their corresponding ‘requirements’ also the specific tasks related to passenger transport (considering ferries, daytrip and cruise vessels) have to be considered. Further, the resulting large variety of vessel types with different technical and operational conditions lead to a corresponding differentiation into specific tasks and subtasks and accordingly time occupancy, levels of physical workload and cognitive attention. Last but not least, different nautical as well as infrastructure and traffic related conditions result in further specifications. Naturally, this variety of operational and working conditions is reflected in a variety and bandwidth of tasks and activities.

For the different vessel types and for each of the 11 tasks including subtasks, the time occupancy for both boatmasters as well as boatmen has been recorded.

For the parameters ‘level of attention’ and ‘physical workload’ a classification into 4 levels has been choosen as follows (Spencer e.a. 2006):

* = extremely undemanding (very low)
Physical workload: extremely undemanding, lots of spare capacity (e.g. sitting all day during navigation or monitoring unloading);
Level of attention: requires rarely or nearly none of time attention; some additional activity needed to stay ‘fit for duty’.

** = undemanding (moderate)
Physical workload: moderately undemanding some spare capacity (e.g. slow walking all day)
Level of attention: requires some time attention; being able to combine the actual task with other non-complex activities like talk about anything whether or not work related, or read simple messages.

*** = demanding (high)
Physical workload: moderately demanding, little spare capacity (e.g. manually digging or sweeping cargo hold; manually transferring luggage/ groceries on or from board).
Level of attention: requires attention most of the time; not being able to combine with other activities, however able to talk during actual task about the actual task (exchanging actual updates, giving instructions about execution).

**** = extremely demanding (very high)
Physical workload: extremely demanding, no spare capacity (e.g. manually cleaning chemical tanks in confined space, also wearing personal protective equipment).
Level of attention: pure focus; requires (nearly) full-time attention, no spare capacity; silence needed for concentration without any disturbance.

Based on this categorisation an aggregated overview of these parameters per task and per competence (boatmaster and boatman) is provided in Table 2. Most vessels operate strict hierarchy in task allocation and working times (some do intensive cooperation, flexible working times and task allocation). Further findings are outlined on task level below. In addition findings on long working days and sometimes limited recovery are explained in the explanation below the summary in Table 2.

Task / Parameter	Time occupancy Boatmaster Range (h) Min-Max	Time occupancy Boatman Range (h) Min-Max	Level of attention Boatmaster * low **** high	Level of attention Boatman * low **** high	Physical workload Boatmaster * low **** high	Physical workload Boatman * low **** high
1 Navigation Voyage planning, org. crew change Sailing & maneouvring, Mooring & unmooring, Organize and control work	0 - 14	0 - 6	** - *** (can be peak: ****) (depends e.g. on naut., traff & weather	** (can be peak: ***)	*	*-** (can be peak *** for high volume vessels
2 Operation of the craft Bunkering, Ballast water & waste mgt.	0 - 1	0,2 – 1	**	**	*	* - **
3 Cargo handling, stowage, passengers e.g. handling hoses, tank clean. Freight document. & control Checking strength & stability; Passengers	0 - 3	0,1 - 9	** (*** if chemical or containers)	** (can be peak ***)	*	* - ** (can be peak ***)
4 Inspection Periodic insp. (ship / hardware / software etc.)	0,3 - 3	0,1 - 4	**(***)	** (***)	*	*(**)
5 Maintenance & repair Maintenance (prep. & coordi.) planning ext. maintenance (…)	0 - 3	0,1 – 1 2 – 8 (tanker, convoy, cabin)	**	**	*	* - ***
6 Communication Crew mgt. & shift handover Organisation & exec. of training	0 – 2,5	0 – 1,8	** (***)	** (***)	*	*
7 HSE, Emergency drills Control work & rest time (shifts) Developing safety plans Instruct the crew in safety drill	0 – 0,5 (1,4)	0 – 0,1	** (peak in emergency: ****)	** (peak in emergency: ****)	*	*
8 Entrepreneuring Acquisition (follow-up cargo) Commercial accounting Personnel administration Ship account. (port duties etc.)	0 – 2,4	0	**	--	*	--
9 Other tasks Studying, waiting, Housekeeping (Cooking, cleaning accommodation) Teaching apprentices	0 - 3	0 - 7	*-**	*-**	*-**	*-**
10 Recovery & free time Pause, leisure, sleep, standby	On individual basis	On individual basis	*	*	*	*
11 Travel Commuting to/from vessel	On individual basis	On individual basis	*	*	*	*

Table 2: Observed (ranges of) time occupancy, level of attention and physical workload per task (source: field study and presentation at Focal Group 12. Sept. 2018, cf. meeting minutes)

TASK 1
Navigation

- The time occupancy for the boatmaster during sailing / manoeuvring is usually uninterrupted
- Employees usually follow shift rhythm; ship owners tend to work as long as it is allowed by regulation
- The time occupancy of the boatman is dictated by logistics planning and resulting journey planning which sometimes disturbs recovery
- When the level of attention during navigation is (extremely) undemanding (* or **) the following less demanding tasks can be undertaken in parallel, provided that these tasks are performed within reach of navigational displays and controls (in the wheelhouse):
  - task 4 (remote) inspection,
  - task 6 communication
  - task 8 simple entrepreneuring.

  Other tasks like cargo planning (making/ adopting container planning) should not be executed due to interference of required high levels of attention.
- As regards workload demanding peaks may occur due to complex traffic, obstacles or reduced sight or heavy weather. Peaks often are predictable (except for unforeseen unfavourable weather conditions).
- Peaks are in practice seldom coped with by alternation or extra recovery.
- Preparation of the journey is depending on (believed) familiarity; mostly implicit and ad hoc or via friends that are (believed to be) familiar.

TASK 2
Operation of the craft

- The time occupancy varies depending on ship type, size etc. but in general is considered rather short. Physical workload can be physically demanding due to heavy hoses for bunkering in large vessels. Cognitive level of attention is moderate (fuel)/ extremely undemanding (water).

TASK 3
Cargo handling

- The time occupancy during loading and unloading varies and depends on cargo requirements, passengers, ship size, local situation etc.
- The time occupancy during the voyage is low or moderate in case of dangerous cargo but extremely low in case of other cargo.
- The division of work between boatmaster and boatman and care for cargo is handled differently.
- The following tasks can be done in parallel during monitoring of the (un)loading: task 4 (remote) inspection, task 6 communication and task 8 entrepreneuring.
- The mental workload for boatmaster and boatman are considered undemanding except for dangerous cargo. The boatmaster is also responsible for stability and structural load.
- The physical workload is demanding in some cases like e.g. barge coupling, handling cargo hatches or hoses for liquid cargo or tank cleaning.
- Administration of cargo handling in several subsectors like liquid bulk and container transport requires additional time occupancy. This is due to all kinds and even not harmonized quality performance systems for several stakeholders. About the same data have to be shared in digital systems in different ways. This is a time consuming administrative burden, in general negatively perceived by the crew.

TASK 4
Periodic inspection

- The time occupancy varies strongly and to some extent depends on the low/ high precision standard of the boatmaster; the task is mostly performed by the boatman.
- Physical workload is generally moderately undemanding. Level of attention is demanding.
- In principle this task is sometimes completely outsourced to service partners (also including ‘predictive maintenance’); especially at shipping companies but also at self employed vessels.

TASK 5
Maintenance & Repair

- This task also to some extent depends on the requirements and standards of the boatmaster; painting is often done, because boatmen are available.
- This task also in general can be outsourced to an (internal or external) service partner; in some cases this is already practiced irrespective of whether it concerns shipping companies or self employed vessels.
- Time occupancy correlates generally to the age of equipment parts and is dependent on type of cargo (sensitive to dirt). Physical workload is generally moderately undemanding with peaks to moderately (e.g. sanding) or extremely demanding.
- Seasonal influences appear here: spring work on deck and in winter work inside.

TASK 6
Communication

- This covers both internal communication with the crew as well as external communication as part of the navigation and to a limited extent addressing entrepreneuring (owners).
- The time occupancy is limited, communication is often combined with navigation.
- The mental workload in general is moderately undemanding, but this also depends on the experience of the crew. In case of foreign crews and languages communication sometimes is highly demanding (e.g. cabin vessels in France with foreign boatmasters).

TASK 7
HSE / Emergencies

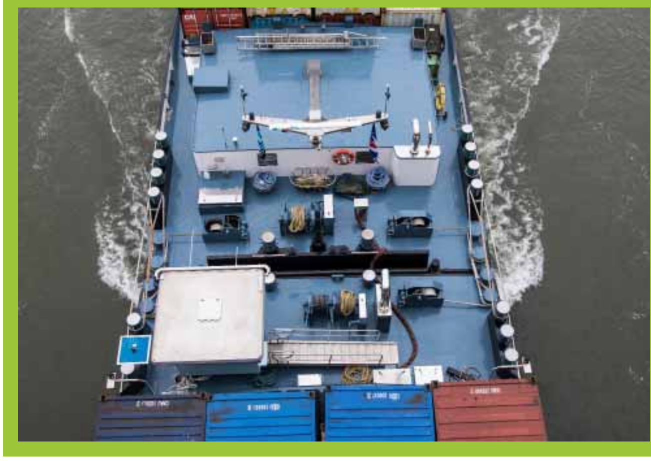
- Usually regular HSE and emergency trainings are scheduled, mostly for employees and shipping companies.
- In case of (seldom) emergency this requires full time occupancy and is highly demanding.
- Type and size of crew required for handling emergencies is determined by safety plans that belong to vessel design/ approval. This demands are beyond the scope of TASCS.

TASK 8
Entrepreneuring

- This task addresses self employed boatmasters (owner operators); it is not relevant for employees (onboard). This task also in general can be outsourced to an (internal or external) service partner; in some cases this is already practiced irrespectively whether it concerns shipping companies or self employed vessels.
- Usually, this task is performed in parallel during navigation. It is handled in various ways, e.g. in terms of long term freight contracts, use of service partners, use of transport market places, being member of a cooperative, or 'outsourcing' to a family partner (not counted as crew member) or an agency.

TASK 9
Other tasks

- The tasks addressed and the time occupancy vary intensively from case to case and depend e.g. on individual structures and organization and size of crew on board.
- The corresponding tasks are e.g. studying (mainly addresses young and unexperienced crew members), housekeeping like cooking and cleaning the accomodation, teaching/ coaching apprentices but also waiting at terminals.
- Waiting is daily business and is mostly replaced by some maintenance or additional breaks.



TASK 10
Recovery / Pause

- In the different companies and vessels various standards and approaches for the on/off-board time as well as the shift system are applied. As regards the on/off-board time among others long rhythms (e.g. 14/14 or 28/28 days) are applied next to short rhythms (7/7 days).
  - The shift system among others also depends on the used mode of operation. In mode B (24hr operation) e.g. often a 2 × 6hr shift system is applied while in mode A1 and A2 often 1½ × 8hr shifts are used within a 14/14 roster pattern. Foreign crew mostly has 28/28 roster pattern due to long travel times.
  - The different approaches are perceived differently from different persons depending on e.g. individual preferences, age and personal constitution. While some crew-members appreciate the 14/14 or 28/28 day on/off-board changes others regret them due to e.g. family reasons.
- The 2 × 6hr shift system leads to short uninterrupted sleep phases of on average 4 (minimum 3 and at maximum 5 hours on different times of the day. 1½ × 8hr shifts are often appreciated but sometimes also declined due to alternating day/night shifts. From a scientific point of view it has been proven that working hours are considered dominant in the workload – recovery relation and thus affecting safety and health. These wide varying habits, with corresponding risks ask for optimisation by use of fatigue management systems.
- In case of larger crew on board more strict start and end of shift times occur. In 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.
- Besides, also the quality of rest is addressed. In addition to the length of uninterrupted rest /sleep, in some cases also the quality of rest is important. Quality of recovery is determined by e.g. location of the accomodation (distance from engine/ entrance to the accommodation and deck/ wheel house lifting installatation, location compared to dancefloor on hotel vessels) and the perceived level of noise and vibrations. Although vessels have been approved on all relevant regulations before launching the vessel, still large differences occur in experienced levels of noise and vibrations due to age / state of the installations, up-/downstream sailing etc.
- As regards ship owners (owner operators) it has been observed that they - compared to employed crew members - often take less holidays and - especially younger ship owners - are willing to work as much as allowed while elder ship owners tend to prefer more recreation time, e.g. in terms of free weekends.

TASK 11
Travel

- Travelling addresses the trip between vessel and home. Sometimes, these are regional or national journeys but often they are international, e.g. between Poland or Czech Republic and Germany or between the Danube and the Rhine corridor. In extreme cases also a journey from Latvia to Germany has been reported.
- These journeys are handled quite differently, no general rules have been observed. In a few cases they are counted as working time, in most cases as private time, and sometimes as partly work and private time. A few companies require a night in a hotel before boarding if preceeded by long travels.

General observations

In addition, despite of the large variety of tasks and operational conditions certain general findings have been observed.

While navigation and (if applicable) entrepreneuring usually are tasks of the boatmaster only, most other tasks are addressed to boatmaster and boatman as well, however to different extent and intensity.

In general, it has been observed that the **level of attention** for boatmaster and boatman is often moderately or extremely undemanding, in some cases demanding and during (seldom) peaks extremely demanding. Such peaks mainly refer to exteme nautical situations, like navigation under challenging situations such as heavy weather, intensive fog, high traffic density, narrow bridges etc. or (seldom) emergency situations. While high traffic density, narrow bridges and emergency are rather characterised by usually short duration, other situations like e.g. radar navigation during fog or at night usually last longer. Except for emergency, most of these elements are predictable on the short and long term, based on stretch planning and weather forecast.

The **physical workload** for the boatmaster is generally considered extremely undemanding. For the boatman in most cases physical workload is considered undemanding or extremely undemanding. However some tasks are considered (extremely) demanding, such as rope handling during (un)mooring of large vessels, the handling of heavy hoses or the handling of dangerous goods, e.g. intermitting tank cleaning, replacing heavy parts in machinery etc. In relation to the total working time they are considered small peaks. Some of these tasks are easier to handle with additional hands. Such additional personnel, however, do not necessarily have to be on board, except for dealing with dangerous goods. Moreover, for most tasks technical support is available.

No interviewed crew said that more crew on board is needed over and above the (currently) regulatory required number. Accordingly, the present level of personnel is considered as 'upper level' for the development of the envisaged crewing instrument.

The registered vessel age is considered no indicator for (technical) equipment.

3.1.2 Conclusions

The observed findings as regards the different tasks addressed provide a comprehensive overview on the time occupancy as well as on mental and physical workload of the crews on inland vessels. These findings provide valuable insight into the working conditions.

At the same time these findings serve as an important basis and starting point for the development of the envisaged crewing instrument. Based on these observations general correlations as well as proper indicators for reasonable ranges of various parameters and conditions for simultaneity have been derived. As core conclusions it can be deduced that manning shall be based on time occupancy in combination with workload and fatigue/ recovery aspects and that navigation time is limited by fatigue.

This is further outlined in chapter 4.

3.2 Expert workshop

In the expert workshop expected future technical as well as non-technical developments were reflected on with experts from various fields with a specific view to corresponding impacts on crewing. Amongst others, transport demands and logistic requirements were intensively reflected, addressing transport volumes in the different market segments, the trends towards smaller shipment sizes and the still growing rate of containerisation as well as the strong intermodal competition (between the modes) and the resulting price pressure. Also, the labour market, the increasing shortage of qualified crew members and the corresponding need for commuting often from abroad with long journeys was addressed.

As regards the long lasting trend towards larger vessels (economies of scale) it is considered unclear whether this trend will continue or will 'run out of steam', e.g. due to the expected climate change and infrastructure limits. There are also signals indicating an increasing need for smaller vessels.

The core findings with impact on the approach of the tool are outlined below.

- Within a certain timeframe for the pure navigation in general **one** qualified person is needed considering that all necessary tools are in the wheelhouse to control all functionalities on board. This timeframe is limited by the maximum working time and fatigue; in case of longer navigation alternating personnel is needed.
- As regards navigation the length and width of the vessel in general is considered not relevant. In contrast, the relation between vessel size and infrastructure dimensions, e.g. navigation of (large) vessels in narrow and confined waterways is considered more relevant.
- Beyond navigation further crew member(s) are needed for further tasks (as far as relevant), e.g. for mooring, loading and unloading, cleaning, maintenance etc.
- In general, it is considered possible to **outsource** (parts of) such additional tasks to (external) service partners, e.g. cleaning, painting, maintenance of engines, monitoring of (un-)loading or to IT-equipment etc., depending on the specific circumstances (organisational solutions). Also, **organisational approaches** addressing tasks like (un)coupling, (un)mooring, e.g. in locks etc. might be feasible in certain cases thereby using a kind of pooling of personnel (considering comprehensive approaches beyond company level).
- Also, **technical solutions** are considered possible approaches to reduce time occupancy and physical workload of such additional tasks. Automation approaches like automated coupling, uncoupling or mooring systems in general are available and might be a solution for certain cases, thereby also considering safety questions, costs and maintenance. This also refers to physically demanding tasks like lifting heavy ropes or hoses of very large vessels. Such options need to be checked on a case-to-case basis.
- Due to the shortages of qualified workforce in all (transport) sectors further automation processes are expected in the future.

Finally, innovations of any kind, whether technical or organisational, have to be properly assessed on their impact on health and safety of the crew, the safety of navigation and other elements like environment. These risk assessments should prove that the innovation does not create any additional risks and that the adjustment of the crew is legitimated.

CREWING INSTRUMENT

4

4.1 Approach and basic philosophy of the tool

Present crewing regulation mainly is based on vessel type, length of the vessel, technical equipment and mode of operation. The relevant tasks and their characteristics however are not (directly) addressed. The present approach determines the required crewing for a vessel in general (i.e. not per single journey).

Contentwise however it is considered reasonable, and also conventional in other transport sectors and safety critical industries, to put the crew and the tasks to be carried out in the focus of attention as the tasks determine time occupancy as well as mental and physical workload and thus the need for recovery and alternation, respectively by replacing colleagues or by interruption of execution of the tasks (pause). Correspondingly, **task-based approaches** which means incorporating the type of activities and time occupancy including workload usually are the core of workload and organisation redesign projects. Examples are safe sailing in the maritime sector and naval marine but also all kinds of traffic management or process industry. Based on these considerations, also for TASCS a task-based approach has been choosen.

Further information with relevance for the development of the envisaged crewing instrument has been gained from the field study and the expert workshop. Based on these findings and considerations the suggested TASCS-approach is built on the following steps:

- The new approach starts from scratch, leaving existing conceptual frameworks and tables.
- The guiding idea for the development of this instrument (and precondition for its application) is to maintain the same level of safety as before.
- The level of automation has been incorporated in order to develop the instrument more futureproof according to the approved level of automation (CCNR CC/CP (18) 21)[7] (cf. table 3 below).
- The instrument is focused on competences at management level (boatmaster) and operational level (boatman) as a basis, derived from ES-QIN.
- For each competence the minimum required time occupancy is calculated per vessel and per specific, single journey, e.g. Rotterdam - Mannheim (i.e. not for the vessel in general). As a journey not the 2 or 4 week time period on board of the vessel but in contrast the single stretch is recognized.
- The total minimum time occupancy is the sum of time occupancies of 11 tasks including recovery. Besides the pure sailing and other navigational tasks also certain tasks for pre- and postprocessing, e.g. loading and unloading, preparation of a journey etc. are addressed. Thereby, also the type and amount of cargo is considered.
- Physical workload and cognitive level of attention are considered as well, as they do influence the effective minimum time occupancy and simultaneity. After all the duration and the type of work (physical and cognitive) affects being fit for duty. The duration and the type of work are dealt with in terms of extension or reduction of the calculated time occupancy.
- The resulting minimal time occupancy per competence and per journey still has to be translated into the needed minimum number of persons per competence, depending amongst others on the acceptable daily working time or business model chosen (e.g. use of a fixed crew dedicated to a vessel or a crew in a flexible pool).

[7] Central Commission for the Navigation on the Rhine, CCNR: 'First international definition of automation levels in Inland Navigation' (CCNR CC/CP (18) 21), Strasbourg, 2018.

	Level	Name Designation	Vessel command (steering, propulsion, wheelhouse, etc.)	Monitoring of and responding to navigational environment	Fallback performance of dynamic navigation tasks	Remote control
Helmsman 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 enhanced by warning or intervention systems *E.g. navigation with support of radar installation*				No
	1	**Steering assistance** 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 *E.g. rate-of-turn regulator* *E.g. trackpilot (track-keeping system for inland vessels along predefined 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				
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				Subject to context specific execution, remote control is possible (vessel command, monitoring of and response to environment or fallback performance). It may have an influence on crew requirements (number or qualification)
	4	**High automation** the sustained context-specific performance by a navigation automation system of all dynamic navigation tasks and fallback operation, without expecting a human boatmaster responding to a request to intervene8 *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	**Full automation** the sustained and unconditional performance by a navigation automation system of all dynamic navigation tasks and fallback operation, without expecting a human boatmaster will respond to a request to intervene				

Table 3: First international definition of levels of automation in Inland Navigation (CCNR: CC/CP (18) 21)

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

Specifications

Irrespective of the minimum calculated time occupancy as explained above, depending e.g. on the specific situation or on the technical equipment of the vessel etc. also additional or reduced time occupancies may arise. Additional time occupancy e.g. can emerge in case of young, unexperienced crews or additional tasks out of this scope or in case of higher (company internal) standards for maintenance. But also rosters (Fatigue Management System) and the presence of trainees have to be considered.

The question of **simultaneity of tasks** also needs to be considered: tasks with high or extreme level of attention cannot be done in parallel. This refers to tasks of level *** or **** such as conducting an inspection round, preparing the container stowage plan, navigating in difficult area or circumstances, entering a lock etc.. tasks with low or moderate level of attention like level * or ** might be combined with another task of the same or lower workload and attention level.

Technical equipment, modernisation and automation as well as outsourcing of certain tasks may affect the time occupancy and workload of nautical personnel. In the workshop on future technical and non-technical developments it was considered possible to **outsource** (parts of) the non-navigational tasks to (external) service partners, e.g. cleaning, painting, maintenance of engines, monitoring of (un-) loading or IT-equipment etc., depending on the specific circumstances. Outsourcing of tasks like (un)coupling, (un) mooring, e.g. in locks etc. might be feasible in certain cases thereby using a kind of pooling of personnel (considering comprehensive approaches beyond company level).

Also, **technical solutions** are considered possible approaches to reduce time occupancy and physical workload of such additional tasks. Automation approaches like automated coupling, uncoupling or mooring systems in general are available and might be a solution for certain cases, thereby also considering safety questions, costs and maintenance. This also refers to physically demanding tasks such as lifting heavy ropes or hoses of very large vessels. Such options need to be checked on case to case basis.

The grades for navigation conditions ('easy', 'normal', 'demanding') and state of equipment ('brand-new', 'mixed', 'used extensively') are defined quite coarse. They could be defined more precisely – and the mathematical model in the background can regard any level of detail – but this would lead to an increased number of input parameters and the tool would be less handsome. Here, the best compromise has to be found.

Structure and context

Schematically, the structure of the Crewing Instrument is described in the upper part of Figure 5. This figure also shows the context in which the instrument should be interpreted.

First of all it must be clear that complying with the Crewing Instrument is not a guarantee (in a liability sense) that sailing is safe. It is a solid base for operational planning, but it can by default not take into account unforeseeable extreme circumstances. Consequently, 'good seamanship'[9] always prevails.

1. After calculating the minimal time occupancy per competence per journey, also requirements from safety plans for e.g. evacuation or fire fighting have to be taken into account. These emergency plans first have to be be incorporated after calculating the minimum crew needed in order to calculate the optimal crew needed.
2. Business model dilemmas like how to deal with less experienced crew or how to organise personnel, e.g. dedicated to a vessel or organised in a flexible pool have to be taken into account after calculating the minimum crew needed in order to calculate the optimal crew needed. Already existing social dilemmas like what tasks to offer to crew if no sailing or cargo transfer is planned are not affected by this tool.
3. Furthermore, the instrument does not interfere with existing regulations from the **EU Working Time Directive**. Figure 5 shows how legal regulations and company characteristics should be combined with the instrument to design daily operational planning for safe sailing. It is proposed that at least the combination of maximum allowed working times and the amount of required competences (the outcome of the Crewing instrument) shall be implemented in a system or device that can be used for enforcement.
4. In addition, it is suggested to apply a **Fatigue Risk Management System (FRMS)** for use in inland waterway transport. Regulation always refer to the minimal requirements, agreed upon after negotiations. Innovative or progressive organisations often comply to additional and higher standards, taking the actual state of art in science into account, like ISO standards on quality, environment or health and safety.

[9] In the Netherlands 'goed zeemanschap' is defined in the Dutch 'Binnenvaart politiereglement art. 1.04 & 1.05'
A corresponding equivalent EU-regulation has not yet been identified.

5. FRMS are already in place in aviation and rail, for instance. Accordingly, the International Air Transport Association (IATA) which supports aviation with global standards for airline safety, security, efficiency and sustainability explains on it's website: "A FRMS allows an operator to adapt policies, procedures and practices to the specific conditions that create fatigue in a particular aviation setting. Operators may tailor their FRMS to unique operational demands and focus on fatigue mitigation strategies that are within their specific operational environment."[10]. Accordingly, a FRMS may be used to make the fleet owners and boatmasters more aware of fatigue risks, and provide them with mitigating measures. Consequently, a FRMS framework should be developed that can easily be applied by the vessel owners as well.

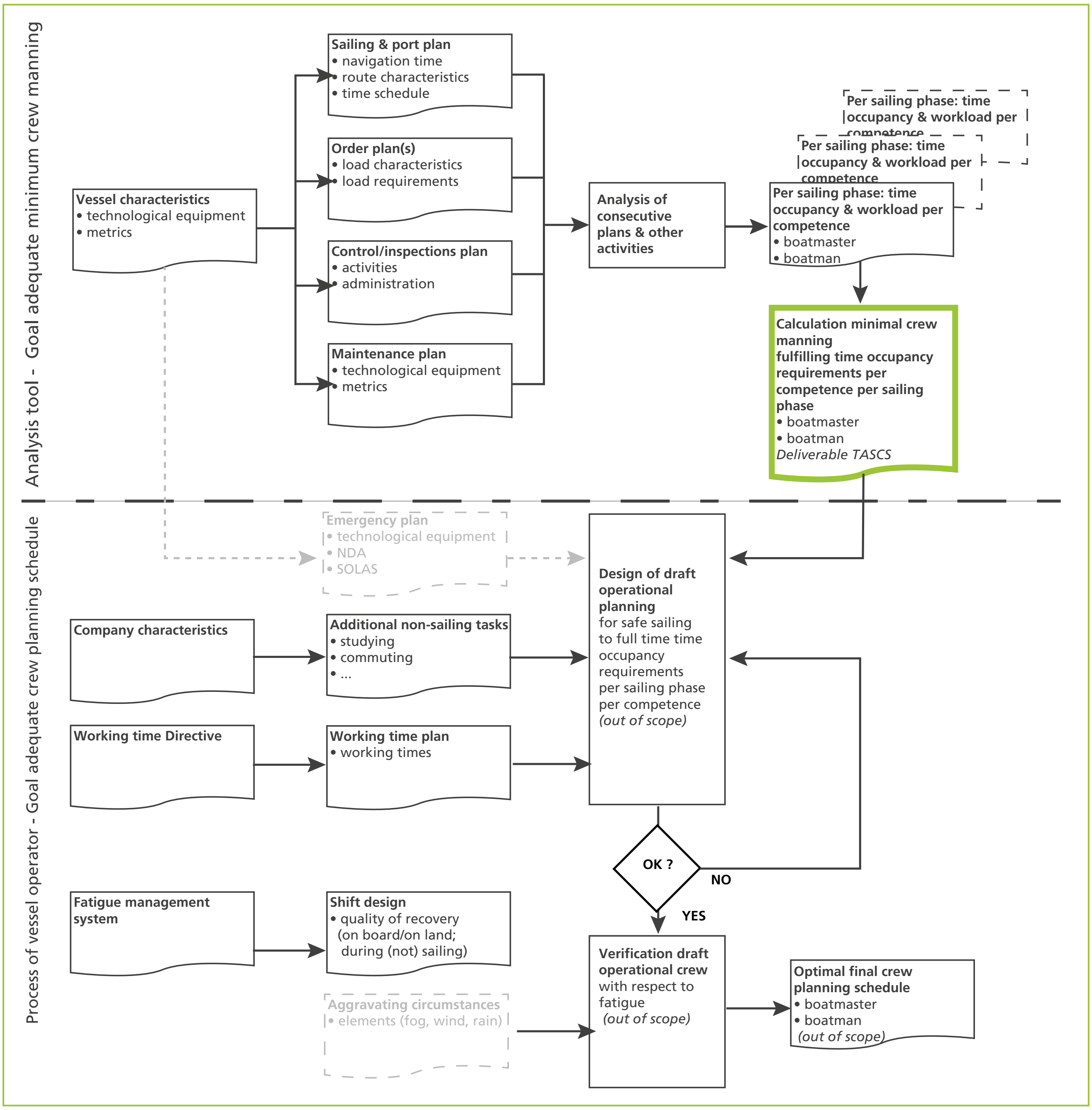


Figure 5: Positionning of the TASCS crewing tool in the general crew planning

Accordingly, the lower part of Figure 5 suggests the following next steps after the Crewing instrument has been accepted and implemented:

- Integration of EU Working Time Directive and the Crewing Instrument into an enforceable system or device.
- Development of an easy-to-use Fatigue Risk Management System framework.

[10] https://www.iata.org

4.2 Calculation rules

Within the crewing instrument several formula and algorithms are used. In general, the applied figures (default values or suggested options) are based on observations of the field study, i.e. on real cases. Thereby, averages rather than extremes have been used in order to be as representative as possible.

In this chapter, the applied calculation rules are explained per task and per competence. Thereby both mathematical as well as verbal descriptions are provided.

The instrument basically calculates the effective time occupancy for each task. Within one task, phases of higher workload are compensated by phases with lower workload where regeneration (recovery) is possible. These effects are implicitly included in the observed time occupancies per task. In general, there is no extra regeneration (recovery) time to be considered for higher work loads.

An exception applies for the task of navigation: Here the user can input whether the navigation conditions are easy, normal or demanding. For easy and normal conditions the time occupancy is equal to the navigation time. For demanding conditions the effective time occupancy is 10% higher than the navigation time. That means for each hour navigation 1.1 person hours are needed.

Some tasks can be done simultaneously (e.g. navigation and internal communication). The simultaneity can be infected by the workload. Again, under easy navigation conditions more tasks can be done simultaneously than under normal navigation conditions. Under demanding navigation conditions no other task can be done simultaneously.

In the tool a default minimum value is needed for recovery. In principle, no distinction is made between employees and self-employed crew members, as from a biological point of view there are no differences. As a reference it is assumed that on average a physical workload of ** as well as a mental level of attention of ** is acceptable for an 8hr working day. It is common sense in research that 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 the also occurring need for sleep of 9 hours; the variation is based on individual characteristics. We assume also that if it is foreseen that recovery will be disturbed (boatman assisting with locks/ (un)loading) then the crew can in advance compensate (as currently observed in practice). Some sleep debt might remain but will be compensated in the time at home after the maximum of two weeks of work (being also two weeks at home), provided a healthy roster (according to a fatigue management program). Unforeseen disturbed recovery should be compensated during the shifts.

Apprentices are considered in terms of additional times for boatmaster and boatmen for the education of trainees (task 9) and in terms of slight time reductions for certain tasks for boatmen.

4.2.1 Mathematical description

The following tables provide an overview on the used symbols as well as on the applied calculation rules and algorithms per task and per competence. Chapter 4.2.2 provides a verbal description.

t_{nav}	Total time, the ship is sailing (engine on, rudder under control).
t_{day}	Daily sailing (engine on, rudder under control) time.
t_{ext}	Time buffer for activities that can be done before or after sailing the stretch
n_{days}	$= \frac{t_{\mathrm{nav}}+t_{\mathrm{loading}}+t_{\mathrm{unloading}}}{t_{\mathrm{day}}}$
$n_{masters}$	number of boat masters
n_{men}	number of boat men
n_{locks}	number of locks *
M	Simultaneity matrix, default $\mathbf{M} = \begin{bmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{bmatrix}$

Table 4: Symbols

* Only locks are considered because of impact on mental effort of boatmaster (higher than during sailing) and on time occupancy and physical workload of the boatmen. Passing narrow bridges only have short impact on the mental effort of a boatmaster during sailing.

Boatmaster	1 Motor cargo vessel	2 Motor tanker vessel	3 Container vessel	4 Push convoy	5a Day-trip vessel	5b Ferry	6 Cabin vessel	7 Tug/Tow boat
1 Navigation	Level of automation: 0 $t_n = t_{nav}$ 1 $t_n = 0.9 \cdot t_{nav} + 0.1 \cdot n_{locks} \cdot 1h$ 2 $t_n = 0.8 \cdot t_{nav} + 0.2 \cdot n_{locks} \cdot 1h$ 3 $t_n = 0.4 \cdot t_{nav} + 0.6 \cdot n_{locks} \cdot 1h$ 4 $t_n = n_{locks} \cdot 1h$ 5 $t_n = 0$							
	$t_{mooring} = 0.2h$ $t_{unmooring} = 0.15h$				$t_{mooring} = 0.05h$ $t_{unmooring} = 0.05h$		$t_{moorg.} = 0.2h$ $t_{unm.} = 0.15h$	
For easy and normal navigation conditions $f_1 = 1.0$, for foreseeable demanding navigation conditions $f_1 = 1.1$. $t_1 = f_1(t_{nav} + t_{mooring} + t_{unmooring})$ For easy navigation condition $\mathbf{M}_{1,4} = \mathbf{M}_{1,5} = \mathbf{M}_{1,6} = \mathbf{M}_{1,8} = -1.0$, for normal navigation condition $\mathbf{M}_{1,4} = \mathbf{M}_{1,5} = \mathbf{M}_{1,6} = \mathbf{M}_{1,8} = -0.8$.								
2 Operation of the craft	—	—	—	—	—	—	—	—
3 Cargo handling, stowage and passenger transport	$t_{loading} = \frac{m_{cargo}}{\dot{m}_{loading}}$ $t_{unloading} = \frac{m_{cargo}}{\dot{m}_{unloading}}$			$t_{coupling} =$ $t_{uncoupling} =$ $0.5h \cdot n_{barges}$	$t_{loading} =$ $t_{unloading} =$ $\frac{n_{Pax}}{720\frac{1}{h}}$	$t_{loading} =$ $t_{unloading} = 0$	$t_{loading} =$ $t_{unloading} =$ $\frac{n_{Pax}}{600\frac{1}{h}}$	—
			$t_{planning} = 1h$					
	Default values: $\dot{m}_{loading}$ $= \dot{m}_{unloading}$ $= 400\,\frac{t}{h}$	Default values: $\dot{m}_{loading}$ $= \dot{m}_{unloading}$ $= 90\,\frac{t}{h}$	Default values: $\dot{n}_{loading} =$ $\dot{n}_{unloading} =$ $20\frac{1}{h}$					
	for ADN-goods $h_{adn} = 2h$ for additional administration, else $h_{adn} = 0$							
$t_3 = t_{loading} + t_{unloading} + t_{adn} + t_{planning}$								
4 Inspection	$t_4 = 0.25h\ n_{days}$							
5 Maintenance/ Repair	$t_5 = 0.25h\ n_{days}$							
6 Communication	$t_6 = 0.25h\ n_{days}$							
7 HSE, Emergency drills	$t_7 = 0.05h$	if ADN: $t_7 = 0.25h$ else: $t_7 = 0.05h$	$t_7 = 0.05h$	$t_7 = 0.05h$	$t_7 = 0.05h$	$t_7 = 0.05h$	$t_7 = 0.05h$	$t_7 = 0.05h$
8 Entrepreneuring	$t_8 = 1h\ n_{days}$							
9 Other tasks	$t_{studying} = \frac{10}{60}h$ $t_{hygiene} = 0.5\ h\ n_{days}\ n_{masters}$ $t_{trainees} = 0.75\ h\ n_{days}\ n_{trainees}$							
$t_9 = t_{studying} + t_{hygiene} + t_{trainees}$								
10 Recovery/ Pause	$t_{10} = t_{rest}\ n_{days}\ n_{masters}$							
11 Travel	$t_{11} =$ user input							

Table 5: Applied formula for a boatmaster

General remark: Presented figures based on field study and expert input. Further specification is considered subject of the validation process.

Ad 1: Assumed: lock passage takes 1h for a vessel on average. (Un-)mooring for day trip vessels and ferries take fewer time than other vessels, because of use of prefab ropes, fit for duty repeatedly. No time calculated for (un-)mooring pushed convoys and tug/tow boat because of coupling/decoupling units. Demanding navigation conditions: e.g. use of official meteorological warning codes or fog with sight less than 3 times vessel length etc.;

Ad 3: boatmaster has no time occupancy in "(dis-)embarking" passengers on the ferry. Tug/Towboats with very individual requirements. Subject of validation process.

Ad 5: 0,25h/day for supervision. 'State' of equipment (old, new etc.) and corresp. algorithm might be added (Subject of evaluation process)

Ad 9: 'Studying' addresses on-the-job-training, e.g. getting familiar with new regulations etc.

Boatman	1 Motor cargo vessel	2 Motor tanker vessel	3 Container vessel	4 Push convoy	5a Day-trip vessel	5b Ferry	6 Cabin vessel	7 Tug/Tow boat
1 Navigation	$t_{mooring} = 0.2h$ $t_{unmooring} = 0.15h$				$t_{mooring} = 0.05h$ $t_{unmooring} = 0.05h$		$t_{mooring} = 0.2h$ $t_{unmooring} = 0.15h$	
$t_1 = t_{mooring} + t_{unmooring}$								
2 Operation of the craft	$t_2 = 0.1h\ n_{days}$	$t_2 = 0.1h\ n_{days}$	$t_2 = 0.1h\ n_{days}$	$t_2 = 0.1h\ n_{days}$	$t_2 = 0.1h\ n_{days} + 0.5h$	$t_2 = 0.1h\ n_{days}$	$t_2 = 0.1h\ n_{days} + \frac{n_{Pax}}{50}$	$t_2 = 0.1h\ n_{days}$
3 Cargo handling, stowage and passenger transport	$t_{cleaning} = 1.2h \frac{m_{cargo}}{1000t}$	$t_{loading} = \frac{m_{cargo}}{\dot{m}_{loading}}$ $t_{unloading} = \frac{m_{cargo}}{\dot{m}_{unloading}}$ $t_{cleaning} = 6h + \frac{m_{cargo}}{500t}$		$t_{coupling} = t_{uncoupling} = 0.5h \cdot n_{barges}$	$t_{loading} = t_{unloading} = \frac{n_{Pax}}{720\frac{1}{h}}$	$t_{loading} = t_{unloading} = \frac{n_{cars}}{240\frac{1}{h}} + \frac{n_{passengers}}{6000\frac{1}{h}} + \frac{n_{bicycles}}{1800\frac{1}{h}}$	$t_{loading} = t_{unloading} = \frac{n_{Pax}}{600} h$	
	for ADN-goods $t_{adn} = 1.5h\ n_{days}$, else $t_{adn} = 0h$							
$t_3 = t_{loading} + t_{unloading} + t_{adn} + t_{cleaning}$, if trainees onboard: t_3 is reduced by 12.5%								
4 Inspection	Sensors: none: $t_4 = 1h\ n_{days}$ partially: $t_4 = 0.5h\ n_{days}$ full: $t_4 = 0$							
if trainees onboard: t_4 is reduced by 12.5%								
5 Maintenance/ Repair	Equipment: brand-new: $t_{maintenance/repair} = 0.25h\ n_{days}$ mixed: $t_{maintenance/repair} = 0.5h\ n_{days}$ used intensively: $t_{maintenance/repair} = 1h\ n_{days}$ $t_{housekeeping} = 1.5h\ n_{days}$							
	$t_5 = t_{maintenance/rep} t_{housekeeping}$	$t_5 = 1.5 \cdot t_{maintenance/repa} t_{housekeeping}$	$t_5 = t_{maintenance/rep} t_{housekeeping}$	$t_5 = t_{maintenance/rep} t_{housekeeping}$	$t_5 = t_{maintenance/rep} t_{housekeeping}$	$t_5 = t_{maintenance/rep} t_{housekeeping}$	$t_5 = t_{maintenance/rep} t_{housekeeping}$	$t_5 = t_{maintenance/rep} t_{housekeeping}$
if trainees onboard: t_5 is reduced by 12.5%								
6 Communication	$t_6 = 0.25h\ n_{days}$							
7 HSE, Emergency drills	$t_7 = 0.05h$	if ADN: $t_7 = 0.25h$ else: $t_7 = 0.05h$	$t_7 = 0.05h$	$t_7 = 0.05h$	$t_7 = 0.05h$	$t_7 = 0.05h$	$t_7 = 0.05h$	$t_7 = 0.05h$
8 Entrepreneuring	$t_8 = 0h$							
9 Other tasks	$t_{hygiene} = 0.5\ h\ n_{days}\ n_{men}$ $t_{trainees} = 0.5\ h\ n_{days}\ n_{trainees}$							
10 Recovery/ Pause	$t_{10} = t_{rest}\ n_{days}\ n_{men}$							
11 Travel	$t_{11} = $ user input							

Table 6: Applied formula for a boatman

General remark: Presented figures based on field study and expert input. Further specification is considered subject of the validation process.

Ad 1: (Un-)mooring for day trip vessels and ferries take fewer time than other vessels, because of use of prefab ropes, fit for duty repeatedly. No time calculated for (un-)mooring pushed convoys and tug/tow boat because of coupling/decoupling units.

Demanding navigation conditions: e.g. use of official meteorological warning codes or fog with sight less than 3 times vessel length etc.

Simultaneity

As mentioned above, during regular sailing, when the level of attention is (extremely) undemanding (not being passing a lock or (un-)mooring) the following equally or less demanding tasks can be performed simultaneously by the boatmaster: inspection supervision (task 4), maintenance supervision (task 5), communication (task 6) and simple entrepreneuring (task 8), provided that theses tasks are within reach of navigational displays and controls (in the wheelhouse). Other tasks such as cargo planning (preparing or adopting container planning) shall not be executed in parallel due to interference of required high levels of attention.

For both, boatmaster and boatman, the total time occupancy is calculated from the vector of task specific times $\mathbf{t}$, and the simultaneity matrix $\mathbf{M}$:

$$\mathbf{t} = [t_1, \cdots, t_{11}]^{\mathrm{T}}$$

$$t_{\text{total}} = \|\mathbf{Mt}\|_1$$

Minimum number of persons

For (initial) calculation of the minimum number of crew members a time buffer t_{ext} is defined for short trips for work that can be performed before or after navigation:

$$t_{\text{ext}} = \begin{cases} t_3 + t_4 + t_6 + t_7 + t_8 + t_9 & , t_{\text{nav}} < t_{\text{day}} \\ 0 & , t_{\text{nav}} \geq t_{\text{day}} \end{cases}$$

$$n_{\text{masters}} = \frac{t_{\text{total,boatmaster}}}{n_{\text{days}} \cdot 24\text{h} + t_{\text{loading}} + t_{\text{unloading}} + t_{\text{ext}}}$$

$$n_{\text{men}} = \frac{t_{\text{total,boatman}}}{n_{\text{days}} \cdot 24\text{h} + t_{\text{loading}} + t_{\text{unloading}} + t_{\text{ext}}}$$

Since the minimal total time occupancy per qualification level depends on the number of persons in this qualification level $(t_9 = f(n_{\text{men/masters}}))$, the minimum number of persons is calculated iteratively in the tool: the calculation is repeated until n_{masters} and n_{men} converge.

The resulting minimum number of persons is considered the lower level. Further influencing factors beyond the scope of TASCS have to be considered as well (lower part of figure 5). This addresses for instance the working time, fatigue management, the assignment of young, unexperienced crew members or company internal regulation which may lead to additional crew members. (See chapter 4.1 of the report.)

4.2.2 Explanatory description

In addition, the applied calculation rules are explained per task and per competence using verbal descriptions.

TASK 1
Navigation (Boatmaster)

- Sailing: the net amount of sailing time of the vessel is translated in the same amount of time for the boatmaster (including 1 hr per lock).
- Because of the relatively low level of attention needed in general, parallel performance of one of the next tasks is allowed: 4 (Remote) Inspection, 6. Communication, 8. Entrepreneuring. It is assumed that the devices needed for these parallel tasks are easily accessible from the steering position, thereby not affecting proper sight and communication lines etc.
- The level of attention can incidently peak because of sudden complex crossing or obstacles or sudden fog/ heavy weather, respectively. These acute peaks that cannot be foreseen should not affect the allowed time allocation or the minimum crew manning needed. Compensating for acute peaks during time on board is considered the responsibility of the crew by additional recovery or exchange of tasks, if necessary using FRMS.
- However, longer lasting peaks in cognitive level of attention that can be foreseen during particular stretches of heavy/ complex traffic and obstacles, or during predicted heavy weather circumstances (storm, intense fog) result in a compensation ('malus') in time allocation needed. Such aggravating situations resulting in a 'malus' can be compensated by either additional manning (continuing the process, by replacement) or additional recovery (interruption of the process).
- Also an alleviating situation (e.g. additional automation or other business model like outsourcing) can be compensated ('bonus') with less manning (change of competences needed) or less need for recovery.

TASK 1
Navigation (Boatman)

- Lock passage: For every lock passage 1 hour is assumed for the boatman (except 0,5hr for daytrip vessels due to priority locking)
- The physical workload is mostly undemanding and attention some of the time needed. In case of passing narrow bridges or locks the level of attention increases to nearly all the time needed for that passing. However for these small peaks no malus correction is included for crew manning.
- This task – in future – can be fully or partially outsourced to technical alternatives, if high levels of automation are available resulting to automated navigation (outsourcing of human work to a "technical colleague"). This results in a 'bonus' factor in time allocation needed for crew manning. Nevertheless, still some time allocation is foreseen in this mode for the boatman and boatmaster as this automation needs supervision (including higer levels of attention).

TASK 2
Operation of the vessel (Boatmaster and boatman)

- The net amount of time needed for operation of the craft is the net input in the calculation tool.
- This task is sometimes outsourced, out of the IWT crew. E.g. ferries have other departments providing this service

TASK 3
Cargo handling, stowage and passenger transport (Boatmaster and boatman)

- The workload for cargo handling varies widely and among others depends on the type of cargo (dry bulk, liquid bulk, containers) or passengers respectively (with or without luggage [cruise vs. daytrip vessels], with or without cars or bikes [ferries]) but also on the speed of the transhipment facilities in different ports and terminals. Correspondingly, cargo-specific approaches for loading and unloading are used.
- Further tasks address the stowage plan (boatmaster) or reefer connections (boatman) in case of container transport, ballast water management (boatmaster), ADN-documentation in case of dangerous cargo (boatmaster), inspection of cargo and cargo handling systems during navigation (boatman), cleaning the cargo hold (boatman) or coupling and uncoupling of barges and vessels (tug/tow) at the start- and endpoint of the journey (boatmaster and boatman) as well as control of tautness of wires during the trip (boatman). For all tasks, task specific approaches are applied.
- Additional time is calculated in case of dangerous cargo (ADN) in terms of 2 h for a boatmaster and 1.5 hr for a boatman.
- In case of trainees on board a reduction of 12.5% of t3 is assumed (for a boatman only).
- Inspection of the cargo and cargo handling systems can be performed simultaneously with the general ship inspection during the journey (boatman).
- In general, cargo handling or (un)coupling of barges can be outsourced to (internal or external) service partners.

TASK 4
Periodic inspection (Boatmaster and boatman)

- For the boatmaster this task is calculated with 0.25 hr per day.
- For the boatman the calculated time depends on the status of installed sensors: If no sensors are installed 1 hr/day is calculated; for partially installed sensors 0.5 hr/day is calculated and for the case of fully equipped vessels no time is calculated. In case of trainees on board, a time reduction of 12.5% is assumed.

TASK 5
Maintenance and Repair (Boatmaster and boatman)

- For the boatmaster this task is calculated with 0.25 hr per day.
- For the boatman the calculated time depends on the status of equipment: In case of brand-new equipment 0.25 hr/day is calculated; in case of partially new and partially used equipment 0.5 hr/day is calculated and for the case of intensively used equipment 1 hr/day is calculated. Housekeeping is calculated with 1.5 hr/day. Again, in case of trainees on board, a time reduction of 12.5% is assumed.

TASK 6
Communication (Boatmaster and boatman)

- For the boatmaster this task is calculated with 0.25 hr/day
- For the boatman this task is calculated with 0.25 hr/day as well.

TASK 7
HSE, Emergencies, Calamities (Boatmaster and boatman)

- For the boatmaster and the boatman this task is calculated with 0.05 hr/day, in case of ADN-cargo 0.25 hr/day.

TASK 8
Entrepreneuring (Boatmaster)

- For the boatmaster this task is calculated with 1 hr per day (if applicable); for a boatman this task usually does not apply.

TASK 9
Other tasks (Boatmaster and boatman)

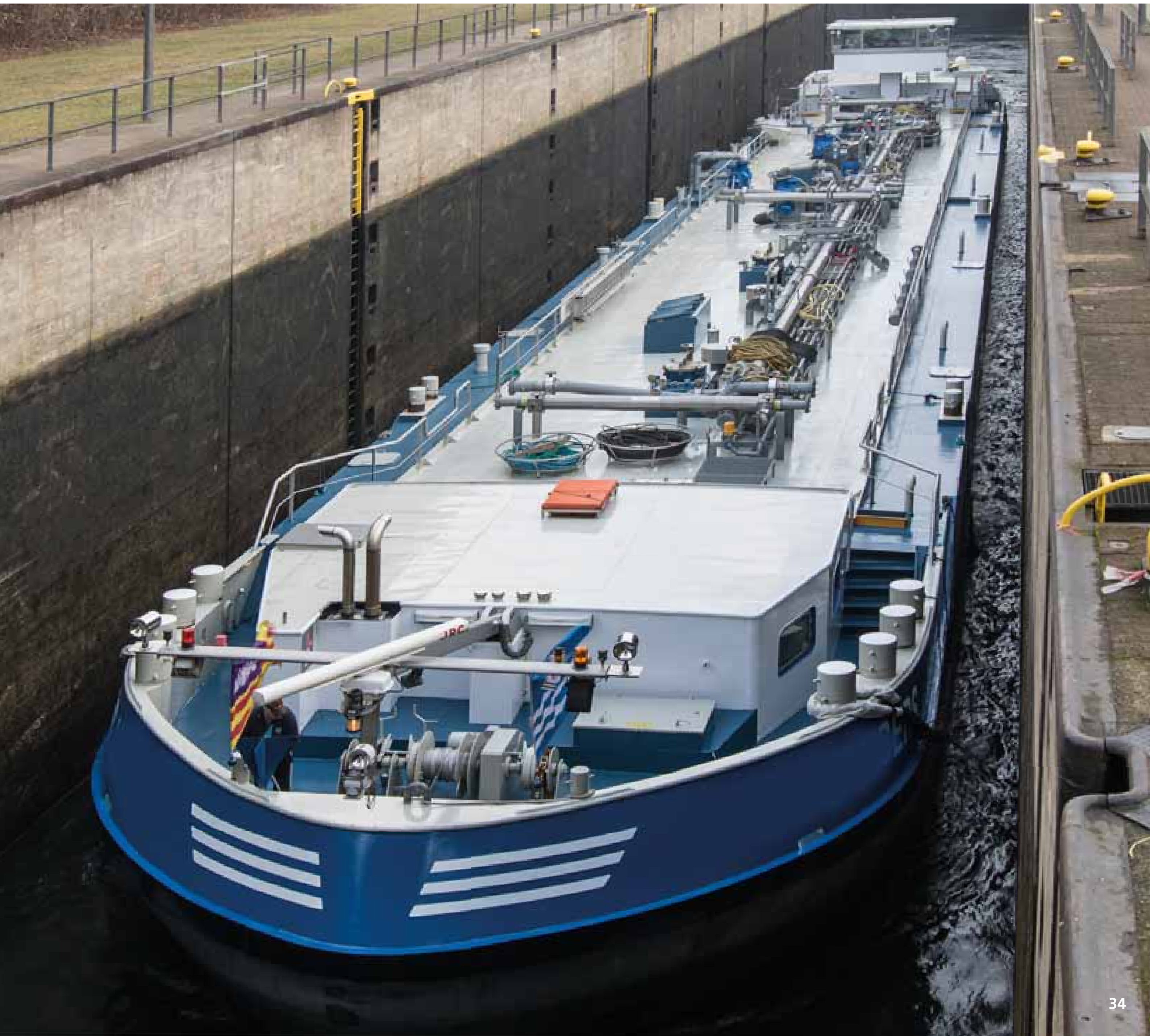
- For boatmasters and boatmen 0.5 hr/day and per person are calculated for hygiene and additional 0.75 hr/day and per trainee (boatmaster) and 0.5 hr/day and per trainee (boatman). An additional 10 minutes are considered for stydying (boatmasters).

TASK 10
Recovery / Pause (Boatmaster and boatman)

- This task is calculated with the specific time for rest per day and per person (manual input, default 8 hr/day)
- Further specification might be reasonable e.g. as regards the quality of rest. This might address for instance noise or interrupted recovery in case of locking etc. Such potential adjustments are dealt with in chapter 5.1.

TASK 11
Travel (Boatmaster and boatman)

- For this task a specific (manual) user input is foreseen.



4.3 Explanation and illustration

The tool has been developed as an online tool and is available under

https://www.dst-org.de/TASCS

For illustration purposes, selected examples have been calculated with the new instrument. The results has been compared with the existing regulation.

4.3.1 Example dry bulk vessel

The first example is a dry bulk vessel with a length of 110 m, a width of 11.45 m, operating in mode A1, transporting 1500 t (no ADN goods) and travelling 66 h. The calculation with the tool leads to the following result:

	Task	Boatmaster	Boatman
☑	Navigation Automation level: 1 – Steering assistance Navigation conditions (traffic density, sight, confined waters): normal	59.4	0.3
☑	Operation of the craft	0.0	0.5
☑	Cargo handling, stowage and passenger transport ☐ Dangerous goods (ADN)	7.5	1.8
☑	Inspection Machines and systems are equipped with sensors and bridge displays: partially	1.3	2.5
☑	Maintenance/Repair State of equipment: mixed ☑ Housekeeping (cooking, cleaning living rooms) by regular crew	1.3	2.5
☑	Communication	1.3	1.3
☑	HSE, Emergency drills	0.1	0.1
☑	Entrepreneuring	5.0	0.0
☑	Other tasks	3.4	10.1
☑	Recovery/Pause	8 h/day 40.2	8 h/day 40.2
☐	Travel		
	loading/unloading [h]:	7.5	
	Total journey duration [h]:	120.6	
	Total hours of work(simultaneity considered):	116.1	59.3
	Number of crew members (not considering the additonal factors):	1	1

Table 7: Example dry bulk vessel

In comparision to the calculated result, the present regulation requires for a vessel with L > 86 m and equipment standard S2 a larger crew, namely 1 boatmaster, 1 helmsman and 1 apprentice.
The need for a third person cannot be derived from the time occupancy. One reason for an additional person might be an easing of the mooring process.

4.3.2 Example Rhine ferry

The second example is a Rhine ferry. Here the tool is used for calculating the time occupancy for one river crossing (15 min):

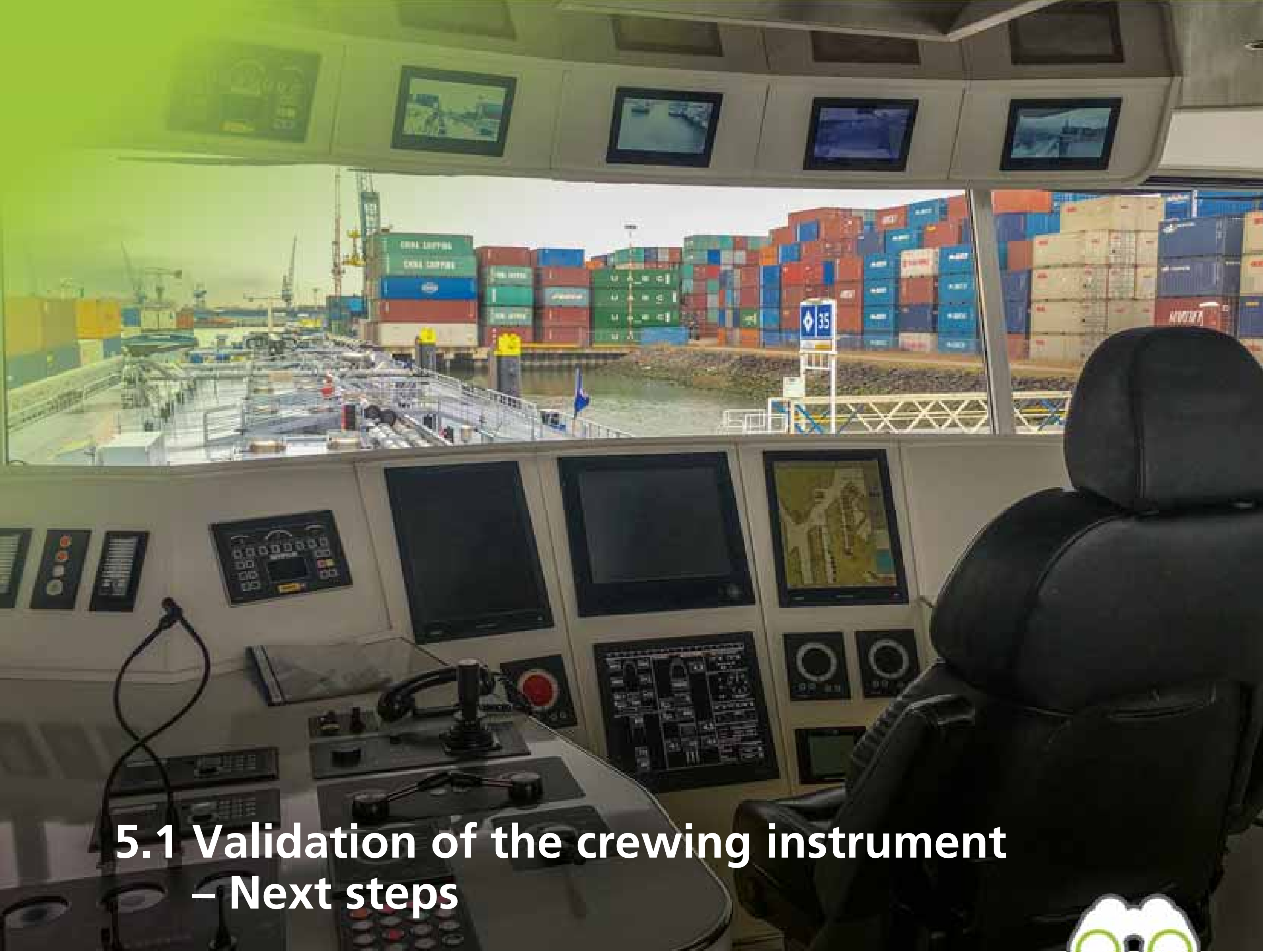
	Task	Boatmaster	Boatman
☑	Navigation Automation level: 0 – No automation Navigation conditions (traffic density, sight, confined waters): normal	0.2	0.1
☑	Operation of the craft	0.0	0.0
☑	Cargo handling, stowage and passenger transport ☐ Dangerous goods (ADN)	0.0	0.1
☑	Inspection Machines and systems are equipped with sensors and bridge displays: partially	0.0	0.0
☑	Maintenance/Repair State of equipment: mixed ☐ Housekeeping (cooking, cleaning living rooms) by regular crew	0.0	0.0
☑	Communication	0.0	0.0
☑	HSE, Emergency drills	0.1	0.1
☑	Entrepreneuring	0.0	0.0
☑	Other tasks	0.0	0.0
☑	Recovery/Pause	8 h/day 0.0	8 h/day 0.0
☐	Travel		
	loading/unloading [h]:	0.1	
	Total journey duration [h]:	0.4	
	Total hours of work(simultaneity considered):	0.3	0.2
	Number of crew members (not considering the additonal factors):	1	1

Table 8: Example Rhine ferry

The result of 1 boatmaster and 1 boatman matches the present regulation, but this example also shows a restriction of the tool: a series of single journeys cannot simply be concatenated or interlinked. While the number of crew members for one journey is correct, the same people cannot work continuously on any number of consecutive journeys. Accordingly, the working time needs to be considered as well.

EVALUATION AND OUTLOOK

5



5.1 Validation of the crewing instrument – Next steps

The developed crewing instrument provides a new, task-based approach for the calculation of the minimum crew size. While present systems mainly are based on vessel characteristics and mode of operation, this instrument determines the needed minimum crew size (and competences) for the specific tasks and conditions of a certain journey. This is considered reasonable as the tasks determine time occupancy as well as mental and physical workload and thus the need for recovery and alternation, respectively. Accordingly, this approach is considered a complete **system change**.

A further guiding idea for this instrument (and precondition for its application) is to maintain the same level of safety as before. Also, the level of automation has been incorporated in order to consider future developments and to provide a more futureproof instrument. This task-based approach offers the chance to specify the needed times for the different tasks on an individual level. Depending on the task and the specific conditions, e.g. level of attention the duration and the type of work are dealt with in terms of extension or reduction of the calculated time occupancy and workload.

In addition, this approach in principle also enables vessel owners to assess and evaluate the usefulness of innovation, technical modernization (e.g automation) or organizational changes: If such modernization or organizational changes would be implemented, how much time would it need to amortize the investment due to saved personnel costs?

Concluding, this provided instrument is considered a well documented and feasible approach for a future-oriented determination of the necessary crewing of inland vessels and a proper basis for the corresponding implementation process. Nevertheless, the tool should be subject of intensive reflection between the involved actors and parties. Irrespective of the fact that the instrument has been tested from selected users during the development process of TASCS and has been adjusted accordingly, such additional validation needs to be addressed systematically.

For other vessel types than considered in this project, the tool has to be extended.

The neccessary **evaluation process** on the one hand has to address the question of what level of detail and specification is needed to maintain the required high safety standards. On the other hand the instrument can only be applied and accepted by the users, if it is considered transparent, easy to use and easy to understand. Hence, it has to be kept handy and pragmatic enough. In general, the instrument offers the chance to describe technical features and workload in-depth and to consider a large variety of details. This however has to be critically reflected in terms of applicability and handability in practice and should be subject of further negotiations and reflections with the involved bodies and institutions.

Besides, such questions also refer to other issues as illustrated with some examples (not complete list):

- The type and amount of cargo is addressed in the tool. Nevertheless, the the load condition ((partly) loaded or empty), the size of the vessel etc. might affect the manoeverability of the vessel. Corresponding adjustments might be reasonable.
- Recovery is addressed in the tool. The quality of recovery however not only depends on time but on various impacts, e.g. location of the accomodation and the question of noise, vibration etc. which might be implemented or not. As regards disturbed recovery, e.g. in case of locks either advance compensation or compensation at home after e.g. 2 weeks on board might be considered.
- A large variety also exists as regards the shift systems and roster patterns. In the actual mode B for instance, a 2 × 6hr shift system often is applied while in mode A1 and A2 often 1½ × 8hr shifts are used within a 14/14 roster pattern. Foreign crews mostly have 28/28 roster pattern due to long travel times. These questions should be subject of discussion in the tool in the context of Fatigue Risk Management Systems (see also chapter 5.2).
- Commuting to and from the vessels is considered in the tool as well. As this might be different for different crew members the tool might be adjusted accordingly.

5.2 Incorporating the crewing instrument

For the integration of the TASCS crewing instrument into an enforceable system or device, existing regulations from the **EU Working Time Directive** have to be considered. According to Figure 5 legal regulations and company characteristics should be combined with the instrument to design daily operational planning for safe sailing. It is proposed that at least the combination of maximum allowed working times and the amount of required competences (the outcome of the Crewing instrument) shall be implemented in a system or device that can be used for enforcement.

In addition, it is strongly recommended to apply a **Fatigue Risk Management System (FRMS)** as already in place in other transport sectors e.g. in aviation, rail and road transport. Such a system should be used to make the vessel owners and boatmasters more aware of fatigue risks, and to provide them with mitigating measures. Accordingly, a FRMS framework should be developed that can easily be applied by the vessel owners as well.

5.3 Enforcement process

As mentioned, the suggested new crewing instrument is based on the approach to determine the needed crew (size and competences) per vessel and per individual journey. This requires a system change also as regards the necessary enforcement procedures. While present regulation implies constant crew sizes and competences the suggested instrument allows situation (journey)-specific adjustments of the crewing. This approach assumes that crew-planning has to be inserted into a corresponding (digital) system in advance of the journey. The enforcement party can then come on board and compare the plan with the actual situation.

Simultaneously, the addressed working time aspects could be dealt with in the corresponding systems as well. Respective approaches addressing new technologies for enforcement like digital tachograph and crew portfolios were shared by the European Commission.

In case of foreseen outsourcing of tasks, the crew manning plan shall be accompanied by proper risk assessments of effects on safe sailing (and health and safety of crew) and copies of agreements with proper certified partners or approved technical innovations.

SUMMARY

6

Summary

The Inland Waterways Transport (IWT) sector is characterised by specific on-board working and living conditions. At present, heterogeneous educational as well as crewing standards exist in the different European countries and river basins. The EU-wide harmonization of the educational standards is already in progress. Accordingly, a harmonized European crewing framework is considered desirable in order to contribute to improved labour mobility and to face the general demographic challenges. The leading IWT crewing regulation in force is the Regulation for Rhine Navigation Personnel (RNP) dating back almost 30 years. The last three decades however have witnessed considerable changes that impact on the sector – be it technological or non-technological.

Against this background, the Social Partners in 2014 jointly agreed on the need for the development of new crewing requirements for vessel crewmembers on the European Inland Waterway Network and initiated the investigation 'Towards A Sustainable Crewing System - TASCS' with support of the European Commission. TASCS aimed for the development of an in-depth workload assessment leading to a documented proposal for an easy to use and easy to enforce crewing instrument. The investigation has beed assigned to a consortium consisting of DST – Development Centre for Ship Technology and Transport Systems (coordinator), Intergo human factors & ergonomics and Prof. Peter Turnbull. The research took place in close cooperation between the project team, the Steering Group (SG) with European Social Partner delegates and a Focal Group (FG) of dedicated representatives from the IWT sector including skippers, crew members, fleet managers etc.

The investigation considered all relevant parameters that impact working conditions. Accordingly, the overall system with its elements that contribute to performance has been studied including the relevant relations and correlations of the various research parameters. Furthermore, the study considered the relevant European regulations on working time, safety, standardised competencies and current technical, logistic and human factors standards and state of the art knowledge. Scientifically well established models incorporating safety, workload, task effectiveness, fatigue and recuperation that are used in transport industries, are covered.

The **first milestone** of the investigation was a comprehensive **field study** based on observations and interviews of the crews during their operational work of 50 representative vessels operating in the interconnected inland waterways in Europe covering all seasons. Resulting from the different cargo categories (dry bulk, liquid bulk, containers) as well as the corresponding requirements a large variety of vessel types, sizes and equipments exists with corresponding specific technical features and a resulting specification of tasks for the crew. Also for passenger vessels specific requirements, features and corresponding tasks have been considered. Accordingly, a differentiation of the field study into 7 vessel types has been choosen. Work, recovery and commuting have been addressed. In total, 11 tasks have been distinguished; thereby, reference has been made to the clustering according to ES-QIN and to additional tasks that occur in practice, which are known to influence workload, level of attention and thus the need for recovery. For all vessels the tasks and the corresponding time occupancy as well as the physical workload and the level of attention have been assessed.

At the same time these findings serve as an important basis and starting point for the development of the envisaged crewing instrument. Based on these observations general correlations as well as proper indicators for reasonable ranges of various parameters and conditions for simultaneity have been derived. As core conclusions it can be deduced that crewing shall be based on time occupancy in combination with workload and fatigue/ recovery aspects.

As a **second milestone**, expected **future (technical and non-technical) developments** were discussed and reflected in a workshop with experts from various fields of expertise with a specific view on corresponding impacts on crewing.

Within a certain timeframe for the pure navigation in general one qualified person is considered necessary assuming that all necessary tools are in the wheelhouse to control all functionalities on board and considering the maximum working time and fatigue. As regards navigation the length and width of the vessel in general is considered not relevant. In contrast, the relation between vessel size and infrastructure dimensions, e.g. navigation of (large) vessels in narrow and confined waterways is considered more relevant.

In general, it is considered possible to outsource (parts of) non-navigational tasks to (external) service partners, e.g. cleaning, painting, maintenance of engines, monitoring of (un-)loading or to IT-equipment etc., depending on the specific circumstances (organisational solutions). Also, organisational approaches addressing tasks like (un)coupling, (un)mooring, e.g. in locks etc. might be feasible in certain cases thereby using a kind of pooling of personnel (considering comprehensive approaches beyond company level).

Also, technical solutions are considered possible approaches to reduce time occupancy and physical workload of such additional tasks. Automation approaches like automated coupling, uncoupling or mooring systems in general are available and might be a solution for certain cases, thereby also considering safety questions, costs and maintenance. This also refers to physically demanding tasks like lifting heavy ropes or hoses of very large vessels. Such options need to be checked on case to case basis.

Due to the shortages of qualified workforce in all (transport) sectors further automation processes are expected in the future.

The **third important milestone** was the development of a **proposal for a new crewing instrument**. While the present crewing regulation is mainly based on vessel type, length of the vessel, technical equipment and mode of operation the envisaged new instrument is built on a task-based approach; it determines the needed minimum crew time occupancy per competence (boatmaster/boatman) for the specific tasks and conditions of a certain journey. With this base-calculation additional steps have to be performed. Additionally, regulations on maximum allowed working times and company characteristics should be combined with the instrument to

design daily operational planning for safe sailing. In addition, it is suggested to apply a **Fatigue Risk Management System (FRMS)** for validating the crew plan as are already in place e.g. in aviation and rail transport. Such a system may be used to make the vessel owners and boatmasters more aware of fatigue risks, and to provide them with mitigating measures. Accordingly, a FRMS framework should be developed that can easily be applied by the vessel owners as well.

Accordingly, this new approach starts from scratch, leaving existing conceptual frameworks and tables. The guiding idea for the development of this instrument (and precondition for its application) is to maintain the same level of safety as before. Also, the level of automation has been implemented in order to consider future developments and to provide a more futureproof instrument.

This task-based approach offers the chance to specify the needed times for the different tasks on individual level. Depending on the task and the specific conditions, e.g. level of attention the duration and the type of work are dealt with in terms of extension or reduction of the calculated time occupancy and workload. In addition, this approach in principal also enables vessel owners to assess and evaluate the usefulness of innovation, technical modernization (e.g automation) or organizational changes. Accordingly, this approach is considered a complete **system change**.

Concluding, the provided instrument is considered a well documented and feasible approach for a future-oriented determination of the necessary crewing of inland vessels and a proper basis for the corresponding implementation process. An additional structured validation should be the next step for the involved actors and parties. This evaluation process has to validate details and specifications with respect to the criteria set for easy use and easy to understand.

As the suggested new crewing instrument is based on the approach to determine the needed crew (size and competences) per vessel and per individual journey, this requires a system change also as regards the necessary enforcement procedures. While the current regulation implies constant crew sizes and competences, the suggested instrument allows journey-specific adjustments of the crewing. This approach assumes that the crew-planning has to be inserted into a corresponding (digital) system in advance of the journey which then can be checked by the enforcement party on board (comparison of the plan with the actual situation). Simultaneously, the addressed working time aspects could be dealt with in the corresponding (digital) system as well.

REFERENCES

Clarke G. (Ed) (2012). Fatigue management toolkit – Dissemination, development and exploitation.

Central Commission for the Navigation of the Rhine, CCNR (2018). First international definition of levels of automation in Inland Navigation; (CCNR CC/CP (18) 21).

CESNI (2018). European Standards for Qualification in Inland Navigation, ES-QIN, Edition 2018; (CESNI (18) 54 add. 2 final)

COUNCIL DIRECTIVE 2014/112/EU (2014). Directive implementing the European Agreement concerning certain aspects of the organisation of working time in inland waterway transport, concluded by the European Barge Union (EBU), the European Skippers Organisation (ESO) and the European Transport Workers' Federation (ETF).

Dawson D., Noy Y.I., Härmä M., Åkerstedt T., Belenky G. (2011). Modelling fatigue and the use of fatigue models in work schettings. Accident analysis and prevention, 43, 549-554.

Diggelen van J., Janssen J.B., Van den Tol W.A. (2016). Crew design tool. In: Proceedings INECpaperCDT.

EN 16710-2 (2016). Ergonomics methods – Part 2 A methodology for work analysis to support design.

EN–ISO 6385 (2016). Ergonomics principles in the design of work systems.

EN-ISO 10075 (1991). Ergonomic principles related to mental workload.

EN-ISO 26800 (2011). Ergonomics – General approach, principles and concepts.

EN 614 (2009). Safety of machinery – Ergonomic design principles.

ETF (2018). Minutes of the Midterm Meeting (29.5.2018), Expert Workshop (28.6.2018) and Focal Group Meeting (12.9.2018) of TASCS.

Holtmann B., Bross, H., Gründer, D. (2009). DST-Bericht 1923: Technische und organisatorische Maßnahmen zur Reduzierung des sicherheitsrelevanten Personalbedarfs in der Binnenschiffahrt. (in German)

Hursh S.R., Raslear T.G., Scott Kaye A., Fanzone J. (2006). Validation and calibration of a fatigue assessment tool for railroad work schedules.

ICAO, IATA and IFALPA (2015). Fatigue management guide for airline operators.

Jepsen e.a. (2017).MARTHA the final report 2017-01.

Kester T.G.A van (2014). Exploitatiewijzen en bemanningseisen in de binnenvaart. Masterthesis Erasmus University Rotterdam. (In Dutch)

Lee J.D., Rothblum A. (2000). Simplified crew size evaluation method. US Coast guard research and development center. Report no. CG-D-13-00

Philips R.O. (2016). Countermeasures for use in fatigue risk management. TØI Institute of transport economics, Norwegian center for transport research. TØI report 1448/2016.

Reidd K.J., Turek F.W., Zee P.C. (2013). Enhancing sleep efficiency on vessels in the tug/ tow-boat/ barge industry. National cooperative freight research program. NCFRP report 36.

Rothblum A., Lee J.D. (1995). Modeling Crew Size for commercial ships. In: Proceedings Huan factors and ergonomics society annual meeting.

Somvang V., Hayward B, Cabon P. (2016). Preparing guidance on biomathematical fatigue models. Rail safety and standards board, London

Spencer M.B., Robertson K.A., Folkard S. (2006). The development of a fatigue/ risk index for shift workers. Health & Safety Executive research report 446/2006, London.

Thomas, H. and Turnbull, P. (2013). Mapping the Situation of the Ferry Trades in the Western Mediterranean Sea: Final Report. European Transport Workers' Federation.

Turnbull, P. (2010). From Social Conflict to Social Dialogue: Counter-Mobilisation on the European Waterfront. European Journal of Industrial Relations, Vol.16, No.4, pp.333-49.

Turnbull, P. (2009). Training and Qualification Systems in the EU Ports Sector. European Transport Workers' Federation.

Velez E.J. (2014). Manning analysis in naval ship concept design. Master thesis Virginia polytechnic institute and state university.

Zeilstra M., Bruijn de D., Weide van der R. (2009). Development and implementation of a predictive tool for optimizing workload of train dispatchers. Proceedings: 3rd international conference on Rail Human factors, Lille.

ANNEX

The TASCS Steering Group consisted of the following members

Andrea Beckschäfer (ESO)

Nick Bramley (ETF)

Jacques Kerkhof (ETF)

Gerard Kester (ESO)

Michiel Koning (EBU)

Andreas Stommel (EBU)


tex