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Oplegnotitie

Rapport Best practices trackpilots

Het gebruik van trackpilots in de binnenvaart is de afgelopen jaren sterk toegenomen. Het is de verwachting dat trackpilots in de komende jaren nog geavanceerder worden en daarmee steeds meer navigatietaken van de schipper overnemen. De schipper krijgt dan meer de taak om de juiste gang van zaken te bewaken in plaats van continue zelf te sturen.

In de simulatorstudie van het project Intenties Delen[1], waarvan het eindrapport in december 2022 beschikbaar is gekomen, wordt gewezen op de risico's van het gebruik van een trackpilot. Tijdens dat project hebben de leveranciers van trackpiloten aangegeven open te staan voor suggesties om hun producten te verbeteren ten aanzien van veiligheid.

Daarom is MARIN in het voorjaar van 2023 gevraagd te komen tot 'best practices' voor trackpilots. De 'best practices' geeft richtlijnen ten aanzien van de vormgeving en het gebruik van de trackpilot met als doel de veiligheid op de vaarweg te verbeteren.

Bij de totstandkoming van de 'best practices' is intensief gebruik gemaakt van een groep met stakeholders. Van die groep maakten fabrikanten van trackpilots, belangenorganisaties, een verzekeraar en Rijkswaterstaat deel uit. Zij zijn in de gelegenheid geweest commentaar te leveren, de inhoud van het rapport is echter geheel de verantwoordelijkheid van MARIN.

De 'best practices' kunnen door marktpartijen worden gebruikt voor het veiliger maken van hun producten en het stellen van randvoorwaarden aan het gebruik er van.

[1] https://open.rijkswaterstaat.nl/overige-publicaties/2022/digital-intention-sharing-simulation/

TRACK PILOT-AUTOMATION

Determining Best Practices for implementation on board inland vessels

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TRACK PILOT-AUTOMATION

Determining Best Practices for implementation on board inland vessels

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1 INTRODUCTION & RESEARCH OBJECTIVE

Inland shipping is an important element in the transport system within Europe. Through inland shipping relatively high volumes of different types of cargo can be distributed efficiently between different kinds of destinations such as seaports, inland harbours and industrial areas. Additionally, inland vessels have the potential to become more and more sustainable over the coming years. Just like in other sectors and industries, inland shipping has its challenges as well as opportunities. One of the most urgent challenges is a shortage of qualified skippers and crews. Another problem is a perceived substantial accident rate with potentially severe consequences.

Inland shipping is a vital component is the Trans-European Transport Network (TEN-T) of roads, railways, airports and water infrastructure in the European Union. The TEN-T network is part of a wider system of Trans-European Networks (TENs), including a telecommunications network (eTEN) and a proposed energy network (TEN-E or Ten-Energy). The European Commission adopted the first action plans on trans-European networks in 1990.

Automation in inland shipping is, by policy makers as well as Industry, seen as a crucial technical development to address these challenges and to profit from opportunities in the nearby future [Ref 1]. This development is taken step by step, introducing increasing levels of automation to the wheelhouse of inland vessels. The aim of the automation in the current developments is that skippers benefit from the automation in performing the safe navigation of the vessel. the system is assisting them in the performance of their task. On the other hand, as long as the vessel is not fully automated, the skipper still has supervision over the navigation task. This research focuses on the implementation of Track Pilot-automation on board of inland vessels.

1.1 Benefits of Track Pilot-automation

Track Pilot-automation intents to take over part of the primary sailing tasks, namely automatic steering on a predefined track. Delegating part of the manual sailing responsibilities can bring advantages for the operator and may enhance overall operational safety. Additionally, the Track Pilot-automation is viewed as a foundation for introducing new functionalities, potentially elevating the level of automation on board and presenting new possibilities.

1.1.1 Reduced workload

With automating the steering task, the operator is liberated from manual steering – whether it's an autopilot setting the rate of turn, or with direct rudder control. This liberation adds to a lower task load and therefore may result in a lower workload, depending on the human-machine collaboration: how well the system-design supports the operator in using the system, monitoring and understanding it. With a well-designed human-machine collaboration, more available cognitive resources can be allocated to other primary tasks, such as on monitoring the system and environment to maintain situation awareness and identify potential hazards. This creates the opportunity to have more time and attentional resources to assess the situation and strategize decisions regarding coping with the current situation and how to anticipate on envisioned future navigational situations.

A reduced workload could additionally lead to reduced fatigue, which directly impacts crew well-being, fostering a healthier working environment. A Track Pilot-automation allows, instead of sitting, to walk around in the wheelhouse more often without directly compromising safely steering the vessel. It helps to sustain alertness. As the mental strain associated with constant manual steering is taken away, this may help to staying alert during the (long) sailing periods. It has been observed that some skippers tend to sail up to 14 hours a day, which is a mental strain for the prolonged alertness that is required.

A better situation awareness and more time for navigational decision-making could result in better or more anticipating behavior, which in return would benefit the overall navigational safety.

1.1.2 Less steering errors

The Track Pilot-automation is able to steer better on a desired line than a human, which could result in a more predictable and precise-course keeping, for those conditions the Track Pilot-automation can handle. Some skippers that were interviewed mentioned that they can already recognize which vessels sail on a Track Pilot-automation due to a more consistent course-keeping behavior. Furthermore, a Track Pilot-automation reduces the margin of error associated with manual steering, especially in cases when vigilance is reduced due to long sailing hours. The automation therefore helps to mitigate the risk of human errors in manual steering – and in potential, avoiding accidents and collisions.

1.1.3 Platform for future automation/ functionalities

With sailing partially automated, data from the Track Pilot-automation can be logged, stored, reused, and utilized for data analyses to optimize tracks/routes. This, in turn, allows for further refinement of Track Pilot-automation performance through subtle adjustments to the vessel's heading when sailing, to maximize fuel efficiency and to reduce operational costs. The opportunities to enhance logged data with analyses for the benefit of navigational operations and, on a broader scale, logistics are diverse.

For instance, data regarding sailing behavior and Track Pilot-automation performance, when combined with environmental data including information about surrounding vessels (AIS), can be instrumental in identifying near-misses and analyzing accidents and incidents. Insights derived from such analyses can prove valuable for regulators and manufacturers, offering leads to implement changes to the fairway or system and ultimately enhancing navigational safety. Such analyses and insights could for example be performed and given by independent parties.

1.1.4 Automation development

The Track Pilot-automation system serves as a foundational platform for the integration of additional automation features and advanced functionalities. Numerous functionalities can be seamlessly incorporated in the future, building upon the current steering automation capabilities of the Track Pilot-automation system. One such functionality explored by MARIN involves the potential benefits of sharing intentions among inland vessels, specifically sharing track lines. It has been concluded that a well-implemented procedure for sharing intentions could enhance overall navigational safety [Ref 0.].

Additionally, some manufacturers have already implemented collision detection, which alerts the skipper when the Track Pilot-automation system identifies a risk of passing too closely. While this functionality has the potential to improve situation awareness by detecting potential collision threats, on-board observations indicate that it may also introduce adverse effects and compromise navigational safety. Implementing these new functionalities requires careful consideration, both from a system and human factor perspective, to fully realize their potential.

The key message, however, is that increasing the level of automation – whether through speed regulation, collision detection, or direct decision support – offers functionalities that can not only enhance overall navigational safety but, in addition, also transform the maritime transport sector. This transformation may lead to more effective traffic management, just-in-time voyages, and innovation spin-offs facilitated by the Track Pilot-automation system as a technological innovation platform.

1.1.5 Reduced fuel consumption

Overall, Track Pilot-automation is expected to be contributing to a reduction of fuel consumption by inland vessels. On the other hand, any conclusive research on this topic has not yet been performed.

1.2 Risks of Track Pilot-automation

While underway, the skipper needs to interact with the automation, overseeing its performance and the way it contributes to safe navigation of the ship. Therefore, depending on the level of automation, the interaction with the automation changes the tasks the skipper has to perform in order to safely navigate the vessel. As a paradox, this means that automation can be both beneficial to the task at hand and, at the same time, causing additional risks to that same task. From this perspective, in the design and implementation of automation it is crucial that this paradox is addressed in either design criteria, best practices, industry standards and/or regulatory frameworks.

The Track Pilot-automation has the specific purpose to steer the vessel along a preset track, adding opportunities and risks to the navigation task of the skipper. Although several manufacturers have already designed and installed Track Pilot-automation on board vessels, a common and generally accepted set of criteria does not yet exists. Such a set of criteria should address additional risks to the navigation task that are a direct result of Track Pilot-automation.

1.3 Research objective

Rijkswaterstaat Water, Traffic and Environment (RWS WVL), being part of the smart shipping program within the ministry, has asked MARIN to carry out the Safety case and best practices study on the design and implementation of track pilots on inland vessels. The objective of this formulation of ‘best practices’ is to address the additional risks which originate from Track Pilot-automation implementation allowing to use the operational benefits of Track Pilots.

The research objective is therefore formulated as:

"To establish 'best practices' for the use of track pilots. The 'best practices' provide guidelines for the design and use of the track pilot (in inland shipping) with the aim of improving safety on the waterway.”

1.4 Scope

In this research, MARIN explicitly established ‘best practices’ for the implementation of Track Pilot-automation on board inland vessels. This includes interfacing with other equipment, as far as it deemed relevant for formulating best practices for Track Pilot-automation. This means that ‘best practices’ for the design and implementation of other existing equipment (autopilot, radar, ECDIS, propulsion etc.) is out of scope in this particular research

1.5 Document structure

Chapter 2 and Chapter 3 address the theoretical framework and research methodology, followed by the results (best practices) in Chapter 4. As Track Pilot-automation is in the early stages of the product development process and is continuously being developed the “answers” are not definitive. In order to address some noteworthy aspects the document will therefore be completed with a Discussion Chapter in Chapter 5.

2 THEORETICAL FRAMEWORK

For the purpose of Risk Assessment and Risk Mitigation MARIN operates from the view that the human operator play a central role in complex socio-technical systems. The human operators must have the ability to perform their tasks, meaning that they require highly reliable and accurate resources. This contains information, knowledge, experience, engagement, time, acceptable levels of workload, procedures, instructions, understanding and means to actually take the required action when necessary.

In general, due to automation there will be a larger system dependency, as part of a task which is taken over by a computer. How the system will function and change over time with new updates and functionalities will impact the human-system collaboration in broad terms. It affects how human operators will use the automation to their own benefit.

The human is seen as an essential element in the system, to (1) monitor the automation performance, as (2) supervisor controller and to (3) take over when the automation is not able to cope with the situation or when the systems fails. As it is still required to monitor the system and above all the monitor the environment, the operator still needs to be actively in the loop, being engaged with the overall goals and tasks.

Therefore MARIN uses a high-level system model that incorporates Human Factors as a framework to analyse changes to existing socio-technical systems, for example changes to the inland navigational operational process in the wheelhouse of an inland vessel. Underneath the high-level model an iterative cognitive information processing model is used to describe the operational process that has to be performed to reach an overall goal and underlying tasks. Subsidiarity to this cognitive information process a specific model is used to map changes in cognitive task performance due to adding automation to the task.

The High Level system model, the cognitive information processing model and the model to map changes in cognitive task performance are described in the following paragraphs and extracted from literature review, as mentioned in Chapter 3.

2.1 High-level system model

The maritime environment can be considered as a complex system in which both internal and external elements are present. Internal elements include entities that are part of an object in waterways, such as vessels, cargo, technical conditions, and management. On the other hand, there are external elements that influence an object, such as weather conditions, laws and regulations, insurance terms, cargo contracts, and water levels. The complexity of the maritime environment arises from the uncertainty in how all these actors come together to create a range of both safe and unsafe scenarios. The associated risks, or the effects of these uncertainties on the objectives related to nautical safety as intended by Rijkswaterstaat (RWS), are naturally dynamic. Therefore, theoretically, within the complex maritime environment, an infinite number of scenarios can occur.

However, the internal and external actors, individually and collectively, are usually not sufficient on their own to make unwanted events actually occur. Science has repeatedly determined that the performance of the human actor plays a primary role in the safety of complex systems, when addressing questions about safety.

MARIN, therefore, operates on the concept where safety is viewed from the complex relationship between humans, internal elements, and external elements within the context of the maritime environment. In Figure 2-1 this relationship is visualized as the interaction between Human, System and Procedures.

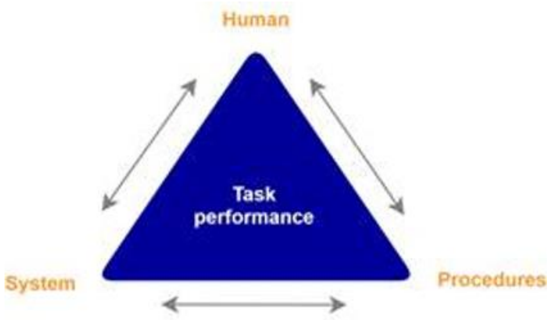

Figure 2-1: Task Performance - Extracted from the "Handbook of Human Factors and Ergonomics" from Salvendy (2012)

2.2 Cognitive information processing: Situation awareness model from Endsley

As stated, MARIN approaches its methodology based on the perspective of the acting human within the system. For this reason MARIN sees Mica Endsley's framework of Situation Awareness, Decision Making and Action Planning [Ref 2.] and the known threads to these constructs [Ref 4.] as the fundament for identifying different causes to risks in the complex maritime system, as depicted in Figure 2-2.

Endsley distinguishes three levels of situation awareness (SA), with the quality of each level depending on the quality of the underlying level. At Level 1, the cognitive process involves the perception of (relevant) information in the environment, where the acting human forms an image of the surroundings that is as complete as possible and relevant to their task. However, this image consists of a merged whole of this information. In Level 2, the interpretation of that image takes place, where the effects and values of the available information are linked to task execution. In Level 3, anticipation of the information occurs. The cognitive process continues with the projection of the information into a future scenario or scenarios based on which decision-making ultimately takes place, followed by the execution of actions.

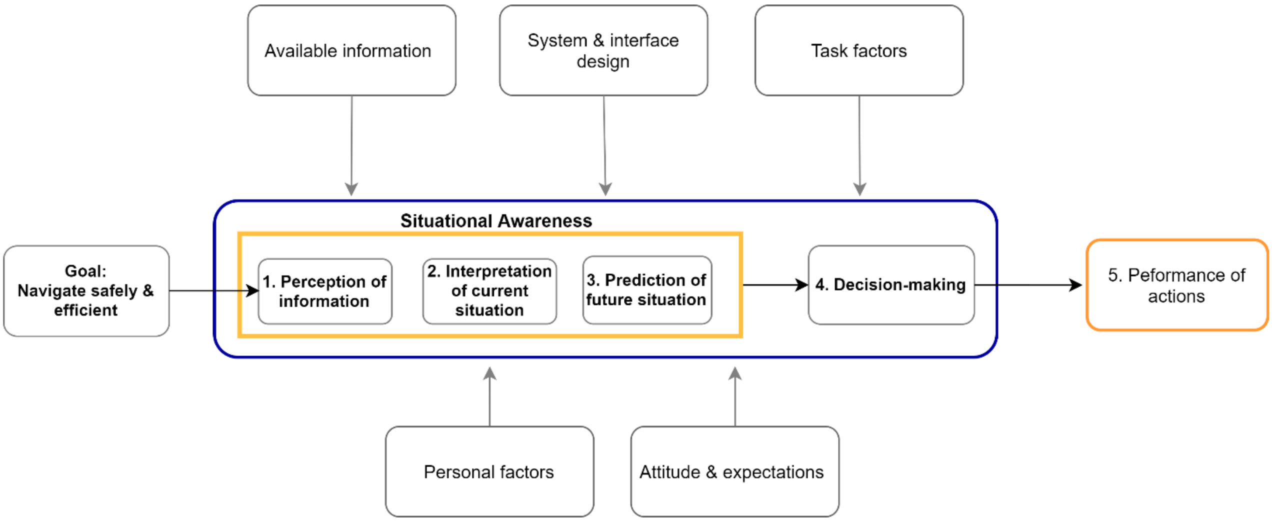

Figure 2-2: Situation Awareness model adapted from Endsley (1995)

2.3 Changes in cognitive task performance. HASO-model (Human-Autonomy System Oversight)

This research focusses, in broad terms, on reaching an operators overall goal while using automation to conduct a particular task necessary to reach that goal. As this particular task is critical to reach the goal, the operator effectively overseeing the automation and its interacting with the system must be maintained. If this can be established, the automation will be beneficial to safety. On the contrary, any degradation of that effectiveness is considered the overall risk related to adding the automation to the system.

Endsley described eight major threats to Situation Awareness [Ref 4.]. Neither of these threats act as an isolate threat, meaning that they are interconnected depending of the context of the task performance at hand:

- Attentional Tunneling;
- Requisite Memory Trap;
- Workload, Anxiety, Fatigue, and Other Stressors;
- Data Overload;
- Misplaced Salience;
- Complexity Creep;
- Errant Mental Models;
- Out-of-the-Loop Syndrome

"Out-of-the-loop Loss of Situation Awareness" (OOTL) is the threat that is considered typical and by far most relevant for implementation of automation within a system. It manifests as a degradation of Situation Awareness both on automation performance as well as " *the state of the elements in the environment the automation is supposed to be controlling*" [Ref 4.].

OOTL is particularly addressed in the Human Automation System Oversight (HASO) model [Ref 3.], considering new challenges and factors influencing the effectiveness of oversight of the automation and human-automation interaction. The HASO-model is depicted in Figure 2-3 wherein all described factors add to the output, with a central important place for the cognitive construct 'Situation Awareness' as a main mediating factor.

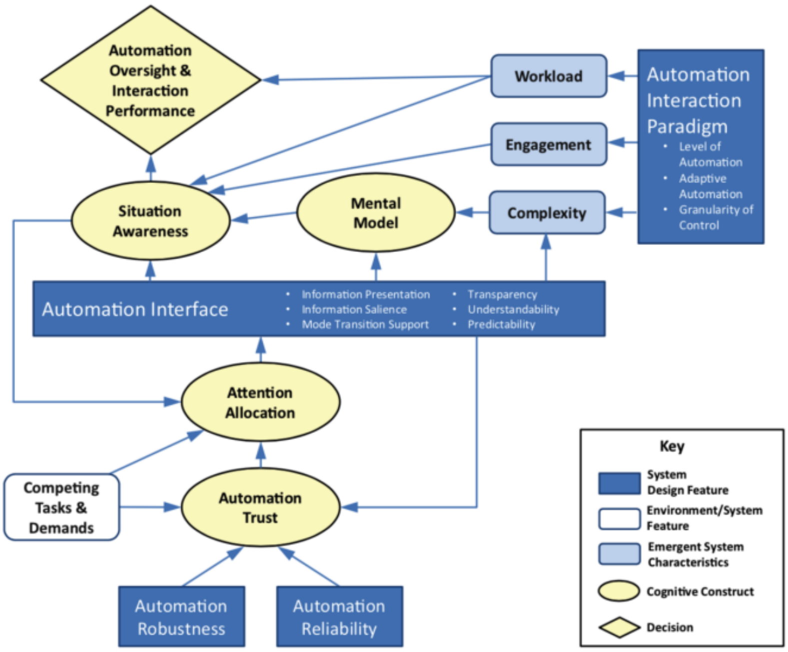

Figure 2-3: Human–autonomy system oversight (HASO) model. Endsley (2017)

Within the HASO model, OOTL is considered as emerging from various relevant factors that can be described as System Design Features, System Characteristics, Environmental Features and critical Cognitive Processes. Since, for the purpose of this research, OOTL is acknowledged to be the overall risk to the safe operation of the system, these features and characteristics can be considered as *Risk Contributing Factors* (RCF).

For that reason, in in APPENDIX 1, we describe all the relevant features and characteristics in the HASO-model and extract tangible RCF's from these descriptions. These RCFs can then be used in a ***Risk & Performance Analysis*** for the purpose of identifying concrete risks and determining Best Practices, as being the objective of this research. The RCFs extracted from the HASO-model are summarized in Table 2-1.

Table 2-1: Summary of Risk Contributing Factors

Summary of Risk Contributing Factors extracted from the features and characteristics in the HASO-model.		
Features/ Characteristic		Risk Contributing Factors
Competing tasks and demands	1	The presence of competing tasks and demands
	2	The ability to perform those tasks and demands parallel to the automation
Trust	3	The disability to monitor system performance in a clear and easy way
	4	The disability to switch of the automation and change to manual mode in an easy (intuitive) way.
	5	The automation has high levels of reliability
	6	The automation has high levels of robustness
Attention Allocation	7	High levels of trust.
	8	Presence of other tasks and demands and the ability to engage in those tasks and demands during the operation of the automation.
Mental Model	9	High levels of complexity
	10	Inadequate Information presentation related to the performance of the automation
	11	Inadequate information presentation related to the operating mode of the automation
	12	Inadequate Information presentation about the (design)limits of the automation (brittleness)
Level of Automation	13	Inaccurate information presentation
	14	Filtering away of relevant information
	15	Cueing irrelevant information
	16	Relevant information not easy to access and/or asses.
	17	Decision support by showing recommendations only
	18	The automation has high levels of complexity
	19	The automation has low levels of reliability
	20	The automation has low levels of robustness
Adaptive Automation	21	Since Adaptive Automation might be a solution to prevent loss of engagement and/or allocation, a missing determination of where and when Adaptive Automation is beneficial can be considered as a risk related to system design.
Granularity of Control	22	The control actions are too complex.
	23	The control actions are not clear and/or understandable and/or
	24	The control actions have the possibility to let the operator engage to a wrong metal model or goal.
	25	The control actions have insufficient possibilities to change system-modes in an easy and intuitive way
Automation Reliability	26	The automation does not indicate and warn the operator in a sufficient way when it's performance degrades due to malfunction, missing or incorrect sensor-data or interference from other systems or sensors.
	27	The automation generates too many false alarms.
	28	The automation generates too much underperformance and/or malfunctions
	29	The automation has the opportunity to operate outside design parameters without sufficient warning.
Automation Robustness	30	The automation has to be used too much outside design parameters in order to be useful to the operator.
Automation Interface	31	Relevant information is not presented in a clear and understandable way, both audible, visible or otherwise noticeable.
	32	Relevant information is not presented in a salience way
	33	Automation interface does not provide for easy, understandable and intuitive Mode Transition
	34	Automation does not provide transparency, understandability and predictability in automation complexity, automation performance, activated mode and (future) course of actions, making it difficult for the Human Operator to stay in the loop and interfere with the automation in a proper way.

2.4 Levels of automation

Following the HASO-model the ***Level of Automation*** is one of the factors that must be considered in the design and implementation process, as described in APPENDIX 1. This means that we do not use the Level of Automation, such as determined by the Central Commission for the navigation of the Rhine (CCNR) in 2022, as a reference to decide on the applicability of 'Best Practises'. Instead we consider the Level of Automation as a factor that may or may not have consequences for safe use of Track Pilot-automation, since " improving safety" is the main objective of our research.

3 RESEARCH METHOD

This research focusses on a skippers goal to safely navigate inland waters, using Track Pilot-automation to follow a preset route. Since following a safe route (task) is critical to reach the goal, the skipper must effectively maintain oversight of the automation and its interacting with the vessel and it's complex environment.

To arrive at a satisfactory and robust set of Best Practices regarding design and implementation of Track Pilot-automation, MARIN will follow a 7-stage research process as depicted in Figure 3-1. In this research, both stage 2&3 and stage 4&5 are executed simultaneously.

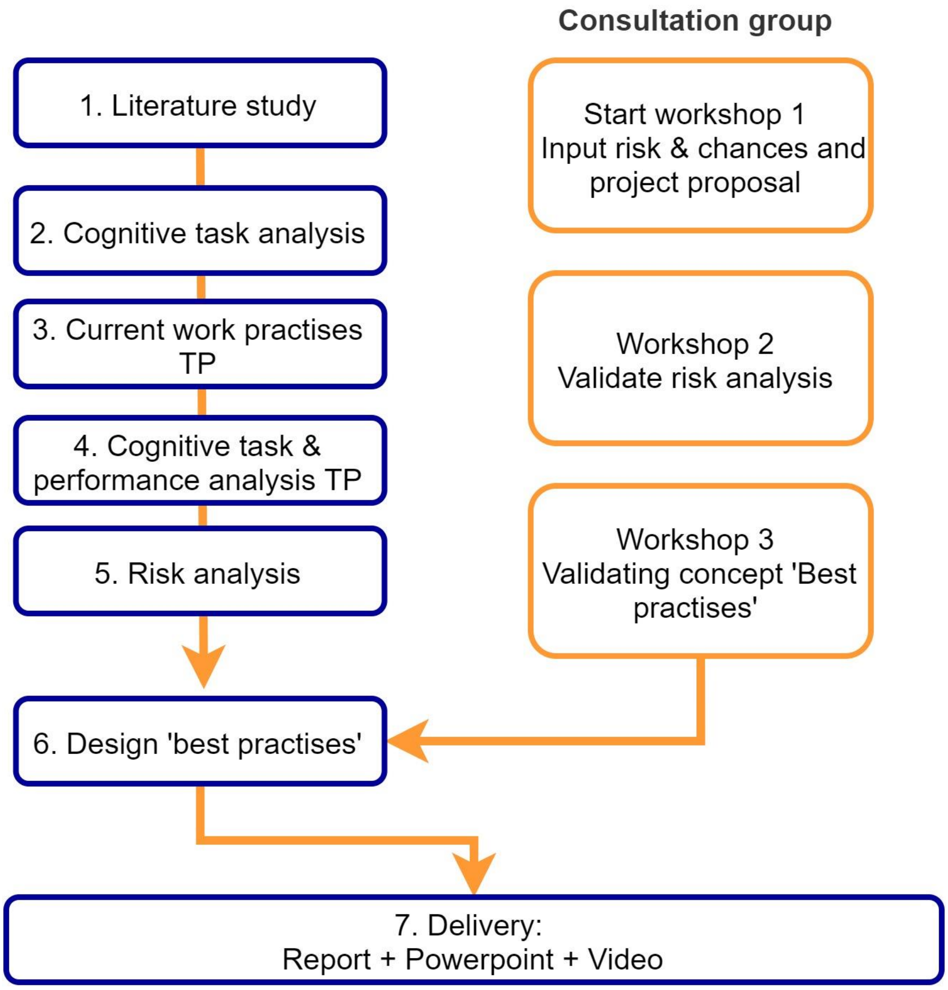

Figure 3-1: Research Process

As shown in Figure 3-1, Literature Study was followed by a Cognitive Task Analysis creating an overview of necessary tasks to reach the overall goal, together with an overview of those tasks that are affected by the Track Pilot-automation. The Cognitive Task Analyses describes the navigational tasks on a cognitive information process level, by deconstructing the main task in smaller ones and the underlying decision-making process involved in executing these tasks. The purpose is to provide insight into the differences in sailing with and without Track Pilot-automation and to analyse its design.

The Cognitive Task Analysis is followed by a description of what Track Pilot-automation is within the scope of this research, where after three main '*safety cases'* were determined. Within the scope of these '*safety cases'*, a Risk & Performance analysis was conducted, connecting the Risk Contributing Factors (as extracted from the HASO-model, see Chapter 2) with the Track Pilot-automation affecting the cognitive task of navigating a vessel on inland waters.

Finally, the Risk & Performance analysis served as input for determining ‘Best Practices’.

3.1 Literature review

The study on 'Intent Sharing' conducted by MARIN in 2022 [Ref 0.] is used as a starting point where experience with Track Pilot-automation has been gained and Track Pilot-automation is considered an innovation platform for advancements such as sharing navigational intentions with the surroundings.

Secondly, the literature review focused on conducting a review of (international) maritime conventions, guidelines and industry standards for the implementation or use of automation for navigation on inland waterway vessels. Other transport domains also fell within the scope of the literature review to investigate whether lessons from other domains could be used in shaping 'best practices' for Track Pilot-automation.

Thirdly, based on the MARIN perception that any research that is focused on the Maritime Operation must recognize the Human Operator as a central focal point, MARIN reviewed scientific literature in order to determine the best suitable Human Performance models for this specific research. As already described in Chapter 2, both Endsley’s Situation Awareness model and HASO-model were found to be exceptional useful as reference models to identify risks and best practices for automation implementation.

Finally, the literature review addresses the navigational tasks (execution) on inland waterway vessels with and without Track Pilot-automation, in preparation for the second and third stage of the research. Both (1) the overall goal of the tasks that are partly affected by new automation and (2) a Cognitive Task Analysis to map the changes to task-performance in the operation, served as the system-context wherein both risk and performance analysis were being conducted during the research.

A list of all reviewed literature can be found in the References.

3.2 Cognitive Task Analysis of a Navigational Task

The literature review served as input for creating a cognitive task analysis of the navigational task without Track Pilot-automation. A cognitive task analysis describes the task in steps at the information processing level of a human operator, establishing a reference framework for comparing with the navigational task with a Track Pilot-automation on board.

Simultaneously with the literature review, the current practices of navigating vessels in the Netherlands have been examined by means of on board observations and interviews. The aim was to make comparisons between navigating with a Track Pilot-automation and without, and to make the performance changes transparent, focusing on constructs such as workload and 'Situation awareness' according to Endsley's model. When describing current practices with Track Pilot-automation, attention was also given to the benefits enjoyed by skippers, known risks, key considerations, and the general experience and attitude regarding the use of Track Pilot-automation on an inland vessel.

To make the comparison and description of current practices, the researchers conducted multiple voyages with various inland vessels on different routes. Vessels and routes are chosen to provide a representative overview of how Track Pilot-automation is used in various waters and conditions. In addition, interviews have be conducted with end-users, such as skippers and helmsmen.

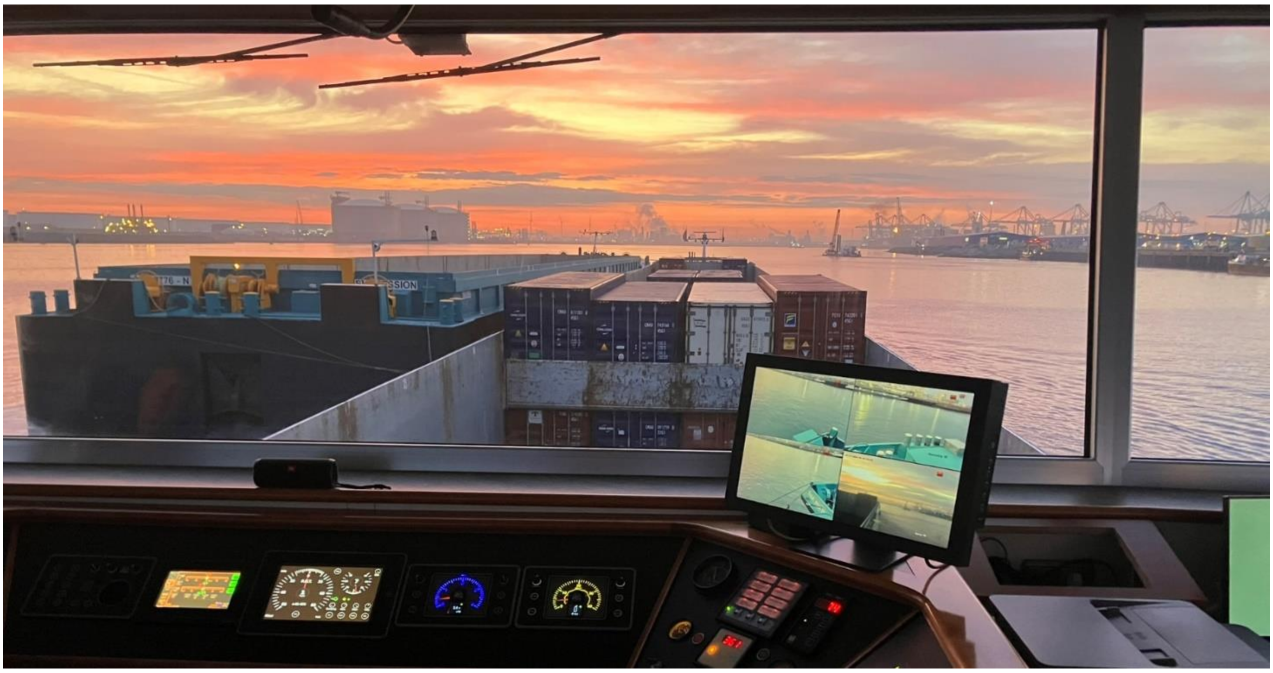

Figure 3-2: On board an inland vessel, during the research

As shown in Figure 3-1 , parallel to this research process, with the purpose to extract additional information and to gain broad support and consultation, MARIN formed a consultation group that includes representatives from relevant stakeholders, including client representatives, Insurance Company representatives, Branch organizations and Track Pilot-automation manufacturers. In this sense, the stakeholder-consultation group served as a sounding board for the development of Best Practices for Track Pilot-automation.

More specific, the stakeholder-consultation group was consulted during three workshops to acquire knowledge about the use, risks and opportunities of Track Pilot-automation and to validate potential solutions in the form of Best Practices. Additionally, relevant stakeholders have been consulted individually during the project to gather knowledge about risks, key considerations, design-parameters of existing Track Pilot-automation and suggestions for a safe implementation of Track Pilot-automation on inland vessels.

3.3 Safety Cases

The Cognitive Task Analysis served as input for creating 'safety cases,' outlining the sensitivities related to the performance variability of a skipper when using Track Pilot-automation on inland vessels. In Chapter 4, these ‘safety cases’ act as a framework wherein the Cognitive Task Performance, Risk & Performance Analysis and Determination of Best Practices are brought together.

Risk & Performance Analysis and Determination of Best Practices are described in the next paragraphs.

3.4 Risk & Performance Analysis

The next step in the research involved a risk and 'human performance' analysis. The Cognitive Task Analysis described in paragraph 3.2 served as a starting point. In this step, the effects on task characteristics, work environment, information provision, and specifically the human-track pilot interaction and track pilot (information) design on performance have been analysed, using the list of Risk Contributing Factors (Table 2-1) as a reference. These Risk Contributing Factors are, as described in Chapter 2, extracted from the HASO-model (paragraph 2.3). This provided an integrated view of the task, procedures, and the possible **risks** for workload, engagement, Situation Awareness, Decision-making process and Action Execution of the skipper.

3.5 Determining 'Best Practices'

Following the previously described activities, user-perspectives have been gathered from end users along with domain experts to develop functional ‘Best Practices’ for the overall design, configuration, and usage of Track Pilot automation. These ‘Best Practices’ are designed to mitigate the risks identified in the Risk and Performance Analyses, in order to allow the use of the operational benefits of Track Pilots in a safe way.

Feedback on the initial 'Best Practices' have been collected in the third workshop with the stakeholder consultation group. Furthermore, the request specification from RWS mentions specific attention to "interoperability," which is translated here as the transfer of knowledge and system usage from system A to system B. This will be considered as an additional focus, imposing requirements on user interaction and information presentation.

It is important to notice that, following the Theoretical Framework in Chapter 2, cognitive challenges merging from automation implementation often take place without consciously noticing by the Human Operator involved. We therefore consider Track Pilot-automation manufacturers having a primary responsibility to mitigate cognitive challenges that are emerging due to the implementation of Track Pilot-automation, instead of leaving it all to the responsibility of the skipper or helmsman on board.

3.6 Reporting

The collected input, performed analyses, and developed "best practices" is compiled into this report. A PowerPoint presentation will be delivered after finalising the report

the client and members of the stakeholder consultation group were given the opportunity to review the draft version of this report. Their review comments are added to the report in APPENDIX 4, together with comments from MARIN addressing if and why review comments have or have not resulted in changes to the draft report.

4 RESULTS

4.1 Introduction

In this chapter the results of the research are presented following as much as possible the research process described in Chapter 2.4. Starting with the Cognitive Task Analysis, an overview of necessary tasks to reach the overall goal is created, together with an overview of those tasks that are affected by the Track Pilot-automation. The Cognitive Task Analyses describes the navigational tasks on a cognitive information process level, by deconstructing the main task in smaller ones and the underlying decision-making process involved in executing these tasks. The purpose is to provide insight into the differences in sailing with and without Track Pilot-automation and to analyse its design.

The Cognitive Task Analysis is followed by a description of what Track Pilot-automation is within the scope of this research, where after three main '*safety cases'* were determined. Within the scope of these '*safety cases'*, a Risk & Performance analysis was conducted, connecting Risk Contributing Factors (as extracted from the HASO-model, see Chapter2) with the Track Pilot-automation affecting the cognitive task of navigating a vessel on inland waters.

Finally, the Risk & Performance analysis served as input for determining 'Best Practices' and 'Recommended Best Practices'. Regarding these Best Practices, MARIN recognized the fact that risks to safe navigation are not always only related to the implementation of Track Pilot-automation alone. Other failing equipment, environmental circumstances, obstruction, personal factors or even a substandard attitude of the Human Operator, can lead to failure. In some cases the ***Track Pilot Automation Interface*** can provide measures to mitigate other risks than those risks emerging from the implementation of Track Pilot-automation. When this is the case, we refer to 'Recommended Best Practices'.

4.2 Cognitive Task analysis

4.2.1 Goal setting

Following literature review and workshops with the stakeholder-consultation group, Track Pilot-automation must be considered as beneficial to reaching the overall goal of a skipper of an inland vessel, being *navigating safely during a voyage from a place of departure to a preset destination.* The Cognitive Task Analysis was performed, mapping tasks and subtasks that are essentially necessary to reach that goal.

4.2.2 Track Pilot-automation objectives and functionality, focus and scope of this research

During the research three different suppliers of Track Pilot-automation have been encountered as being implemented on board inland vessels. Their main objective of Track Pilot-automation is to keep the vessel sailing on a preset route or track during a voyage, with as less as possible deviation from that track under as much as possible challenging environmental circumstances.

In its essence, track-pilots control the rudder of the vessel by generating computerized output to the steering-pilot system via a system interface. This means that Track Pilot-automation explicitly is designed to take over the steering task of the Human Operator, with no objectives to automate other specific tasks that are necessary to be performed in order to reach the main goal. At the time of this research, those other tasks all have to be performed by the skipper in the wheelhouse.

While the Track Pilot-automation is actually engaged, the skipper still has the ability to manually steer the vessel by manually setting of rudder angles ('Follow Up' (FU)) or the vessel's 'Rate of Turn' (RoT). For this, we consider the Track Pilot-automation as *non-critical* for reaching the overall goal, meaning failure of the automation does not leave the skipper with a malfunctioning or 'unsafe-to-operate' vessel.

Of course, the skippers ability to oversee the performance of the Track Pilot-automation is considered critical for safe performance of the vessel. Also the ability to regain manual control in an easy and intuitive way is an important design criteria of the automation. As stated in paragraph 4.3.1, following the Cognitive Task Analysis, monitoring automation as part of the ‘monitoring vessel task’ can be considered as critical to safe performance.

Although new functionalities, such as collision warning, collision avoidance and speed control, are expected to be added to the Track Pilot-automation, these functionalities are outside the scope of this research. On the other hand, the theoretical framework and methodology used in this research can be used in the same way for additional research with a focus of new functionalities, adding new elements to the safety cases that are determined in this research.

4.2.3 Cognitive Task Analysis

The Cognitive Task Analyses (CTA) focusses on the navigational aspect of sailing with an inland vessel. Other goals and tasks that can intervene or conflict with the primary navigation task are not addressed within the CTA, but are addressed in the Risk & Performance Analysis as ***competing tasks and demands*** being a risk for ***Attention Allocation*** within the HASO-model. Competing tasks and demands are, for example, answering phone calls from clients which could be seen as one of many entrepreneur tasks to which many inland skippers fall. Other examples are cargo handling or teaching and instructing personnel during transit.

The result of the Cognitive Task Analyses with implementation of Track Pilot-automation is depictured in Figure 4-1. A more detailed task decomposition can be found in APPENDIX 2.

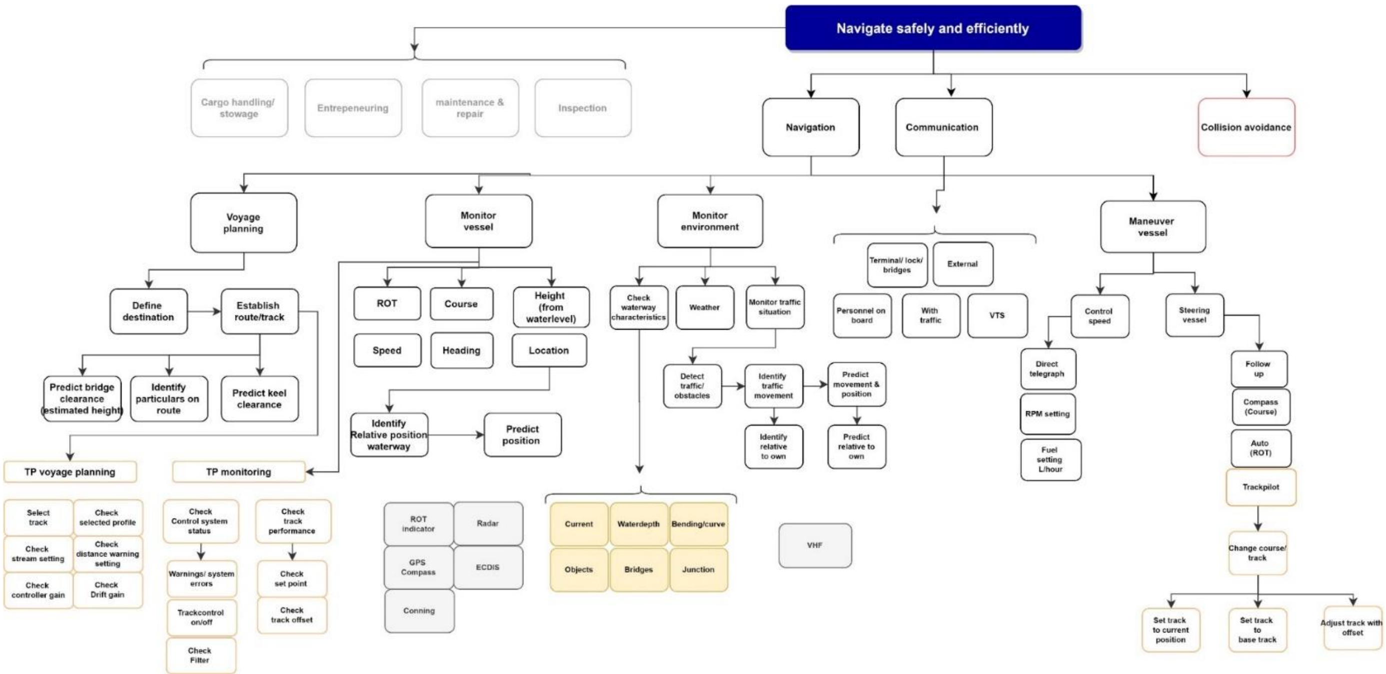

Figure 4-1 Cognitive Task Analysis navigating inland vessels with Track Pilot-automation implemented

4.3 Determining Safety Cases

The next step in the research process was the determination of relevant ‘*Safety Cases’.* They serve as underlay for the Risk & Performance analysis in paragraph 4.4.

There are various ways to determine relevant Safety Cases considering implementation of automation. For this research we considered three main criteria:

1. Number and nature of tasks affected by the automation, extracted from the Cognitive Task Analysis;

2. Different Levels of Automation as being defined in the description of the HASO-model (APPENDIX 1) and regarding the different affected tasks identified in criterion 1;

3. System Design Features conform HASO-model that are not already addressed by the first and second criteria.

4.3.1 Safety Case criterion 1 - Number and nature of tasks affected by the automation

As can be extracted from the Cognitive Task Analysis, tasks affected by the Track Pilot-automation concerns in particular:

- **Voyage planning**. Since routes or tracks can be selected from or generated by external databases and are designed by others than the human operator, the way the operator creates and understands a mental model of the voyage changes. Without Track Pilot-automation, the skipper plans his route by himself, using his experience and long-time memory to picture difficulties, obstructions and other criteria to select a route. Using pre-designed or generated routes the skipper does not know what kind of criteria are used to design the route. To stay in-the-loop and monitor performance, he needs to check and verify the route before commencing his voyage.

- **Vessel monitoring**. This tasks changes just by adding a new component to the wheelhouse. The Track Pilot-automation is an additional system that needs to be monitored.

- **Environment monitoring**. Extracted from interviews there is a strong possibility that the skipper missing cues about environmental conditions just by not being engaged with the actual steering of the vessel anymore. The skipper, for instance, does not ‘feel’ how much wind and current affect the course and position of the ship because he is not steering the vessel by himself. He must rely on other information to maintain proper Situation Awareness.

  In addition, engagement with the main goal can be deteriorated just by a degradation of attention to tasks and goals.

- **Manoeuvre vessel**. During the voyage, the skipper must be able to switch back to manual steering both under normal operation as well as in emergency situation. In such cases the skipper needs to know how to switch to manual and, more important, in what steering mode the vessel will be in, being Follow Up steering or by Rate-of-Turn setting as explained in paragraph 4.2.2.

  In the long term, skills regarding how the vessel responds under manual control, might be deteriorating as well, following extensive use of the Track Pilot-automation over time.

4.3.2 Safety Case criterion 2 - Different Levels of Automation

As second criterion, for each of the affected tasks in the previous paragraph, the ***Level of Automation*** is determined related to five main stages of cognitive information processing, in accordance with the stages that Ensley describes while explaining the HASO-model [Ref 3.]:

1. Situation Awareness Level 1 – Information perception;
2. Situation Awareness Level 2 – Information interpretation;
3. Situation Awareness Level 3 – Information anticipation;
4. Decision Making & Action planning;
5. Action Execution.

The results of this determination are shown Table 4-1.

Table 4-1: Levels of Automation for every affected task according to paragraph 4.2.1

Affected Task	Level of Automation
Voyage Planning	Decision Making and Action Planning
Vessel Monitoring	Action Execution
Environment Monitoring	Action Execution
Manoeuvre Vessel	Action Execution

4.3.3 Safety Case criterion 3 - System Design Features

In this section we analyse whether the various System Design Features mentioned in the HASO-model are already addressed in one of the first two criteria that can be used to determine the relevant safety cases.

There is a strong need to count for all the System Design Features in the Risk & Performance Analyses, since they represent input to the HASO-model and thus can be considered as a source of risks. For System Design Features that are not addressed in tasks affected by the Track Pilot-automation, risks emerging from these features might be overlooked in the Risk & Performance analysis.

As shown in Table 4-2, this is the case for System Design Features ***Automation Robustness*** and ***Automation Reliability***. Extracted from literature review and interviews, the accompanying task have been identified and shown in the third column in Table 4-2.

Table 4-2: Connecting System Design Features with affected tasks

System Design Feature	Features addressed by affected tasks in combination with Level of Automation	Additional affected tasks apart from the tasks identified in the cognitive task analysis
Granularity of Control	Voyage Planning Manoeuvre Vessel	
Adaptive Automation	Vessel Monitoring, Environment Monitoring Manoeuvre Vessel	-
Automation Interface	Voyage Planning Vessel Monitoring, Environment Monitoring Manoeuvre Vessel	-
Automation Robustness	-	Installation, testing, calibration and maintenance of the Track Pilot-automation
Automation Reliability	-	Installation, testing, calibration and maintenance of the Track Pilot-automation

4.3.4 Safety Case determination

Based on the three above mentioned and analysed criteria for determination, three different '*Safety Cases'* have been identified, that serve as an underlay for the risk & performance analysis in paragraph 4.4:

- Safety Case 1 – Technical Installation, implementation, calibration/tuning, maintenance and repair, addressing ***Automation Robustness*** and ***Automation Reliability***;
- Safety Case 2 – Voyage Planning, addressing the affected Voyage Planning task with Decision Making as ***Level of Automation;***
- Safety Case 3 – Normal & emergency operation of the TP system, addressing affected tasks Vessel Monitoring, Environment Monitoring and Manoeuvre Vessel together with system design features ***Adaptive Automation***, ***Granularity of Control*** and ***Automation Interface,*** with Action Execution as ***Level of Automation.***

4.4 Risk & Performance analysis: Impact of Track Pilot-automation on navigation task

4.4.1 Introduction

The Safety Cases identified in the previous paragraph are used to map the research findings extracted from literature reviews, observations on board vessels, interviews and workshops with the stakeholders consultation group. It allows for Risk & Performance Analysis of all these findings in a structured manner, using the Cognitive Task Analysis, HASO-model and from HASO extracted Risk Contributing Factors to identify Best Practices.

In following paragraphs and matching with the different *Safety Cases*, for every found risk a separate table is added to the report, holding observations, risk & performance analyses and 'best practices' to mitigate the risks identified.

4.4.2 Safety Case 1 – Technical Installation, implementation, calibration/tuning, maintenance and repair

Table 4-3: Risks concerning Inadequate installation on board

Inadequate installation on board	
Relation to HASO-elements	Complexity, Reliability, Mental Model
Corresponding Risk Contributing Factors	9 The automation has high levels of complexity 26 The automation does not indicate and warn the operator in a sufficient way when it's performance degrades due to malfunction, missing or incorrect sensor-data or interference from other systems or sensors. 27 The automation generates too many false alarms. 28 The automation generates too much underperformance and/or malfunctions
Risk & Performance Analysis	Incorrect or improper installation could introduce latent or immediate risks of dysfunction in the Track Pilot-automation. Proper Installation of the Track Pilot-automation on board the vessel, including connection to sensors and hardware, is considered a too much complex task that therefore cannot be performed by skippers, owners of ships or other unqualified personnel.
Best Practice	The best practices aim to an adequate installation process, to minimize introducing technical difficulties, failures or latent conditions/sensitivities and enhance the robustness and reliability of the Track Pilot-automation. Track Pilot-automation manufacturer needs to have an clear installation procedure manual in place that can be adequately used by the technician and can be used as checklist for each installation step; • As each wheelhouse of an inland vessel is different, it needs to be clear beforehand how the Track pilot-automation will be installed and interfaced with the autopilot, to ensure a safe and standardized interfacing and control by the skipper; • There is a checklist in place that is mandatory to fill in by the installation party, for correct installation and for a functional test of the system. The list will be signed by the installation party and will handled over to the skipper and the manufacturer; • The manufacturer provides a list that contains the compatible hardware with the Track Pilot-automation. This list must be accessible on board; • If hardware changes that provides input to the Track Pilot-automation, the manufacturer of the Track Pilot-automation needs to be contacted by the skipper to provide support and to calibrate/retest the system when needed. The manufacturer should approve the new configuration; • All wirings that are used for the Track Pilot-automation will be clearly labelled; • Technicians need to be certified by the manufacturer or other party that is able to provide an adequate training that meets the training objectives specified in this best practices and by the manufacturer. The training for technicians contains the following descriptions: o The learning objectives: what the technician needs to know, understand and which skills are required; o The content of the training, general and specified to the specific Track Pilot- automation and interaction with other hardware; o The exercises to meet the learning objectives; o How the competences are tested and when the technician receives the certificate; The training for the technician needs to cover at least the following subjects: o Proper drawings for installation on wiring and labelling; o How to deal with different Autopilot set-ups; o How to test the system o Which critical installation mistakes can be made and the consequences.

Table 4-4: Risks concerning Inadequate Tuning/Calibration

Inadequate Tuning/Calibration	
Relation to HASO-elements	Complexity, mental model, reliability, robustness, Automation Interface, Granularity of Control
Corresponding Risk Contributing Factors	9 High levels of complexity 10 Inadequate Information presentation related to the performance of the automation 11 Inadequate information presentation related to the operating mode of the automation 12 Inadequate Information presentation about the (design)limits of the automation (brittleness) 22 The control actions are to complex. 23 The control actions are not clear and/or understandable and/or 24 The control actions have the possibility to let the operator engage to a wrong metal model or goal. 27 The automation generates too many false alarms. 28 The automation generates too much underperformance and/or malfunctions 29 The automation has the opportunity to operate outside design parameters without sufficient warning. 30 The automation have to be used too much outside design parameters in order to be useful to the operator. 34 Automation does not provide transparency, understandability and predictability in automation complexity, automation performance, activated mode and (future) course of actions, making it difficult for the Human Operator to stay in the loop and interfere with the automation in a proper way.
Risk & Performance Analysis	Every individual ship has different properties that has influence on the way the ship responds to propulsion, rudder and environmental conditions like wind, current, shallow waters and close passing to other ships. Besides that, the ship's set-up may vary in terms of weight, draft, length and joint barges in front or alongside). Calibration/tuning of the Track Pilot-automation in order to perform in a robust and reliant way is considered critical for safe performance and comfortable use. The calibration/tuning process is also considered a complex task that must be performed by qualified and trained personnel, but also in consultation with the skipper about vessel specific characteristics and areas of operation. On board observations revealed that, occasionally, a Track Pilot-automation didn't went through a calibration process. It is also observed that the calibration process is done differently among the various manufacturers. This reflects on the necessity that there must be a calibration process in place to ensure the best performance within the abilities of the Track Pilot-automation. Such a procedure should be communicated as well to the skipper, to enhance the skipper's mental model in understanding correctly the way the Track Pilot-automation is tuned or calibrated. There are currently no defined performance parameters for the Track Pilot-automation, nor are there criteria for evaluating its reliability and robustness. This poses a problem as it makes it challenging for the skipper to gauge how well the system will perform under various conditions. While we acknowledge that a Track Pilot-automation manufacturers strive to deliver a reliable product, especially in a competitive market, the absence of standardized measures does not prevent the presence of poorly (and cheap) performing Track Pilot-automations in the market, posing a potential risk of disastrous accidents. Hence, we aim to establish best practices that include a concise set of standardized performance measures that can undergo testing. These performance tests could be accompanied by an industry performance certificate, providing assurance to the market that the Track Pilot-automation's performance meets a certain performance level. In addition, when a system offers calibration/tuning options to the user to select or modify Track Pilot-automation settings that impact the Track Pilot-automation/steering performance, measures

	should be taken to prevent the Track Pilot-automation from operating beyond its design parameters or delivering performance that deviates from the skipper's expectations.
Best Practices	The best practices aim to ensure a correct calibration and tuning process: • The manufacturer has a calibration/tuning process in place to ensure the Track Pilot-automation is performing at best; • Together with the skipper or owner of the vessel, the manufacturer need to make an analyses of the different set-up’s in ship’s properties and the environmental conditions it is most likely to encounter during normal operations; • The Track Pilot-automation must be calibrated and tuned for different set-ups until de Track Pilot-automation can function in a reliable and robust way. The calibration/tuning process have to be executed by or under de responsibility of the manufacturer. Calibration/tuning must be ongoing until performance of the Track Pilot-automation is considered reliable and robust by both manufacturer and skipper/owner of the vessel; • The skipper of the vessel receives an overview of the different set-up’s and environmental conditions the Track Pilot-automation is calibrated and tuned for. This prevents the skipper to engage in the wrong mental mode during operation; • If the Track Pilot-automation Interface allows for calibrating or tuning after the initial calibrating process, the manufacturer provides the skipper with clear information on the calibrating/tuning process. This information includes the procedure for calibrating and tuning the Track Pilot-automation after the installation and the effect of different parameters and settings to the performance; • There is information available on board about how to contact the Track Pilot-automation manufacturer in case the Track-Pilot automation underperforms.

Table 4-5: Risks concerning inadequate reliability of the Track-Pilot-automation

Inadequate Reliability of the Track Pilot-automation	
Relation to HASO-elements	Robustness, Reliability, Situation Awareness, Workload
Corresponding Risk Contributing Factors	26 The automation does not indicate and warn the operator in a sufficient way when it's performance degrades due to malfunction, missing or incorrect sensor-data or interference from other systems or sensors. 27 The automation generates too many false alarms. 28 The automation generates too much underperformance and/or malfunctions 29 The automation has the opportunity to operate outside design parameters without sufficient warning.
Risk & Performance Analysis	Hardware and software failures may lead to unexpected behavior or lead to human error in taking over from automation. When sudden take over from automation is necessary, this poses significant dangers, seen from a human factor perspective. This phenomenon is commonly known as "automation surprise" or "out-of-the-loop" situations. It occurs in cases that Situation Awareness is lowered as a result of integrated automation. When a human operator takes over abruptly, there is a higher risk on human error due to sudden increases of workload, which could render stress and panic. Performing under sudden high stress can be detrimental for decision-making and performance as the operator may have a lesser understanding of the current state of the vessel, surrounding conditions, or potential hazards. For example, during observations on board, the ECDIS computer which displayed Track Pilot-automation relevant information had to be reset/restarted due a hardware or software error. Such instances could lead to erratic actions as a first response from the skipper. Sudden takeovers – even when it may not be required – should therefore be reduced by increasing the reliability of the Track Pilot-automation and associated hardware.

Best Practices	The best practices aims to minimize the risk of (sudden) failures and malfunctioning of the Track Pilot-automation and associated hardware and software.
	
	To ensure the reliability of the Track Pilot-automation on board a vessel, it's essential to establish clear hardware and software goal-formulated quality requirements.
	
	• Hardware requirements
	  ○ Redundancy/ reliability:
	    ▪ Implement redundant hardware components to ensure continued functionality in case of a component failure, at minimum a back-up in power supply for the purpose of generating appropriate warnings and alarm.
	    ▪ The system should be able to seamlessly switch to backup components without compromising performance.
	  ○ Failure handling
	    ▪ When critical components fail, secure the automation to a best as possible safe-state by clearly warning and alarming the operator.
	  ○ Durability
	    ▪ Define a minimal standard for Mean Time Between Failures for critical components and take appropriate measures to ensure the average operational time between failures.
	    ▪ Implement hardware components that withstand varying conditions that the hardware is exposed to on a vessel, to minimize failure due to that exposure.
	  ○ Compatibility
	    ▪ Ensure that the Track Pilot-automation seamlessly integrates with the vessel's overall infrastructure without causing conflicts or communication issues.
	    ▪ Ensure components are electromagnetic compatible to prevent interference with other on board systems.

- Ensure hardware interfaces conform to industry standards, to allow a good integration with other on board systems and sensors.
  - Security
    - Ensure hardware enclosures are secure and resistant to prevent unauthorized access or interference.
  - Fault Detection and Diagnostics
    - Incorporate mechanisms for detecting faults and providing clear diagnostics to the skipper to facilitate troubleshooting.
    - Ensure reporting of the logged software failures and errors to the manufacturer.
    - Evaluate the system's ability to identify and communicate faults, aiding in efficient maintenance and minimizing downtime.

- Software Quality Requirements
  - Reliability
    - Develop software that operates reliably under normal and adverse conditions, minimizing the risk of system failures.
    - Prevent enforced system and Track Pilot-automation software updates that compromise or change the Track Pilot-automation performance or control during voyage.
    - Provide control to the user when updates will be installed and ensure notifications not overlapping with critical navigational information.
  - Accuracy
    - Ensure the Track Pilot-automation accurately interprets navigational and GPS data and executes precise steering commands.
    - Evaluate the system's accuracy in maintaining the desired course under varying conditions, including different speeds and upstream and downstream currents
  - Cybersecurity
    - Implement robust cybersecurity measures to protect the Track Pilot-automation from unauthorized access and cyber threats.
    - Conduct vulnerability assessments and penetration testing to identify and address potential security vulnerabilities.
  - Fault Detection and Diagnostics
    - Incorporate mechanisms for detecting faults and providing clear diagnostics to the skipper to facilitate troubleshooting.
    - Ensure reporting of the logged software failures and errors to the manufacturer.
    - Evaluate the system's ability to identify and communicate faults, aiding in efficient maintenance and minimizing downtime.

4.4.3 Safety Case 2 – Voyage Planning

Table 4-6: Risks concerning inadequate Voyage Planning

<table>
<tr><th colspan="2">Inadequate Voyage Planning</th></tr>
<tr><td>Relation to HASO-elements</td><td>Granularity of Control, Engagement, Automation Interface, Trust, Mental Model, Level of Automation</td></tr>
<tr><td>Corresponding Risk Contributing Factors</td><td>3 The disability to monitor system performance in a clear and easy way
11 Inadequate information presentation related to the operating mode of the automation
14 Filtering away of relevant information
16 Relevant information not easy to access and/or asses.
22 The control actions are too complex.
23 The control actions are not clear and/or understandable
24 The control actions have the possibility to let the operator engage to a wrong metal model or goal.
25 The control actions have insufficient possibilities to change system-modes in an easy and intuitive way
34 Automation does not provide transparency, understandability and predictability in automation complexity, automation performance, activated mode and (future) course of actions, making it difficult for the Human Operator to stay in the loop and interfere with the automation in a proper way.</td></tr>
<tr><td>Risk & Performance Analysis</td><td>The preparation of the voyage remains an essential task performed before the beginning of each journey. In doing so, the skippers still needs to create a loading plan, assess the available routes and all other tasks that belongs to voyage preparation. Some tasks are changed with the Track Pilot-automation. The skipper needs to insert or select a sailing route that can be used by the Track Pilot-automation. In addition, the skipper needs to assess the route on the viability.

Although a skipper still has the responsibility to assess the viability of the route and adequately monitor the track during voyage, the change with deploying a Track Pilot-automation conceals in a larger system dependency. Without Track Pilot-automation, the skipper plans his route by himself, using his experience and longtime memory to picture difficulties, obstructions and other criteria to select a route. Using pre-designed routes the skipper does not know what kind of criteria are used to design the route. To stay in-the-loop and monitor performance, he need to check and verify the route before commencing his voyage. The skipper thus depends on the available provided route in a system – either provided by the Track Pilot-automation manufacturer or other party. The likelihood of assessing the route adequately is influenced by different factors: related to the system design and psychological processes that change over time.

All manufacturers provide pre developed or generated routes to select by the skipper during voyage planning and route selection. First of all, It is important to acknowledge the fact that these routes are, most of the times, some kind of an average, generated by combining data from previous voyages of the own ship, or even from voyages of other ships. Second, these pre-developed routes differ depending on environmental conditions (current, wind) and/or loading conditions. With some manufacturers these environmental conditions and loading conditions can be preset independently of the selected route.

The possibility to select a pre-developed route during the process of voyage planning and voyage preparation can be considered as beneficial to the Track Pilot-automation. For the overall goal (safe navigation of the ship) is it necessary to recognize the fact that the environmental conditions (current, weather, water level, local obstruction of the fairway, traffic, ships at anchor, etc.) can be different at any time and moment, in a way that the selected route need to be altered before the voyage starts or even during the voyage. The skipper therefore need to know what environmental conditions and ship specific parameters a (selected) route is accounting for, in order to check and validate the selected route before commencing the voyage. Therefore, if a particular part of the route is considered not preferable or safe according to the skipper or helmsman, he must have te possibility to make changes to a route and save and store the new route for future use and selection.</td></tr>
</table>

	Thus, checking and validating a selected route during voyage planning and preparation should be considered essential for safe navigation in general, but even more when a Track Pilot-automation is in use.
Best Practices	The best practices aim to ensure a route selection process that is beneficial to the skipper, but also provide the skipper with the ability to check and validate the viability of the selected route/track before commencing the voyage: • Manufacturers develop routes to be selected from a database during voyage planning on board ships. • The skipper or helmsman must be able to check and validate the viability of the selected route before departure. • As *recommended best practice* (see paragraph 4.1) it can be considered to add a functionality to the Track Pilot-automation Interface making it impossible for the automation to engage unless the selected route is validated by the skipper. • On board a written procedure must be available and implemented describing route selection, Track Pilot-automation settings, route checking and route validation. • The Automation Interface must provide clear information how selected routes are accounting for environmental conditions and ship specific parameters, if any. (f.i. loading condition, water levels, vessel's configuration).

4.4.4 Safety Case 3 – Normal & emergency operation of the Track Pilot-automation

Table 4-7: Risks concerning inadequate Attention Allocation

Inadequate Attention Allocation	
Relation to HASO-elements	Trust, Reliability, Robustness, Demanding tasks and demands, Attention Allocation, Automation Interface
Corresponding Risk Contributing Factors	1 The presence of competing tasks and demands 2 The ability to perform those tasks and demands parallel to the automation 7 High levels of trust. 34 Automation does not provide transparency, understandability and predictability in automation complexity, automation performance, activated mode and (future) course of actions, making it difficult for the Human Operator to stay in the loop and interfere with the automation in a proper way.
Risk & Performance Analysis	Assuming Trust in the automation is high due to high *reliability* and *robustness* of the automation, the presence of *competing tasks and demands* and the opportunity to engage with those tasks and demand, the human operator possibly lose adequate *attention allocation* to the primary tasks and engaged automation. While sailing along the selected track, it is still necessary for the skipper to monitor the vessel's position and surroundings. However, due to the automation of steering tasks, the monitoring is not done automatically, as it was when the skipper was actively involved in steering to maintain the desired position on the fairway. With the automation of tasks such as determining the necessary control settings- for instance the required rate of turn (RoT) or rudder angle- the skipper is no longer actively *engaged* in the sailing task with maintaining a specific desired position. The diminished level of *engagement* is directly linked to task automation. Significantly, the skipper is no longer obligated to rely on memory to recall the stored plan or procedure and define the necessary inputs for maneuvering the vessel to a desired position. While this is mainly applicable to the execution phase of sailing—specifically, steering the vessel—it is perhaps more critical that the preceding cognitive processes involved in building *situation awareness* are affected. The sequential progression through various information processing stages during manual sailing is disrupted by the implementation of a Track Pilot-automation. In steering, Situation Awareness is crucial for devising an effective steering plan and procedure. However, since this task is now automated, the requisite level of Situation Awareness is also diminished, thereby reducing the imperative to engage with the sailing task compared to the scenario without a Track Pilot-automation. A lower Situation Awareness due to less attention allocated to the interface, could lead to missing out vital information. For example, monitoring the track line in relation to the river, bridges, buoyance, or other objects. Thus, Inadequate Attention Allocation can occur due to using a Track Pilot-automation as the skipper or helmsman become unintentionally distracted from the navigation tasks. In addition, inadequate Attention Allocation can also occur without automation in use, when skipper unintentionally fall asleep/lose consciousness or deliberately leave the wheelhouse (insufficient attitude to the responsibility to navigate safely).

Best Practices	The best practice consists of a *mandatory watch-alarm* as an integrated part of the Track Pilot-automation, aiming at the prevention of unintentional distraction. It simultaneously can be considered as a 'Recommended Best Practice' (see paragraph 4.1) to help prevent the skipper from unintentional falling asleep or deliberately leaving the wheelhouse. The Watch Alarm should be designed as a two-stage minimum alarm system. The first stage involves at least a visual warning or cue that appears on a screen at continuously randomized intervals between 5 and 10 minutes. This visual alert is meant to capture the skipper's attention and prompt them to take action. A proper action must be any system input given by the skipper, such as moving the mouse or pressing a button. At any time a system input is given, the alarm will be set to zero. Although the 5 to 10 minutes interval is not really an objective measure, it seems appropriate in terms of the rate and speed in which surrounding circumstances can change. However, if the skippers fails to respond within 1 minute, the alarm system will escalate to a second stage, which involves an audio alarm in the wheelhouse. In this stage, a loud sound or notification is generated to further alert the skipper. With consensus of the stakeholder-consultation group, if the second-stage alarm is not acknowledged within 2 minutes in the wheelhouse, an alarm throughout the entire vessel should be activated if the vessel involved is equipped with such an alarm. Furthermore, as additional Best Practices for implementation of the watch alarm MARIN recommend: • Make it difficult to bypass the alarm, for example bypassing the alarm by placing an object on the mouse to create continuously system input. • The naming of the visual alarm display should be standardized for the watch alarm as "watch alarm" • Log all watch alarms in a place accessible to the manufacturer, for later data-analysis and incident/accident analyses.

Table 4-8: Risks concerning inadequate Information Generation and Presentation Settings, warnings,alarm

Inadequate Information Generation and Presentation, Settings, warnings, alarms	
Relation to HASO-elements	Automation Interface, Mental Model, Complexity, Attention Allocation, Situation Awareness
Corresponding Risk Contributing Factors	3 The disability to monitor system performance in a clear and easy way 10 Inadequate Information presentation related to the performance of the automation 11 Inadequate information presentation related to the operating mode of the automation 12 Inadequate Information presentation about the (design)limits of the automation (brittleness) 13 Inaccurate information presentation 14 Filtering away of relevant information 15 Cueing irrelevant information 16 Relevant information not easy to access and/or asses. 26 The automation does not indicate and warn the operator in a sufficient way when it's performance degrades due to malfunction, missing or incorrect sensor-data or interference from other systems or sensors. 29 The automation has the opportunity to operate outside design parameters without sufficient warning. 31 Relevant information is not presented in a clear and understandable way, both audible, visible or otherwise noticeable. 32 Relevant information is not presented in a salience way 33 Automation interface does not provide for easy, understandable and intuitive Mode Transition 34 Automation does not provide transparency, understandability and predictability in automation complexity, automation performance, activated mode and (future) course of actions, making it difficult for the Human Operator to stay in the loop and interfere with the automation in a proper way.
Risk & Performance Analysis	Relevant information regarding performance, (future) performance decline, selected mode and unexpected mode transfers of the automation need to be assessed by the skipper or helmsman and therefore be presented by the Automation Interface. However, not all of that information is critical, or critical right away compared to information that is. Different pieces of information therefore need different levels of accessibility, accessibility and salience, and sometimes the salience should increase (escalate). We have observed different designs. To generate Best Practices we need to address: • What information should be presented; • Where the information should be presented (Track Pilot-automation Display, ECDIS[1],..); • How the information should be presented (visible, audible, combination visible/audible); • How salient the information should be presented. From literature review it can be established that one of the major risks of automation in *aviation* is the adding of all kinds of displays around the cockpit, making it difficult for air pilots to find and assess critical information for the safe operation of specific automation and the airplane in general. One significant lesson learned, reflected is the HASO-model, is integration and centralization of (1) safety critical information and (2) cues from different sources and automation as much as possible. We consider the ECDIS-display as the centralized display that hold the most critical information regarding the navigation of the ship in respect to its environment. The presented information should draw the skipper's attention when required and facilitate building up and retaining proper Situation Awareness. The design of the automation interface influences the attention allocation: it can help or make it more complex for the operator to understand the Track Pilot-automation, for example on: which mode is selected, what it is doing, what it will be doing, which setting are used, or when the track line will end. A well-designed interface helps the operator to distinguish the critical information; this should be taken into

[1] Whenever the word ECDIS is used, an alternative visualization system for electronic map is meant as well.

	account in which information must be presented on the interface and to what degree it should be detectable for the operator on ECDIS as the most relevant centralized display. Note the possibility that (parts of) the relevant information might not be generated by the Track Pilot-automation itself, or presented by the Track Pilot-automation Interface. For instance: The selected route projected in the environment (Nautical Chart, ECDIS).
Best Practices	The best practices aims to ensure an information provision that is relevant for the primary task and well-designed to enhance an adequate attention allocation and situation awareness of the skipper. For the purpose of best-practices it is therefore necessary, as a first step, to distinguish between critical and non-critical information and to establish if and when non-critical information becomes critical. This process is showed in Appendix 3. Furthermore, regarding warnings and alarms, certain thresholds, parameters or limits should be established and set in the system. It is important to notice that existing and observed Track Pilot -automations substantially differ in used technology and sensor-dependency. It is therefore not convenient to incorporate strict settings of thresholds, parameters or limits in this document, unless these settings are relevant to prevent unexpected and/or erratic navigation and maneuvering of the vessel (form a perspective of other users of the fairway). • ECDIS should be able to show critical information generated by the Track Pilot-automation and its performance, with salience compared to normal data shown in the ECDIS but not by overlapping with other safety critical data: o Permanent in the ECDIS screen: ▪ Indication if the Track Pilot automation is engaged or not, presented in a box colored green when engaged and grey when not engaged. ▪ Show the set route/track in the ECDIS: • as a green solid line; • as a red line for parts of the track that poses a (predicted) threat (exceeding max. RoT, large drift, substantial off-set,..); ▪ Show the accurate and scaled contour of the own vessel in black with a black dot for the vessels reference point on the track. If ECDIS is providing a contour by itself, this contour must be replaced by the contour generated by the Track Pilot-automation; ▪ Show the ships contour in the accurate ships position and heading compared to the engaged track; o Warning, visible in the ECDIS without an audible alarm: • Predicted offset to track of more than 20 meters (or a limit lower than 20 meter); • Declines in substantial position and course determination up to a maximum of 30 seconds; • The ship approaches the end of the route/track, 15 minutes is advance. o Alarms, both visible on the ECDIS display and audible by sounding alarm in case of: • Offset of track more than 10 meters to port or to starboard compared to engaged track; • Incomplete or missing sensor-data regarding heading and Rate-of-Turn; • More than 30 seconds declines in substantial position and course determination; • Malfunctioning of Track Pilot-automation components (sensors, software, computers, interfaces and connections, displays) • Disengagement of the Track Pilot-automation by manually moving the rudder-tiller on the Steering Pilot-console (emergency switch off) • The ship approaches the end of the route/track, 5 minutes in advance • All other relevant - but non-critical information should not been shown and/or accessible via the ECDIS, but only through the Track Pilot-automation interface and display: o Readiness of the Track Pilot-automation to engage; o Sensor readings; o Environmental conditions that the Track Pilot-automation is accounting for (via selected route or by manual input in the system during voyage planning and route selection process); o Vessels Loading condition the Track Pilot-automation is accounting for (via selected route or by manual input in the system during voyage planning and route selection process);

	• No Track Pilot-automation should be presented in a (digital) overlay over other information in the wheelhouse;
	• ‘Recommended Best Practices’ (see paragraph 4.1) regarding non-critical information permanent presented in the ECDIS screen:
	  o Vessels actual path parallel to the track in transparent green color;
	  o Track marked in red near bridges and near locks.

Table 4-9: Risks concerning inadequate Controls

Inadequate Controls	
Relation to HASO-elements	Automation interface, complexity, mental model, workload
Corresponding Risk Contributing Factors	4 The ability to switch of the automation and change to manual mode in an easy (intuitive) way. 9 High levels of complexity 11 Inadequate information presentation related to the operating mode of the automation 22 The control actions are too complex. 23 The control actions are not clear and/or understandable 24 The control actions have the possibility to let the operator engage to a wrong metal model or goal. 25 The control actions have insufficient possibilities to change system-modes in an easy and intuitive way 33 Automation interface does not provide for easy, understandable and intuitive Mode Transition 34 Automation does not provide transparency, understandability and predictability in automation complexity, automation performance, activated mode and (future) course of actions, making it difficult for the Human Operator to stay in the loop and interfere with the automation in a proper way.
Risk & Performance Analysis	The control interfacing to the human operator is vital for an adequate and effective control of the Track Pilot-automation. To prevent incorrect use or misunderstanding the Track Pilot-automation, the controls should be clear, unambiguous and accessible from the sitting position. It has been observed that there is inconsistency in procedures and provided controls for engaging the Track Pilot-automation and switching to different operation modes. In certain instances, the autopilot-interface and controls facilitate the engagement of the Track Pilot-automation and mode switching. However, in other cases, the buttons for automation engagement conveyed different meanings based on the system settings, introducing potential confusion. Notably, the buttons used in all observed wheelhouse situations were not originally designed for toggling the Track Pilot-automation on and off. This inconsistency in the human-machine interface, encompassing buttons and the digital screen, presents a challenge in effectively controlling and operating the system. The controls do not consistently align with real-world expectations, creating complexity within the system. Moreover, as configurations vary across different wheelhouses, there is an increased risk of transfer effects for skippers working on different vessels at different times, potentially their working impacted by the previously learned knowledge on how to operate the Track Pilot-automation at another vessel These potential errors in mode switching and in controlling the Track Pilot-automation can have a significant impact on safety. Misinterpretations or accidental actions may lead to unintended consequences, affecting the vessel's control and navigation. The risk of making incorrect decisions during mode transitions underscores the importance of clear design, user-friendly interfaces and hardware controls, and effective feedback mechanisms to minimize the likelihood of human errors and enhance overall safety. Additional observations revealed that the routes that were provided by the manufacturer were often suboptimal, either too much in the middle of the fairway or too close to berms or bank protections. This mainly occurred as a result of (unexpected) environmental conditions and while already underway. Therefore, if a particular part of the route is thus considered not preferable or safe according to the skipper or helmsman, he must have te possibility to make changes to a route and save and store the new route for future use and selection.

	Finally, erratic/unpredictable manoeuvring was observed in cases the Track Pilot-automation was engaged when the vessel was at a substantial distance from the track. The risk of confusion with both the skipper of the vessel and the skippers of other skippers must be considered.

Best Practices	The interface for controlling the Track Pilot-automation should be easy to operate and exposed to the operator in a way that matches the mental model and expectations for control by the skipper:
	• Controls:
	    o Standardized shape, color, symbol and naming of *physica*l buttons for engage/disengage Track Pilot-automation, which can be part of the Autopilot-interface or grouped next to Autopilot-interface;
	• Ability to engaging/disengage Track Pilot-automation:
	    o For engaging Track Pilot-automation, to prevent overshooting and unpredictable or erratic sailing behavior towards a track, the best practices states that the angle between heading and the track line cannot be more than 30 degrees and the distance to the line not more than 20 meters;
	    o In emergencies the track pilot should be switched off with one button or immediately by manually moving the rudder tiller on the Steering Pilot-interface, providing for immediately fallback to ‘Follow Up’ rudder control;
	• To deal with unexpected sub optimality of selected routes/tracks while underway, the skipper or helmsman have the ability to change a selected route/track by *both:*
	    o Shifting the whole route to port or starboard parallel to the original selected route. The shifted route must be visible on the ECDIS, replacing the original route;
	    o Changing the route by shifting waypoints, while keeping the route smooth enough to cause no erratic or unexpected course alterations of the ship;
	    o The skipper or helmsman have te possibility to save and store a changed route, making it possible to select this route for future voyages.

Table 4-10: Risks concerning inadequate Education and Training

<table>
<tr><th colspan="2">Inadequate Education & Training</th></tr>
<tr><td>Relation to HASO-elements</td><td>Complexity, mental model. Attention Allocation, Automation Interface, Situation Awareness</td></tr>
<tr><td>Corresponding Risk Contributing Factors</td><td>18 The automation has high levels of complexity
22 The control actions are too complex.</td></tr>
<tr><td>Risk & Performance Analysis</td><td>To ensure a correct use of the system and to ensure operators intervene on time when this is required, it is vital that the level of automation is well-understood. This can be facilitated by proper understanding of the automation, via a complete information provision via the automation interface and through training and education. More functionalities and modes reflecting the complexity of the automation lead to higher needs of understanding the automation, and more training will be required.

Several on board observations indicated a significant variation in the knowledge and strategies employed by skippers in using the Track Pilot-automation. For instance, it was noted that some skippers gradually learned the reference points utilized by the Track Pilot-automation for steering along the track. This understanding is crucial, as it determines the extent to which the vessel protrudes to the starboard or port side in the presence of crosswinds or in turns. A precise mental model of how the Track Pilot-automation operates is essential for safe usage.

Additionally, onboard observations revealed diverse perceptions of the risks associated with sailing using a Track Pilot-automation. Some skippers displayed a nuanced understanding of the real risks, while others demonstrated less calibrated awareness or underestimated the potential dangers. One example of this is the risk associated with occasional GPS data compromise, such as when sailing under a bridge. In such instances, the vessels position can substantial shift from the original and correct position.

Skippers' varying levels of risk awareness or risk perception influence their behavior, impacting decisions like leaving the wheelhouse for other tasks, ultimately compromising the safety of sailing.</td></tr>
<tr><td>Best Practices</td><td>Skippers, substitute skippers and other crewmembers that operate the vessel together with the automation need to have, as a minimum, basic knowledge and understanding of the controls, modes, mode-selection, mode-transfers, alarms and their meaning, performance indicators, and associated risks in order to collaborate with the system in a safe way and without losing Situation Awareness.

The best practices aim to provide comprehensive information in order to help users operate the Track Pilot-automation safely, efficiently, and in accordance with the manufacturer's guidelines:

• Every vessel must have a clear and easy understandable-manual on board, written in the German, Dutch, French and English language. The manual needs to address and explain as a minimum:
  o Safety precautions: Clear instructions on safety precautions and guidelines for using the Track Pilot-automation, emphasizing situations where manual control should be prioritized and potential risks associated with system operation. To name a few:
    • Sailing under bridges, between hills or mountains, trees or other circumstances that can compromise the GPS data receiving;
    • Risk of jumping of the track line, due to alternations of GPS data;
    • High required RoT;
    • High current & winds;
  o Navigation considerations: Information on how the Track Pilot-automation integrates with navigation tasks, including considerations for different environmental conditions and traffic situations, retaining an active monitoring strategy;
  o Provided controls and Interface elements;</td></tr>
</table>

	○ Operation procedures: step-by-step guidance on using the Track Pilot-automation in various modes, including (dis)engaging, adjusting track line and how to cope with navigation conditions that may be more difficult for the Track Pilot-automation; ○ Available settings and consequences on sailing behavior. This includes details on customization options based on the vessel's characteristics and prevailing conditions; ○ Different operation modes and mode-selection/ switching; ○ Emergency Procedures: Protocols for handling emergencies or unexpected situations, including procedures for manual takeover in case of system failure or malfunction; ○ Alarms/warnings and their meaning and performance indicators. It should also address the specific risks of losing situational awareness due to degrading Attention Allocation (leave the wheelhouse unattended, perform competing tasks and demands); ○ Troubleshooting: Guidance on identifying and resolving common issues or malfunctions with the Track Pilot-automation. This may include error messages, diagnostic procedures, and troubleshooting tips; ○ Update & maintenance procedure and settings; • On board every ship, the Ship-Owner must establish a procedure that guarantees familiarization with the Track Pilot-automation and the Track Pilot-automation manual.

Table 4-11: Risks concerning long and short term declination of Engagement and/or Competence

Long and short term declination of Engagement and/or Competence	
Relation to HASO-elements	Engagement, Attention Allocation, Workload, Adaptive Automation,
Corresponding Risk Contributing Factors	8 Presence of other tasks and demands and the ability to engage in those tasks and demands during the operation of the automation. 21 Since Adaptive Automation might be a solution to prevent loss of engagement and/or competence, a missing determination of where and when Adaptive Automation is beneficial can be considered as a risk related to system design.
Risk & Performance Analysis	While automation can enhance efficiency and reduce the need for manual sailing, it poses a challenge in terms of skill retention. If skippers rely extensively on the Track Pilot-automation, their manual skills related to the task may deteriorate over time due to lack of practice and engagement with the (manual) sailing task. This decline in hands-on proficiency becomes evident when manual intervention is required, such as during system failures, emergencies, or situations where the automated system cannot handle certain aspects effectively. In such situations, there may be a higher risk on high workload, due to a loss or lack of competence, further compromising task performance by the skipper. The risk of skill retention may grow over time, particularly as novice skippers initially sail with a Track Pilot-automation without developing adequate manual sailing competencies. An interviewed skipper noted that this trend might already be emerging, citing an instance where a younger second skipper was accustomed to relying heavily on the Track Pilot-automation and lacked the skills to manually steer the vessel. In addition, literature review indicates that task performance through goal and task engagement is significantly enhanced when operators actively monitor and operate, instead of passively monitoring automation performance. This means that too long periods of sailing with the Track-Pilot automation engaged, could lead to declination of the skippers engagement with the overall goal or task and, as a consequence, leading to failure to perform when necessary.
Best Practices	The best practices aim to use Adaptive Automation as a way to enhance engagement and, in addition, prevent declination of competence of experienced and unexperienced skippers/trainees in the long term. Adaptive automation refers to periodically switching back to manual control or lower Levels of Automation by turning of automation [Ref 3.]. Since automation can create reduced levels of Engagement and/or attention allocation, Adaptive Automation intent to be beneficial to remain good levels of Engagement or restore Allocation. It is able to reduce workload in situations where Human Interaction is necessary, because it brings or keeps the Human Operator in-the-loop in a controlled manner (in time). Additionally, Adaptive Automation can be beneficial to learning progress for novel operators or prevent degradation of skills in the long term for all operators Therefore, a form of Adaptive Automation must, as a responsibility of ship-owners, be in place. Adaptive Track Pilot-automation could, for instance, be integrated by combining Track Pilot-automated steering with cycles of manual steering.

5 DISCUSSION

Track Pilot-automation designs as being described in paragraph 4.1.2 all fall within the scope and focus of this research. Although new functionalities such as collision warning, collision avoidance and speed control, are expected to be added to the Track Pilot-automation, these functionalities are not subject of this research. Also other equipment like ECDIS or Radar is not part of this research, except for interfacing functionalities that are critical for the safe usage of Track Pilot-automation. At the same time, the theoretical framework and methodology used in this research can be used in the same way for additional research with a focus of new functionalities or other equipment, adding new elements to the safety cases that are developed in this research.

In accordance with the research method described in Chapter 3, literature reviews together with interviews , observations, workshops and Cognitive Task Analysis regarding the overall goal of safe navigation, resulted in the determination of three different Safety Cases. This was followed by a Performance and Risk Analysis based on an iterative cognitive information processing model [Ref 2.] and the Human-Autonomy System Oversight-model (HASO)[Ref 3.]. This method finally resulted in the identification of main risks emerging from the implementation of Track Pilot-automation on board of inland vessels, accompanied with 'Best Practices' to mitigate these risks. Table 5-1 shows an overview of the identified Safety Cases and risks that are accounted for in Chapter 4.

Table 5-1: Safety Case and Risks overview

Safety Case	Paragraph	Identified Risks	Table
Technical Installation, implementation, calibration /tuning, maintenance and repair	4.4.2	Inadequate installation on board	*Table 4-3*
		Inadequate Tuning/Calibration	*Table 4-4*
		Inadequate Reliability of the Track Pilot-automation	*Table 4-5*
Voyage Planning	4.4.3	Inadequate Voyage Planning	*Table 4-6*
Normal and emergency operation of the Track Pilot-automation	4.4.4	Inadequate Attention Allocation	*Table 4-7*
		Inadequate Information Generation and Presentation, Settings, warnings, alarms	*Table 4-8*
		Inadequate Controls	*Table 4-9*
		Inadequate Education & Training	*Table 4-10*
		Long and short term declination of Engagement and/or Competence	*Table 4-11*

Within the scope of this research MARIN acknowledges that Track Pilot-automation first of all is beneficial to task-performance. It has the ability to reduce workload when, for instance, sailing in busy port area's resulting in more attention for the environment and, thus, better engagement with the overall goal of safe navigation. Besides that, the Track Pilot-automation presumably performs better than humans in keeping the vessel on track, especially in more challenging environmental conditions due to wind, weather, darkness, low visibility and current.

But, like every technical system and automation, Track Pilot-automation has limitations as well as an effect on the ability of the Human Operator to oversee the automation performance and interaction with the system, also leaving the Operator with challenges in reaching the overall task of maintaining safe navigation. It is important to notice that these cognitive challenges often take place without consciously noticing by the Human Operator involved. We therefore consider Track Pilot-automation manufacturers having a primary responsibility to mitigate cognitive challenges that are emerging due to the implementation of Track Pilot-automation, instead of leaving it all to the responsibility of the skipper or helmsman on board.

The ‘Best Practices’ resulting from this research therefore mainly addresses the additional risks which arise together with the benefits of the implementation of Track Pilot-automation on board inland vessels. This also means that MARIN does not use the *Level of Automation*, such as determined for instance by the Central Commission for the navigation of the Rhine (CCNR) in 2022, as a reference to decide on the applicability of ‘Best Practises’. Instead MARIN considers the Level of Automation as a factor that may or may not has consequences for safe use of Track Pilot-automation, since “ improving safety” is the main objective of our research.

MARIN also recognizes the fact that risks to safe navigation are not always only related to the implementation of Track Pilot-automation. Failing equipment, environmental circumstances, obstructions, traffic, personal factors or even a substandard attitude of the Human Operator, can lead to failure. In some cases the Track Pilot Automation Interface can provide measures to mitigate other risks than those risks emerging from the implementation of Track-Pilot Automation alone. When this is the case, MARIN refers to ‘Recommended Best Practices’ in Chapter 4.

In addition, MARIN is fully aware of the fact that Track Pilot-automation is a main subject in multiple parallel projects and working groups, as also partly reflected in the Reference-list in this research report. As much as possible MARIN has integrated results in the literature review. A project worth mentioning here is a CESNI working group that aims to define how Track-Pilot automation information must be visualized in ECDIS Displays, as is also part of the Best Practices in this research. MARIN recommends that the working group take the Best Practices in this research in consideration.

Finally, it is not always convenient to describe Best Practices in terms of quantified thresholds or limits. In those cases is better to describe than as a goal rather than a very strict number.

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APPENDICES

APPENDIX 1 HASO-MODEL LEGENDA AND RISK CONTRIBUTING FACTORS

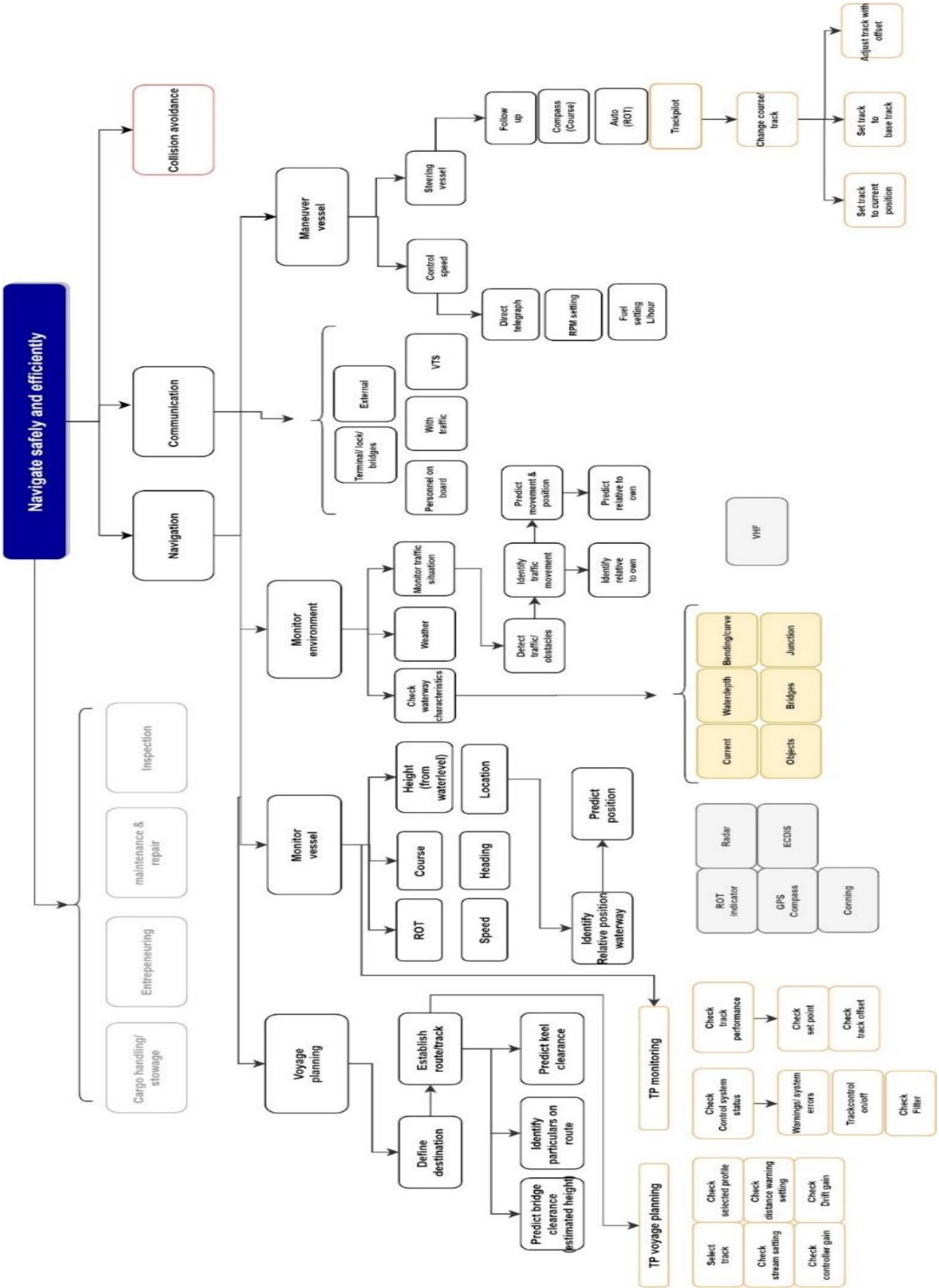
HASO-MODEL, Description of features and characteristics and extracted Risk Contributing Factors	
ENVIRONMENTAL FEATURES	
Feature	**Competing task and demands**
Description	This factor has an influence on *cognitive constructs* ***trust*** and ***attention allocation***. Humans tend to have more trust in automation if there are competing tasks. At the same time competing tasks and demands need allocation of attention, dragging this attention away from performance monitoring of the automation and from keeping overall SA.
RCF	1. The presence of competing tasks and demands
	2. The ability to perform those tasks and demands parallel to the automation
COGNITIVE CONSTRUCTS	
Feature	**Trust**
Description	Trust can be defined as the operators perception of the level of the dependency the operator can safely accept from the automation. It is affected by the operators ability to independently asses the systems performance, the complexity of the automation, the ability to perform the task manually, and the operator's decision freedom. Also both *system design features* ***reliability*** (automation ability to operate accurately) and ***robustness*** (automation ability to operate across a wide range of possible conditions) are shaping factors for the cognitive construct of trust. Higher levels of trust has a negative influence on the *cognitive construct* of ***Attention Allocation***, and therefore on *SA*. This can be seen as a risk-paradox. Automation needs to be trustworthy in terms of reliability and robustness to fulfil its purpose, but can increase OOTL at the same time.
RCF	1. The ability to monitor system performance in a clear and easy way
	2. The ability to switch of the automation and change to manual mode in an easy (intuitive) way.
	3. The automation has high levels of reliability
	4. The automation has high levels of robustness
Feature	**Attention Allocation**
Description	The level of attendance the operator has to displays and environmental information that show how well the automation performs. Attention Allocation is mainly moderated by ***Trust*** and ***Competing tasks and demands***, since high levels of trust give the operator the opportunity the deviate attention to other tasks.
RCF	1. High levels of trust.
	2. Presence of other tasks and demands and the ability to engage in those tasks and demands during the operation of the automation.
Feature	**Mental Model**
Description	Mental model refers to a way of understanding how things work, stored in long term memory. It helps human operators to find, interpret and combine information in a systematic and intuitive way without being dependent on the very limited capacity of the working memory of the human brain. The existence, accuracy and completeness off mental models is formed most effectively through (hands-on) experience. In a less effective manner also by training and education. Mental model as a cognitive process is very strong. It is effective if the operator engages the correct and complete mental model, but risk full if this mental model is not fitting to the actual scenario or is incomplete. In such cases humans have difficulties in recognizing that they applied the "wrong" mental model, even if there is clear conflicting information available that indicates a different scenario or situation at hand.

	The risk of engaging to the wrong mental model is dependent on the ***complexity*** of the system and the way relevant information is presented to the operator through the ***automation interface***. Standardization and the limited use of automation modes are considered good design practices in avoiding operators to engage to the wrong mental model.
RCF	1. High levels of complexity
	2. Inadequate Information presentation related to the performance of the automation
	3. Inadequate information presentation related to the operating mode of the automation
	4. Inadequate Information presentation about the (design)limits of the automation (brittleness)
SYSTEM DESIGN FEATURES	
Feature	**Level of Automation**
Description	The level of automation ranges from only automation that enhances SA, to automation designed to help with or take over Decision Making or just automated Action Execution, up to fully automated systems with (almost) none interaction with the Human Operator. For the purpose of this research is important to stay with the five main sub-processes of the cognitive information process Edsley uses to describe the HASO-model. In general, automation that is purely designed to enhance SA is significant beneficial to ***workload*** and performance, when accurate and easy to understand. If not accurate, if relevant information is being filtered or when they cue irrelevant information or warnings compare to other information, this type of automation can create substantial risks. In these cases, overall performance can be worse compared to settings without the automation. Automation that interferes in Decision Making has basically the same issues, but can also generate more risk if the automation provides wrong advises or recommendations. Again, performance will be worse than compared to a system without recommending courses of action. Besides that, performance of the Human Operator may be slowed down because the operator has to compare automation recommendation with his own SA, e.g in case the operator is distracted by other competing tasks and demands. Automation that is designed and implemented to take over certain tasks in Action Execution can be very beneficial in limiting workload. This may, on the other hand, cause loss of Engagement and Attention, but is also increasing workload if the automation has high false alarm rates or when the operator need to restore loss of SA due to OOTL. If working with the automation is too complex, higher rates of workload can also be expected.
RCF	1. Inaccurate information presentation
	2. Filtering away of relevant information
	3. Cueing irrelevant information
	4. Relevant information not easy to access and/or asses.
	5. Decision support by showing recommendations only
	6. The automation has high levels of complexity
	7. The automation has low levels of reliability
	8. The automation has low levels of robustness
Feature	Adaptive Automation
Description	Adaptive automation refers to periodically switching back to manual control or lower ***Levels of Automation*** by turning of automation.

	Since automation can create reduced levels of ***Engagement*** and/or ***attention allocation***, Adaptive Automation intent to be beneficial to remain good levels of Engagement or restore Allocation. It is able to reduce ***workload*** in situations where Human Interaction is necessary, because it brings or keeps the Human Operator in-the-loop in a controlled manner (in time). Additionally, Adaptive Automation can be beneficial to learning progress for novel operators or prevent degradation of skills in the long term for all operators
RCF	1. Since Adaptive Automation might be a solution to prevent loss of engagement and/or allocation, a missing determination of where and when Adaptive Automation is beneficial can be considered as a risk related to system design.
Feature	Granularity of Control
Description	The Granularity of Control of the automation has direct influence on the ***workload*** of the Human Operator, with a strong connection to **Engagement** and **Mental Model.** It ranges from (high to low): • manual control; • the programming of each task parameter and specification; • selecting from a list of pre-setting's; • goal-based control, where only a high-level goal needs to be provided to the system (fully automated). Control actions must provide clear mapping to user goals and ***mental models*** and the automation needs to provide for an easy and intuitive change between system-modes.
RCF	1. The control actions are to complex.
	2. The control actions are not clear and/or understandable and/or
	3. The control actions have the possibility to let the operator engage to a wrong metal model or goal.
	4. The control actions have insufficient possibilities to change system-modes in an easy and intuitive way
Feature	Automation Reliability
Description	The ability of the automation to operate accurately
RCF	1. The automation does not indicate and warn the operator in a sufficient way when it's performance degrades due to malfunction, missing or incorrect sensor-data or interference from other systems or sensors.
	2. The automation generates to many false alarms.
	3. The automation generates to much underperformance
	4. The automation has the opportunity to operate outside design parameters without sufficient warning.
Feature	Automation Robustness
Description	The ability of the automation to operate in a wide range of possible conditions
RCF	1. The automation have to be used to much outside design parameters in order to be useful to the operator.
Feature	Automation Interface
Description	The Automation Interface is a very important component of the automation. If it's designed right, is has the possibility to mitigate much of the risks that comes with the Risk Contributing Factors identified in this section of the report. If it's done insufficient, it makes performance related to OOTL even more worse by itself. In terms of *system usability* – how the controls and interface design support the operator - a poorly designed system adds *complexity* and discourages its use, while a well-designed system facilitates the skipper's task.

	Principles of good design encompasses *information provision, human-Track Pilot-automation interaction*, and *information presentation design*. A design that prioritizes ease, readability, understanding, and effectiveness in automation increases the likelihood of human operators consistently using the system for this crucial task. System design, therefore, serves as a performance-influencing factor that can be intentionally crafted and modified to positively impact human performance.
RCF	1. Relevant information is not presented in a clear and understandable way, both audible, visible or otherwise noticeable.
	2. Relevant information is not presented in a salience way
	3. Automation interface does not provide for easy, understandable and intuitive Mode Transition
	4. Automation does not provide transparency, understandability and predictability in automation complexity, automation performance, activated mode and (future) course of actions, making it difficult for the Human Operator to stay in the loop and interfere with the automation in a proper way.
EMERGENT SYSTEM CHRACTERISTICS	
Characteristic	Workload
Description	Workload relates to the availability of (limited) working memory. High workload creates performance issues for SA, as well as Decision Making and Action Execution. Both too high and too low workload can creates bottlenecks in performance. Low workload creates OOTL, High workload comes with restoring OOTL when it is unexpected. High workload is also related to automation complexity, in cases that, f.i., Granularity of Control has a high level. Also personal factors, mainly stressors like fatigue, anxiety, personal circumstances and disease, may have a negative influence on the availability of working memory.
Characteristic	Engagement
Description	Automation causes an operator to be less actually operating on (sub)tasks necessary to reach to overall goal. Leaving the operator with monitoring the automation, engagement with the overall goal might be deteriorating. The diminished level of *engagement* is than directly linked to task automation. Significantly, the operator is no longer obligated to rely on memory to recall the stored plan or procedure and define the necessary inputs for the operational task. While this is mainly applicable to te execution phase of a task, it is perhaps more critical that the preceding cognitive processes involved in building *situational awareness* are affected. The sequential progression through the various SA processing stages during manual operation is disrupted by the implementation of automation. The requisite level of situational awareness is diminished, thereby reducing the imperative to engage with the task compared to the scenario without automation.
Characteristic	Complexity
Description	

APPENDIX 2 NAVIGATION TASK DECOMPOSITION



1. Voyage/navigation planning
    - 1.1 Define destination
        - 1.1.1 Consult administration/ information source for next rendez/vous
    - 1.2 Determine the route
        - 1.2.1 Vessel characteristics
            - 1.2.1.1 Assess the loading schedule/ stowage plan
            - 1.2.1.2 Calculate the draught and height
            - 1.2.1.3 Define minimal under keel clearance
        - 1.2.2. Route characteristics
            - 1.2.2.2 Travel distance
                - 1.2.2.1.1 Calculate expected travel time & ETA
                - 1.2.2.1.2 Calculate expected fuel
                - 1.2.2.1.3 Required fuel tank stops
            - 1.2.2.3 Water way characteristics
                - 1.2.2.3.1 Assess river water levels/depth & weather forecasts
                - 1.2.2.3.2 Assess tidal streams and river current
                - 1.2.2.3.3 Assess bridges and locks and their dimension limitations
                - 1.2.2.3.4 Assess and avoid shallow waters
                - 1.2.2.3.5 Assess and avoid obstacles & no-go areas
                - 1.2.2.3.6 Check navigational space, curves and junctions
        - 1.2.2. Assessing route plan
            - 1.2.2.1 Define maximum height and extra margin
            - 1.2.2.2 Define feasibility route options
            - 1.2.2.3 Define desirable path/track
        - 1.2.3 Select route
2. Execute voyage/navigation plan
    - 2.1 Manoeuvre vessel to desired path/track
        - 2.2.1 Select steering mode (follow-up, Course, ROT)
            - 2.2.2.1 Control rudder or set course/ROT
        - 2.2.2 Select speed control mode (direct telegraph, RPM setting, fuel setting)
            - 2.2.2.1 Control telegraph, set RPM or fuel settings
    - 2.2 Maintain desired track
3. Monitor the vessel
    - 3.1 Monitor current speed, ROT, course and heading
    - 3.2 Monitor relative position on water
    - 3.3 Detect deviations from intended course/ position and speed
    - 3.4 Monitor systems and alarms/ malfunctions
4. Monitor the environment
    - 4.1 Monitor water way
    - 4.2 Monitor traffic/ obstacles
        - 4.2.1 Detect & identify objects
            - 4.1.1.1 Static objects
            - 4.1.1.2 Moving/dynamic object
            - 4.1.1.3 Traffic density
        - 4.2.2 Evaluate position, heading and speed
        - 4.3.3 Predict future path
5. Collision avoidance
    - 5.1 Evaluate traffic
        - 5.1.1 Identify potential threat/danger
        - 5.1.2 Extrapolate position/ Project path in relation to own path
        - 5.1.3 Determine CPA/CPA

- 5.1.4 Evaluate hydro-dynamic interaction effects
- 5.1.5 Determine safe distance (for passage)

5.2 Communicate

- 5.2.1 Identify intentions of other vessel
- 5.2.1 Arrange a safe passage

5.3 Avoid static objects

5.4 Define course & speed adjustments

- 5.4.1 Determine safe path (relative position in time)
- 5.4.2 Determine manoeuvre and required time
- 5.4.3 Account for hydrodynamic effects
- 5.4.4 Account for available space to manoeuvre
- 5.5.5 Time required/available to get the desired position

APPENDIX 3 CRITICAL/NON CRITICAL TRACK PILOT-INFORMATION

Critical/non critical Track Pilot-information			
Sensor readings	Actual sensor readings are not critical to monitor TP-performance		
Sensor reliability	Critical, if the sensor data-input is compromised by incomplete or missing sensor-data in a way that it dangerously influences the TP performance.	Non critical for sensor-data that is incomplete or missing but does not compromise TP-performance in a dangerous way	Sensor-data that is incomplete or missing but does not instantly compromise TP- performance in a dangerous way, but becomes dangerous over time. For instance when 'dead-reckoning' occurs due to missing, inaccurate GPS-sensor input
TP status (readiness, engaged/not engaged)	Critical, the skipper/helmsman need to know TP is engaged or not engaged.	Not critical, readiness of the TP is not critical information, as long as engagement of the TP is blocked when the TP is not ready	
Offset to track	Non critical within set threshold limits	Critical outside threshold limits	
Predicted offset to track outside set threshold limit (predicted overshoot)	Critical, the skipper/helmsman must be aware of possible overshoot situations well in advance.		
Software/hardware malfunction			
Sensors (AIS, GPS, Compass, Speed log, ROT)	Critical		
Computers	Critical		
Hardware interfaces and connections (Sensors, ECDIS, Autopilot,)	Critical		
TP-display	Critical		
TP-software	Critical		
Selected route/track	Critical, integrated with relevant environmental information (Nautical Chart)		
Ship heading and contour (ship specific, scaled) compared to engaged route/track	Critical. To give the skipper/helmsman a visible, easy to assess overview of the TP-performance (following track)		
Actual sailing-path parallel to engaged route/track	Not critical. Although the followed route or track is not just a small line on a nautical chart, but in reality it is a path, parallel to the engaged route, mainly dependent on drift-angels together with ship length. This information is not safety critical for monitoring TP-performance (if skipper is engaged in safe navigation of the ship), but has the opportunity to enhance Situation Awareness		
Mode-selection	Critical, if TP is integrated with other/additional automation and different modes can be selected (e.g. speed automation, collision avoidance). This is also the case when the TP can both interface with the autopilot as well as the steering gear (FU, bypassed autopilot) Otherwise mode-selection can be presented within TP-status information		
Setting of environmental conditions (if applicable)	Not critical. It might be relevant as the environmental condition change compared to initial settings during voyage planning and route selection, but is not critical to present with salience during TP engagement.		
TP-Setting of loading condition/ draft/height	Not critical for TP-operation. It is only critical during route selection and voyage planning		
Mode transfer	Critical if happens unexpected or unintentionally	Non-critical if transfer was deliberate	

APPENDIX 4 EXTERNAL REVIEW

Comments on draft report					
No.	***Organization***				
1	Rijkswaterstaat	Section	1.1.2	Response accepted by Marin	Partly
		Comment	The advantage of using less fuel (and therefore sailing more sustainable) deserves to be mentioned as well.		
		MARIN response	Added “ reduced fuel consumption”. This advantage is hypothetical and not established by research.		
2	Rijkswaterstaat	Section	1.1.4	Response accepted by Marin	Yes
		Comment	To help the reader, a reference to the white paper on intention sharing, a result of that project, would be suitable (https://www.inlandwaterwaytransport.eu/wp-content/uploads/Paper-Intention-sharing_DIWA_Inland-Navigation-Week.pdf)		
		MARIN response	Added to the report		
3	Rijkswaterstaat	Section	1.3	Response accepted by Marin	Yes
		Comment	Rijkswaterstaat WVL, being part of the smart shipping program within the ministry, has asked MARIN to carry out the Safety case and best practices study on the design and implementation of track pilots on inland vessels.		
		MARIN response	Added to the report		
4	Rijkswaterstaat	Section	2.1	Response accepted by Marin	Yes
		Comment	The sentence says task, but in figure 2-1 it says ‘procedures’.		
		MARIN response	Added to the report		
5	Rijkswaterstaat	Section	2.3	Response accepted by Marin	Yes
		Comment	It would be helpful to mention these eight major threats, making it possible for the reader to judge whether OOTL is the most relevant.		
		MARIN response	Added to the report		
6	Rijkswaterstaat	Section	2.3	Response accepted by Marin	Yes
		Comment	Please explain what an out-of-the-loop loss of situation awareness is.		
		MARIN response	Added to the report		
7	Rijkswaterstaat	Section	4.2.2	Response accepted by Marin	Yes
		Comment	Who’s objective is referred to?		
		MARIN response	Clarified in the report		
8	Rijkswaterstaat	Section	4.2.3, Fig 4-1	Response accepted by Marin	Yes
		Comment	Figure is unreadable due to very small characters. A larger versions should be put in the annex.		
		MARIN response	Added to the Appendix 2		
9	Rijkswaterstaat	Section	4.3.1	Response accepted by Marin	Yes
		Comment	Please explain abbreviation FU and RoT.		
		MARIN response	Clarified in the report		
10	Rijkswaterstaat	Section	4.4	Response accepted by Marin	No
		Comment	Some extra help when reading the tables on the next pages would be helpful. Please explain the relation the different elements of each table have.		
		MARIN response	Already in the introduction paragraph of section 4.4		
11	Rijkswaterstaat	Section	4.4.1	Response accepted by Marin	No
		Comment	‘This list must be accessible on board’. The most useful way of doing this is having an adequate compatibility list online. Is that enough?		
		MARIN response	We argue that the list must be accessible on board. We do not want to prescribe how this have to be achieved, leaving it up to the manufacturer what is the most practical way to do.		
12	Rijkswaterstaat	Section	4.4.1	Response accepted by Marin	Partly
		Comment	“… needs to be contacted by the skipper to provide support and to calibrate/retest the system when needed.” Isn’t that too liberate? I would say that the manufacturer should approve the use of this new configuration.		
		MARIN response	We added the obligation to approve a new configuration, but the obligation to contact the manufacturer remains with the skipper or owner of the vessel.		
13	Rijkswaterstaat	Section	4.4.1	Response accepted by Marin	N/A

		Comment	Why is the best project still concept (table- row)?		
		MARIN response	It will be " final" in the final report.		
14	Rijkswaterstaat	Section	4.4.3	Response accepted by Marin	Yes
		Comment	In the table dealing with 'inadequate information generation and presentation setting warnings alarms' (sic) ECDIS is mentioned. However, the use of ECDIS is not mandatory for all barges: even on Rhine water an alternative visualization system can be used. I would recommend a foot note noting the whenever ECDIS is used an alternative visualization system for electronic map is meant as well.		
		MARIN response	Added to the report		
15	Rijkswaterstaat	Section	4.4.2	Response accepted by Marin	No
		Comment	In the same table: if tracks are 'marked in red near bridges and near locks', as is recommended, wouldn't it be appropriate to warn (first graphical, later audible) that the ship is near a red line as well?		
		MARIN response	The "red" color only serves as way to gain attention. Only in described cases this additional attention allocation will be followed by an alarm (both visible and/or audible)		
16	Rijkswaterstaat	Section	4.4.2	Response accepted by Marin	Yes
		Comment	In the table dealing with inadequate controls it reads: 'This mainly occurred as a result of (unexpected) environmental conditions or other traffic and while already underway.' We find it hard to understand how routes are suboptimal due to other traffic, since actual traffic is not taken into account in the discussed version of the track pilot, as far as I know. Can you explain what was meant here?		
		MARIN response	" Other traffic" deleted from the report		
17	Rijkswaterstaat	Section	5	Response accepted by Marin	Partly
		Comment	Since the conclusions were not included in this draft document, it is impossible to comment on this. It would have been a good idea to mention the kind of conclusions to be drawn, since the outcome of the project is the 'best practices' described in chapter 4. What can be added?		
		MARIN response	Besides the "Best Practices", possible matters added in the conclusion chapter will reflect the way MARIN is looking at relevant issues, such as responsibilities or issues related to "good seamanship" regarding , for instance, voyage planning. These reflections can only be drawn up after the review process. The be more comprehensive, we changed the title of the Chapter to " Discussion" instead of " Conclusions". In addition, we decided not to add another long table with a summary of 'Best Practices" identified.		
18	Rijkswaterstaat	Section	4.4.1	Response accepted by Marin	Yes
		Comment	Best Practice first Bullet: Specify that the TP manufacturer needs to be contacted (not de manufacturer of the new hardware).		
		MARIN response	Added to the report		
19	Rijkswaterstaat	Section	4.4.1	Response accepted by Marin	Yes
		Comment	Inadequate reliability of the TP-automation: Best practices compatibility, first bullet: replace prevent and confirm with ensure		
		MARIN response	Added to the report		
20	Rijkswaterstaat	Section	4.4.3	Response accepted by Marin	Yes
		Comment	Inadequate attention allocation. (P24) Best practices: Do we need to describe why a time of 5 to 10 minutes was chosen?		
		MARIN response	Added to the report		
21	Rijkswaterstaat	Section	4.4.3	Response accepted by Marin	Partly
		Comment	*Inadequate information generation and presentation settings warnings, alarms, best practices concept:* "Show the accurate and scaled contour of the own vessel in black with a black dot for the vessels reverence point on the track" This is indeed important but how does this relate to the contour already provided by the ecdis system? It might be good to include		

			that the ecdis and TP have to use the same source for the position when an overlay is used.		
		MARIN response	We have added to the report that if ECDIS is providing a contour by itself, this contour must be *replaced* by the contour TP-automation is generating.		
22	Rijkswaterstaat	Section	4.4.1	Response accepted by Marin	No
		Comment	*Inadequate information generation and presentation settings warnings, alarms, Recommended best practices:* Presenting of the actual path in green and a red track near bridges contradicts the statement that non critical information should not be shown on the ECDIS. Suggestion: change to: no uncritical information except:.. Marking track red near bridges might lead to confusion with a red track due to predicted treat of off-set from track. In case of a red track due to bridges the track pilot will likely keep preforming as expected. In case of expected off-set the track indicates that the TP will not preform as expected.		
		MARIN response	We do not agree with the statement that the color of the track can be considered as non-critical. The red coloring of the track is meant to gain attention from the operator in case of threats (of any kind). Only in described cases this additional attention allocation will be followed by an alarm (both visible and/or audible)		
23	EOC	Section	1	Response accepted by Marin	Yes
		Comment	There is more inland transport than only between the seaports and inland destinations.		
		MARIN response	Clarified in report		
24	EOC	Section	1	Response accepted by Marin	No
		Comment	Is an 'upcoming' enormous shortage		
		MARIN response	There is already a shortage		
25	EOC	Section	1	Response accepted by Marin	No
		Comment	This line more soften related to the subject Trackpilot		
		MARIN response	Comment unclear to MARIN		
26	EOC	Section	1	Response accepted by Marin	No
		Comment	ie. ?? please be mor clear about this. [Ref 1.] is not clear for me what it is and where to find.		
		MARIN response	" [Ref 1.] is referring to the reference list after Chapter 5		
27	EOC	Section	-	Response accepted by Marin	No
		Comment	Please add your definition of what a you think what a trackpilot and what it does, and please if possible naming of other names in the market like TGain etc. Maybe also mention here that in inland shipping this is a tool.		
		MARIN response	The description of Track pilot-automation is given in section 4.2.2		
28	EOC	Section	1.1.3	Response accepted by Marin	Yes
		Comment	Stored 'and reused'		
		MARIN response	Added to the report		
29	EOC	Section	1.1.4	Response accepted by Marin	No
		Comment	Collision avoidance detection is in development and does in our opinion not work on smaller canals for example. Do we need to add something here?.		
		MARIN response	Collision avoidance detection is only mentioned as a possible future functionality		
30	EOC	Section	2.1	Response accepted by Marin	No
		Comment	Maybe nice to add here 'crossing ships, locks and bridges'		
		MARIN response	These elements are all part of the Navigation Task		
31	EOC	Section		Response accepted by Marin	No
		Comment	[Ref 2.] and [Ref 4.] is not clear for me what it is and where to find.		
		MARIN response	See Comment 26		
32	EOC	Section	4.3.1	Response accepted by Marin	No
		Comment	There are manufacturers where stored-self-made tracks are different than delivered tracks by the manufacturer. For example the first doesn't stop bij locks and/or bridges. See also page 21 'Risk & Performance analyses the third part.		

		MARIN response	Not clear to MARIN what should be changed in the report		
33	EOC	Section	-	Response accepted by Marin	No
		Comment	Can be mentioned something about the risk with crewchanges or relief skippers		
		MARIN response	Already part of the " Best Practices" regarding Education and Training (last bullet) in section 4.4.3		
34	EOC	Section	-	Response accepted by Marin	No
		Comment	Can be mentioned something about uniformity to sail to the track position		
		MARIN response	Not clear to MARIN what should be changed in the report		
35	EOC	Section		Response accepted by Marin	Partly
		Comment	My suggestion is to add the CESNI table here with the automation levels and add on which base this research has taken place		
		MARIN response	The Levels of Automation used in reference to the HASO-model [Ref. ..] are slightly different than the ones used by CESNI. To avoid any confusion we decided to just describe the Level of Automation, since that is what is relevant for the research. To clarify we've added a paragraph in Chapter 2. (Paragraph 2.4)		
36	Argonics	Section	4.3.1	Response accepted by Marin	No
		Comment	Voyage planning is not part of a trackpilot. Trackpilots are used when performing **operational** navigation whereas voyage planning is part of **strategic** navigation. The track to follow in the immediate vicinity (e.g. 1.600m) can be considered a crucial part of the **tactical** navigation and should be monitored by the skipper. Terms used by Hermann Haberkamp in "Navigation mit Radar": Operational -> tactical -> strategic.		
		MARIN response	First of all we disagree with the concept of distinguishing between operational, tactical and strategic navigation. It is all part of the overall navigation goal including related tasks (see Cognitive Task Analysis, sections 3.2 and 4.2.) that have to be performed under the responsibility of the skipper. To perform this responsibility the skipper needs to have access to all recourses that he is able to use for that task, including route selection as part of the Voyage Planning task. Secondly, we have observed skippers to decide on multiple different route options in which one to take, based on possible obstacles, locks partly out of order or presence of bunkering opportunities. A skipper simply cannot decide, in case he is not able to select a convenient or even safe route before commencing his voyage.		
37	Argonics	Section	4.4.1	Response accepted by Marin	Yes
		Comment	Ensure the autopilot system accurately interprets navigations and GPS data and executes precise steering commands. Autopilot system or trackpilot system?		
		MARIN response	Clarified in the report		
38	Argonics	Section	4.4.3	Response accepted by Marin	Yes
		Comment	Show the ship's contour ... drift-angle compared to the engaged track. What is meant is unclear to me.		
		MARIN response	Clarified in the report		
39	Argonics	Section	4.4.3	Response accepted by Marin	No
		Comment	Warning at 20m is not a good idea. If a trackpilot cannot follow a track under nominal conditions, there should be a warning. Trying to predict if the offset will be 20m or more or less seems random.		
		MARIN response	From the perspective of skippers on other vessels, we consider 20 meters as the absolute maximum.		
40	Argonics	Section	4.4.3	Response accepted by Marin	No
		Comment	15 min too long. Tactical navigation concerns the next minutes. 1.600m in advance seems reasonable.		
		MARIN response	We really want to have the skipper attended to the navigation tasks well in advance of approaching the end of track, because, for instance, traffic can become challenging in a very short time or vessel and crew need to be prepared for the next stage in the voyage. Besides that, " distance" is not a practical measure, since it is dependent on the speed over ground of the vessel.		

41	Argonics	Section	4.4.3	Response accepted by Marin	No
		Comment	"Predicted offset to track" is not a good measure. Either a track is navigable or not. See above.		
		MARIN response	Seen from the perspective of skippers on board other vessels, we consider this as a relevant measure to safety.		
42	Argonics	Section	4.4.3	Response accepted by Marin	Partly
		Comment	Limits for engaging the trackpilot are random and unnecessary. Just state: Predictable behavior when switching on is mandatory.		
		MARIN response	Since stakeholders are inconsistent in their understanding of what “predictable behavior” is, we deem it necessary to specify the limits. To be more consistent with other Best Practices, we changed the maximum distance to track from 30 meters to 20 meters (see also MARIN response in Comment 39).		
43	Argonics	Section	4.4.3	Response accepted by Marin	Yes
		Comment	Education: Term autopilot used instead of trackpilot on page 29 and page 20.		
		MARIN response	Clarified in the report		
44	Argonics	Section	4.3.1	Response accepted by Marin	No
		Comment	"The manufacturer provides input ..." The trained installation company will pick compatible hardware.		
		MARIN response	We consider, as a Best Practice, the identification of compatible hardware a responsibility of the manufacturer.		
45	Argonics	Section	-	Response accepted by Marin	Yes
		Comment	Route and track are used interchangeably. Autopilot and trackpilot are sometimes used interchangeably.		
		MARIN response	Clarified in the report		
46	Argonics	Section	-	Response accepted by Marin	Yes
		Comment	Visualization is discussed within the voluntary TGAIN group under the umbrella of the Inland ECDIS expert group.		
		MARIN response	Added to Chapter 5 in the report as a general remark		
47	Argonics	Section	4.4.3	Response accepted by Marin	Yes
		Comment	Adaptive Automation: Seems reasonable. However, we believe that this is not the task of a trackpilot system but rather should be practiced by ship owning companies as part of their rules for skippers.		
		MARIN response	we agree with the idea actual implementation of Adaptive Automation is an responsibility of the ship-owner.		
48	Argonics	Section	4.4.3	Response accepted by Marin	No
		Comment	ROT controllers (autopilots) also do not have a standardized interface just like many systems in the automotive industry. It seems enough to require clear buttons to switch between systems and clear symbols indicating which system is controlling the rudder.		
		MARIN response	To minimize risks we argued that, as a best practice, controls must be standardized physical buttons. Either as part of the Autopilot and if not possible or convenient, by added control buttons interfacing with the Autopilot		
49	Argonics	Section	4.4.3	Response accepted by Marin	No
		Comment	Again, voyage planning is not part of a trackpilot.		
		MARIN response	See MARIN response in Comment nr. 36		
50	Argonics	Section	4.4.3	Response accepted by Marin	Yes
		Comment	Manuals in German, Dutch, French and English should be enough. These are the CCNR languages.		
		MARIN response	Added to the report		
51	Argonics	Section	4.4.3	Response accepted by Marin	Partly
		Comment	Watch alarm: 1) Warning after 5 to 15min 2) Alarm after additional 1min 3) General alarm after additional 2min		
		MARIN response	Clarified in the report		
52	Argonics	Section	4.4.3	Response accepted by Marin	Yes
		Comment	Procedures should come from the ship owning companies and not from trackpilot manufacturers.		
		MARIN response	Added to the report		
53	Argonics	Section	4.4.3	Response accepted by Marin	Partly

		Comment	Redundancy is not necessary since trackpilots are not autonomous systems. The skipper can intervene at all times. Merely, it needs to be clear that trackpilots do not interfere with the other functionality of ROT controllers (autopilots). All other marked paragraphs are not applicable for trackpilots for the same reason: The responsibility of the skipper to monitor the system and manually intervene when necessary.		
		MARIN response	We do not classify the Track Pilot-automation in terms or gradations of “autonomy”, but instead as a form of automation in relation to the theoretical framework as mentioned in Chapter 2. In general, the integration of automation results in a higher risk of operators (unintentionally) being out-of-the-loop, also regarding the actual performance of the automation. We therefore consider it necessary to define warnings and alarms in case of malfunctioning and redundancy for those warning and alarm.		
54	Tresco	Section	-	Response accepted by Marin	Partly
		Comment	Some best practices are indeed good intentions but are described “too general”, so that manufacturers are not able to implement this consistently (e.g.: why does TP require hardware redundancy but not the main auto pilot or rudder hardware?). TP is only automation level 1 (AL1): an aid for steering. Some requirements feel already as AL3 automation…		
		MARIN response	See MARINn Response to Comment 53. In addition, other equipment was outside the scope of this research. To clarify that, we added a paragraph “ scope” to chapter 1.		
55	Tresco	Section	-	Response accepted by Marin	Yes
		Comment	Tresco proposes to leave the visualization to the CESNI/TI TGAIN working group		
		MARIN response	See MARIN Response to Comment 46		
56	Tresco	Section	-	Response accepted by Marin	Partly
		Comment	Best practices are defined for end users and manufacturers. It is sometimes not clear for who the practices are intended to.		
		MARIN response	The observation is right. In those cases where it is unclear we leave it to manufacturers if they provide for the best practices or not. We will add that to the report.		
57	Tresco	Section	-	Response accepted by Marin	Yes
		Comment	Spelling/grammar: We have the impression that the text sometimes confuses “auto pilot” with “track pilot” and vice versa. We have the impression that the text sometimes confuses “route” (= route points) with “track” (= track line) and vice versa. Sometimes "to" is used where "too" is meant.		
		MARIN response	Clarified in the report		
58	Tresco	Section	4.4.1	Response accepted by Marin	No
		Comment	The hardware list is not needed at installation time. It is used during the order phase to see what has to be prepared/paid for.		
		MARIN response	The report doesn’t say that the hardware list is needed for installation purposes.		
59	Tresco	Section	4.4.1	Response accepted by Marin	No
		Comment	“performance measures” is too general		
		MARIN response	It is unclear to MARIN why “ performance measures” is too general		
60	Tresco	Section	Page 19, par 3	Response accepted by Marin	Yes
		Comment	A written overview is unnecessary. The profiles are defined and visible in the TP UI.		
		MARIN response	The word “ written” is been removed from the report		
61	Tresco	Section	4.4.1.	Response accepted by Marin	No
		Comment	All requirements are too general and not directly applicable to TPs. E.g. the redundancy for a TP is the auto pilot. The redundancy for the auto pilot is the emergency steering handle. “autopilot” is used instead of “track pilot”? Hardware should be accessible: after all, only certified crew is allowed @ the bridge		
		MARIN response	See MARIN Response to Comment 53		

			The assumption that only certified crew is allowed at the bridge is untrue.		
62	Tresco	Section	4.4.2	Response accepted by Marin	No
		Comment	Tresco agrees that voyage planning (VP) should be an integration with TP. However, other (non ECDIS) manufacturers could see VP merely as an add-on and thus out of scope in this document.		
		MARIN response	See Comment no. 36.		
63	Tresco	Section	4.4.3	Response accepted by Marin	Partly
		Comment	Unaccepted warnings should turn into local alarms after 1 minute. Watch alarm warnings should be repeated every 5 to 15 minutes (randomized or not). And, unaccepted local alarms should become a general vessel alarm after (recommended) 2 minutes. The connection to the general alarm is out of scope for TP. “at the office of the manufacturer”: this is not always possible because of • no internet connection available on board • manufacturer’s data could be cloud hosted		
		MARIN response	The 5 to 10 minutes interval is not really an objective measure, although it seems appropriate in terms of the rate and speed surrounding circumstances can change.		
64	Tresco	Section	4.4.3	Response accepted by Marin	Partly
		Comment	Tresco agrees with the integration with an ECDIS. Bridge integration is after all our main innovation philosophy. The text should make a difference between local path planning (first visible few KMs) and global path planning (up to a few 100 KMs !). Only the local path planning can be inspected adequately by the skipper. Visualization rules should be left with CESNI/TI (see Comment 2) or to the manufacturers USPs.		
		MARIN response	See Comment no. 36 & 55. In addition, it is not for MARIN, manufacturers or any other party to decide which part of the path the skipper must or must not be able to inspect adequately before the voyage commences. He just need the opportunity to do so.		
65	Tresco	Section	4.4.3	Response accepted by Marin	No
		Comment	It should be noted that a TP “start action” is mostly done with a button on the existing auto pilot. This UI is not controllable for TP manufacturers! Engaging dynamics should be left to the manufacturer. (E.g. Tresco TP can engage safely for angles up to 90°)		
		MARIN response	Regarding “ start action” we observed confusing controls and buttons on the existing autopilot User Interface. This can possible lead to safety issues. What we say is that if an auto pilot cannot provide for safe controls, the Track Pilot-automation manufacturer should, in order to arrive at safe implementation of the TP-automation. Regarding engaging dynamics, we stay with the argumentation we described in the report, derived for observations and from different perspectives (skipper, manufacturer, skippers on board other vessels). See Comment no. 42).		
66	Tresco	Section	4.4.3	Response accepted by Marin	Yes
		Comment	Manuals should be available in the German, Dutch, English and French language.		
		MARIN response	See Comment no. 50.		
67	Tresco	Section	4.4.3	Response accepted by Marin	Yes
		Comment	This is intended for Fleet Owners (processes). This is not something that TP manufacturers can/should enforce.		
		MARIN response	Added to the report		
68	Shipping Technology	Section		Response accepted by Marin	Yes
		Comment	Throughout the document, the terms autopilot and track pilot are used interchangeably. Sometimes autopilot is mentioned when it should be track pilot and vice versa.		
		MARIN response	Clarified in the report		

69	Shipping Technology	Section		Response accepted by Marin	N/A
		Comment	The document still contains many typos. Advice is to go through the document again critically.		
		MARIN response			
70	Shipping Technology	Section	1	Response accepted by Marin	No
		Comment	The document states that the skipper has the supervision over the navigation tasks, this not only he is responsible for these tasks.		
		MARIN response	Report is clear on this matter		
71	Shipping Technology	Section	1.1	Response accepted by Marin	No
		Comment	The document states 'A Track Pilot-automation allows, instead of sitting, to walk around in the wheelhouse'. Without a track pilot this is also already possible with the auto pilot.		
		MARIN response	The report says: " walk around more often"		
72	Shipping Technology	Section	1.1	Response accepted by Marin	Yes
		Comment	18 hours sailing per day is not allowed for a skipper. The maximum is 14 hours.		
		MARIN response	Added to the report		
73	Shipping Technology	Section	1.1.4	Response accepted by Marin	Yes
		Comment	The document mentions 'collision avoidance detection'. This is not correct. Some manufacturers, including Shipping Technology, offer a collision detection application. Collision avoidance is not allowed under current draft legislation.		
		MARIN response	Added to the report		
74	Shipping Technology	Section	1.2	Response accepted by Marin	Yes
		Comment	either' should be 'both' we think. Or just drop the word.		
		MARIN response	Corrected in the report		
75	Shipping Technology	Section	2	Response accepted by Marin	No
		Comment	The document states: The human is seen as an essential element in the system. More than that, the human (captain) is still responsible for safe navigation.		
		MARIN response	Within the theoretical framework, " essential element" is strong enough wording.		
76	Shipping Technology	Section	4.2.1	Response accepted by Marin	No
		Comment	The document states: navigating safely during a voyage from place of departure to a preset destination. We are talking about a level 1 automation system here. The purpose of current track pilots is to allow the ship to travel on the 'stretch' over a track without maneuvering in ports and locks.		
		MARIN response	This section refers to the overall goal to which the Track Pilot automation contributes		
77	Shipping Technology	Section	4.2.3, Figure 4-1	Response accepted by Marin	No
		Comment	The Track pilot voyage planning as shown is not the same for every track pilot. Shipping Technology's track pilot does not require all this to be done by the skipper. The track is generated automatically based on vessel configuration, water levels, draught and historical tracks etc. Characteristics such as current, controller gain etc. are set by the system itself. This approach minimizes human error in configuration. Also distinguish route planning more emphatically from navigation planning.		
		MARIN response	Figure 4-1 is the result of the Cognitive Task Performance and not addressing functioning of Track-Pilot automation itself. Besides that, although we recognize that Track pilot-automation can be beneficial to Human Performance, automation can be a source of Human Error as well, which is shown by theoretical framework and a core element of this research.		
78	Shipping Technology	Section	4.3.1-8	Response accepted by Marin	Yes
		Comment	Please add "or generated". The Shipping Technology track pilot generates a track each time the skipper activates the system. There is no possibility to select a track. It can be validated while activated though.		
		MARIN response	Added to the report		
79	Shipping Technology	Section	4.3.1-10	Response accepted by Marin	No
		Comment	Even with a track pilot, the skipper will still plan the route himself. Prior to a trip, the skipper will determine which waterways he wants to use, whether he can pass under bridges if applicable and whether he can get to his destination with his current draught etc.		

			The track pilot is activated only after the route has been planned and the vessel has been deemed to have departed. The skipper will then check whether the track generated by the track pilot matches his reserve preparation.		
		MARIN response	All sub-tasks that are relevant for voyage planning must be performed before the vessel departs.		
80	Shipping Technology	Section	4.3.1-13	Response accepted by Marin	No
		Comment	We think there should be a separation here in terms of the level of checking. Control of the overall route will only be in terms of waterways that will be navigated. The actual checking of the position of the track on the fairway will be done while sailing, due to constantly changing conditions Here, about 2 km ahead will be checked. As a more general remark, the document should be more clear in a distinction between a route and a track. The terms are used interchangeably, it seems.		
		MARIN response	This paragraph is addressing " voyage planning" exclusively, already separating it from monitoring tasks during sailing.		
81	Shipping Technology	Section	4.3.1-19	Response accepted by Marin	No
		Comment	We believe that there is no difference with the situation when a captain is in the seat and sailing on auto pilot.		
		MARIN response	Observations and Interviews with skippers show the opposite		
82	Shipping Technology	Section	4.3.1-30	Response accepted by Marin	No
		Comment	Most feeling with the ship is needed during maneuvering and is 'developed' even then. Then we are no longer talking about a developed Track Pilot		
		MARIN response	Unclear to MARIN what should be changed in the report.		
83	Shipping Technology	Section	4.4.1.	Response accepted by Marin	No
		Comment	Compatible hardware accessible on board: We see no added value in having such a list available on board. In our view, this is unnecessary because the crew/owner will never look at it. It is up to the TP manufacturer and/or installer to determine whether the equipment installed on board is compatible with the TP. So this list should be available to the manufacturer and installer.		
		MARIN response	The list should also be available to the ship-owner, for the purpose of selecting and buying new or replacement equipment. Or for installers that check or validate deliver equipment before installation		
84	Shipping Technology	Section	4.4.1	Response accepted by Marin	N/A
		Comment	It is observed that the calibration process is done differently among various manufacturers. This is true because the systems are different from each other.		
		MARIN response	-		
85	Shipping Technology	Section	4.4.1	Response accepted by Marin	No
		Comment	Performance parameters: We don't quite see how and also don't quite see the point of this. If a track pilot is performing poorly the owner/skipper will buy another one.		
		MARIN response	This Comment is referring to the table "Inadequate installation on board". " Performance parameters" are not a subject in this section.		
86	Shipping Technology	Section	4.4.1	Response accepted by Marin	No
		Comment	Analyses different set-up's: How? This is worded very broadly. We believe that a ship that encounters different conditions than its specific normal operations but what is normal for other ships should be sailing safely on a TP in those conditions.		
		MARIN response	We have observed underperformance of Track Pilot-automation due to different vessel configuration than assumed by manufacturer, causing distraction and frustration with the skipper in order to " solve" the problem, with increasing risks as a result. The Best Practice here has the objective to be preventive on this matter.		
87	Shipping Technology	Section	4.4.1	Response accepted by Marin	No
		Comment	Calibrated and tuned for different set-ups: In our view, this is not realistic. You cannot pre-test a system for all the situations that can occur. The TP is currently still a tool for the skipper. If he observes that the system is not working properly, he should switch it off. The system should be safe under normal conditions and the skipper must know what the limitations of the system are, this can be written down in the manual. That said, Shipping Technology's track pilot does not have different settings for after activation and/or		

			settings are not adjustable by the helmsman during activation. The models adjust themselves automatically to the circumstances during navigation. Also, to reduce the chance of human machine error.		
		MARIN response	The process of calibrating/tuning described for Shipping Technology is not deviating from the Best Practice, as long as the skipper or ship-owner are aware of what the limitations are and when they occur, and accepting them. This awareness the skipper needs, is a responsibility of the manufacturer.		
88	Shipping Technology	Section	4.4.1	Response accepted by Marin	Partly
		Comment	Redundancy: We are looking at a Level 1 auxiliary system here. A ship with one main engine also has no redundancy, the same goes for the installed pilot. There is only one of these on board as well. In our view, it is good to stick to the basics here: that is, the system must have a system that generates an alarm if any parts of the system fail. As far as redundancy goes: Redundancy of the track pilot is the auto pilot and redundancy of the auto pilot is the emergency steering gear.		
		MARIN response	We do not classify the Track Pilot-automation in terms or gradations of “autonomy”, but instead as a form of automation in relation to the theoretical framework as mentioned in Chapter 2. In general, the integration of automation results in a higher risk of operators (unintentionally) being out-of-the-loop, also regarding the actual performance of the automation. We therefore consider it necessary to define warnings and alarms in case of malfunctioning and redundancy for those warning and alarm. In addition, other equipment was outside the scope of this research. To clarify that, we added a paragraph “ scope” to chapter 1.		
89	Shipping Technology	Section	4.4.1	Response accepted by Marin	Yes
		Comment	Failure handling: What is meant by a fail-safe mechanism and a safe-state? In our opinion there should be a good system in place that generates alarms of warnings when necessary.		
		MARIN response	See Comment nr. 88		
90	Shipping Technology	Section	4.4.1	Response accepted by Marin	No
		Comment	Durability: In our opinion this is overkill for a level 1 steering assistance system. If the equipment breaks down too often, the owner will decide to buy a system from another manufacturer.		
		MARIN response	We have observed unsafe navigation during an extensive period of underperformance of the Track Pilot-automation, before a skipper deciding to stop using certain equipment. New systems are expensive which also influences the period of time skippers accepting struggles (and thus higher risks of unsafe navigation)		
91	Shipping Technology	Section	4.4.1	Response accepted by Marin	Yes
		Comment	Compatibility: We think it is meant track pilot instead of auto pilot.		
		MARIN response	Corrected in the report		
92	Shipping Technology	Section	4.4.1	Response accepted by Marin	No
		Comment	Security: You can screw open any pilot and radar. Why do we have to have a bomb-proof enclosure?		
		MARIN response	Other equipment was outside the scope of this research. To clarify that, we added a paragraph “ scope” to chapter 1.		
93	Shipping Technology	Section	4.4.1	Response accepted by Marin	Yes
		Comment	Accuracy: We think you mean track pilot instead of auto pilot here.		
		MARIN response	Corrected in the report		
94	Shipping Technology	Section	4.4.1	Response accepted by Marin	No
		Comment	Cybersecurity: We think this is overkill. As stated, several times, this is a level 1 steering assist. The skipper is responsible if something goes wrong and can take over immediately at any time. Of course, we do everything we can to meet reasonable standards but such tests seem unnecessary to us at this level of automation.		
		MARIN response	In general, the integration of automation results in a higher risk of operators (unintentionally) being out-of-the-loop, also regarding the actual performance of the automation. We therefore consider it necessary to define measures against malfunctioning or otherwise inaccurate performance.		

95	Shipping Technology	Section	4.4.2	Response accepted by Marin	No
		Comment	Voyage preparation: Voyage planning is done before each journey but also during the journey. Skippers also replan their voyage during the trip due to other ships or changed circumstances. During sailing it is sufficient to monitor/assess the track max. 3 km ahead.		
		MARIN response	See Comment no. 36		
96	Shipping Technology	Section	4.4.2	Response accepted by Marin	No
		Comment	Change/save and store route: This, we think, is not the right course of action. A ship has a certain destination it has to go to. The skipper loads a route for this or lets the system generate a route. Before departure, the skipper validates whether this is the right route: including which fairway is taken, whether he can pass under bridges and whether he can reach the destination with that depth. During the journey to the destination, anything can happen, the water level may change or tide, there may be a ship on its route or, for example, there may be work on a bridge. These are things the skipper has to keep an eye on during the trip and, if necessary, anticipate. This is not something a system, level 1, can do. Adjusting the outline while underway and storing it is not desirable, we think, because the situation could be completely different the next time you sail. In addition, a sailed route or route changed by a user is almost always sub-optimal in comparison to an aggregated route, despite what skippers will say. For example, it will not be as 'smooth'. Or parts where the sailed route was overtaking should be neglected. Changing the route, setting or sailing it yourself is less optimal than the imperfect aggregated routes.		
		MARIN response	“ Change/save and store route” is not an element in section 4.4.2. It is in section 4.4.3 (Inadequate controls). Interviews and observations revealed this as Best Practices for safe operation, leaving it up to the skipper if it is worth to save/store. More specific, based on interviews, observations and the Performance and Risk analysis, we disagree with the assumption that “ a sailed route or route changed by a user is almost always sub-optimal in comparison to an aggregated route, despite what skippers will say”.		
97	Shipping Technology	Section	4.4.2	Response accepted by Marin	No
		Comment	We can provide information based on which the route was generated such as water level and draught. For the configuration of the convoy, we depend on the skipper's information. We can unlock this from the AIS but even then, we depend on the correct input by the skipper. It is impossible to create a watertight automatic system for this; we are and remain dependent on the information provided by the skipper.		
		MARIN response	The methodology described is not deviating from the Best Practice. It is important that the skipper is able to check system-mode and settings. In this case it indeed means he needs to check his own input.		
98	Shipping Technology	Section	4.4.3	Response accepted by Marin	No
		Comment	We would opt for a fixed time, we do not see the advantages of a random time between 5 and 10 minutes. Our suggestion would be: Visual warning between 5 and 15 minutes, after 2 minutes alarm sounds, 1 minute later if the alarm is not accepted the general alarm sounds. In addition, we would also suggest to do this with other alarms such as end of track and locks.		
		MARIN response	The 5 to 10 minutes interval is not really an objective measure, although it seems appropriate in terms of the rate and speed surrounding circumstances can change. In terms of Best Practices, Randomizing this interval is a better measure to discourage a skipper in leaving the wheelhouse.		
99		Section	4.4.3	Response accepted by Marin	No

	Shipping Technology	Comment	Ecdis display as the centralized display: We do strongly not agree with this. A lot is already shown on the ECDIS with which there is a high risk of information overload. The ECDIS should visualize a few basic things such as track pilot on or off and, for example, the status: warning/alarm etc. In our view, there should also be a separate display/interface on which additional information can be shown to the skipper. The ECDIS is an information source, the basic navigational equipment on which a skipper actually sails, monitors and determines and corrects the correct position on are other things such as for example; radar, echo sounders etc. We are also of the opinion that especially at this early stage of automation in inland navigation a separate interface promotes clarity, user-friendliness and safety. Secure integration follows at a much later stage.		
		MARIN response	For navigation purposes, we consider the ECDIS as the appropriate centralized display on which all *critical information* should be presented. As described in the report, preventing critical information to be spread among all kind of different displays (making it more difficult to find and assess this information), is a strong lesson learned from aviation in decades of accident investigation and research. The report clearly defines what information is critical and what information is not.		
100	Shipping Technology	Section	4.4.3	Response accepted by Marin	Yes
		Comment	Indication engaged, tracks etc. Several regulatory/best-practice projects for track pilots are currently underway. These projects are independent of each other and so all different suggestions are emerging from these. Within CESNI, there is currently a project on the visualization of tracks and other issues. We suggest the MARIN join this in its best practices so that there is more line in the regulations/suggestions.		
		MARIN response	See Comment nr. 46		
101	Shipping Technology	Section	4.4.3	Response accepted by Marin	No
		Comment	Warnings in ECDIS. We wonder whether the ECDIS is the suitable medium to visualize all this. A lot of information has already been visualized in the ECDIS and if more information is added, this can lead to undesirable situations. We prefer, for example, to indicate a status of warning (yellow or orange) and alarm (red) on the ECDIS. The information about the warning and/or alarm is displayed on the TP interface. The TP also generates an alarm if necessary.		
		MARIN response	See Comment nr. 99		
102	Shipping Technology	Section	4.4.3	Response accepted by Marin	No
		Comment	Offset: In some cases, 10 meters is too little and in other cases too much. For example, on a narrow canal 10 meters is too much.		
		MARIN response	Although the comment is right, we defined this Best Practice from the perspective of skippers on board other vessels.		
103	Shipping Technology	Section		Response accepted by Marin	No
		Comment	Track pilot information over other information: For example, why shouldn't additional information be visualized in, say, a conning system?		
		MARIN response	It is not for a Track Pilot-manufacturer to decide what is critical information and what not and where any skipper or operator wants it to be presented. Presenting information in overlay over other information can therefore unexpectedly lead to unsafe performance and must therefore be avoided. We have observed this occurring during our research.		
104	Shipping Technology	Section		Response accepted by Marin	No
		Comment	Control: Switching on and off should be simple and clear. How this happens must remain the freedom of the manufacturer, just look at an Alphatron pilot and a Radio Zeeland pilot, they are not the same either. The same applies to various controls in an Audi and a Mercedes. What must be the same is that the skipper takes over control in an emergency. When he grabs the lever he should regain control, in manual mode.		
		MARIN response	Regarding " start action" we observed confusing controls and buttons on the existing autopilot User Interface. This can possible lead to safety issues. What we say is that if, as a Best Practice, an auto pilot cannot provide for safe and standardized controls, the		

			Track Pilot-automation manufacturer should, in order to arrive at safe implementation of the Track Pilot-automation.		
105	Shipping Technology	Section		Response accepted by Marin	No
		Comment	Ability to engage and disengage: These boundaries are a bit arbitrary. Is a product of the way a TP works how the system sails towards the line. The TP should always sail to the line in a safe and controlled manner.		
		MARIN response	Since stakeholders are inconsistent in their understanding of what "Safe and controlled manner" is, we deem it necessary to specify the limits. To be more consistent with other Best Practices, we changed the maximum distance to track from 30 meters to 20 meters (see also MARIN response in Comment 39).		
106	Shipping Technology	Section		Response accepted by Marin	No
		Comment	Suboptimal routes: All routes are sub-optimal, especially if you ask multiple captains. Routes should be safe for normal other traffic under each circumstance and fixed objects. Allowing users to change routes will lead to more unsafe situations in our opinion. Track shifting is in our opinion a good solution but giving captains the option to change a small part of the route is not. Also storing of changes is completely unnecessary. The chance that the situation will be the same again is nil.		
		MARIN response	See comment nr. 96		
107	Shipping Technology	Section	-	Response accepted by Marin	Partly
		Comment	GPS data compromise: This will always happen under bridges and in places where there is insufficient reception. The TP manufacturer should find a solution to this and alert if the situation is unsafe. In this case the perception of the position of the ship will jump and not the track		
		MARIN response	Text corrected regarding "perception of the position". No other corrections to the text added, since this section is dealing with training and education, enhancing users understanding of the limitations and risks of the Track Pilot-automation.		
108	Shipping Technology	Section	-	Response accepted by Marin	Yes
		Comment	Languages: Englisch, German, French and Dutch should be sufficient. These are the official languages for the CCNR.		
		MARIN response	See comment nr. 50		
109	Shipping Technology	Section	-	Response accepted by Marin	Yes
		Comment	Familiarization procedures: This is a responsibility of the ship owner and not the manufacturer		
		MARIN response	Clarified in the report		
110	Shipping Technology	Section	4.4.3	Response accepted by Marin	Partly
		Comment	For a level 1 steering assistant this is overkill. The Skipper will still sail himself very frequently. We also think this is the responsibility of the ship owner.		
		MARIN response	The research revealed that this a major concern to the industry. We agree that this is a responsibility of the ship-owner, as long as only Track Pilot-automation is concerned.		
111	OCIMF	Section	-	Response accepted by Marin	No
		Comment	Recommendations defined by CESNI/CCNR seem to be missing. We would like to see them added to the report.		
		MARIN response	Although part of the Literature Review, for this research we choose not to integrate these recommendations in our report. We have been using a different theoretical framework to stay as objective and independent as possible.		
112	Platform Zero Incidents	Section	1.1.1	Response accepted by Marin	No
		Comment	The track pilot is not gaining a lower workload with the current systems. The skipper's sailing hours and responsibilities stay the same, only his task changes more from steering to controlling.		
		MARIN response	The concept of Workload is broader than only sailing hours and responsibilities, as explained in appendix I		
113	Platform Zero Incidents	Section	1.1.1	Response accepted by Marin	Partly
		Comment	No added value to state that skippers tend to sail 18 hrs on a row. (these are exceptions) *(noted by different commentators)*		

		MARIN response	In relation to the concept of workload, we consider this a relevant remark in the report. To be more factual, we changed “18 hours” to “14 hours”		
114	Platform Zero Incidents	Section	1.2	Response accepted by Marin	N/A
		Comment	I think there are already criteria of use of the track pilot in the market. E.g. Manuals, BPG of PZI, Minimum requirements for the operation and technical design of track guidance assistants for inland navigation (TGAIN) Communication from the CCNR		
		MARIN response	This is true. We have observed these criteria in our literature review		
115	Platform Zero Incidents	Section	1.2	Response accepted by Marin	Yes
		Comment	The risk of loss of knowledge how to sail a barge without track pilot if this systems became a standard. It makes sense to require a minimum classical sailing time or the permanent availability of support e. g. by remote systems.		
		MARIN response	Already addressed in the report in section 4.4.3, “ Adaptive Automation”.		
116	Platform Zero Incidents	Section	3.1	Response accepted by Marin	No
		Comment	They refer to study of 2022. That seems young, however the technical development of the systems increased in 2023		
		MARIN response	Not clear to MARIN what should be changed in the report		
117	Platform Zero Incidents	Section	3.1	Response accepted by Marin	No
		Comment	I miss a list of the literature used for the research		
		MARIN response	A reference-list is part of the report (after Chapter 5, see “Contents”		
118	Platform Zero Incidents	Section	3.1	Response accepted by Marin	No
		Comment	How the helmsmen was involved? What areas where part of the research? Do the system was tested within different water levels and weather conditions?		
		MARIN response	The report is stating the Research Method very clearly. In addition, we did not “test” the various systems, but instead observe the interacting with the skipper/helmsman during navigation.		
119	Platform Zero Incidents	Section	4.2.2	Response accepted by Marin	No
		Comment	Human behavior makes it critical. Also, as trust is built in the system, the reaction time during malfunction might take to long. *(2 commentators)*		
		MARIN response	Not clear to MARIN what should be changed in the report because the comment is already reflected in the report.		
120	Platform Zero Incidents	Section	4.3.1	Response accepted by Marin	No
		Comment	That is only partly true. For example it is possible to connect the track pilot with the ecdis system and skipper could verify the root and risks. By a combination with Covadem charts he have a better view on the water levels.		
		MARIN response	Not clear for MARIN what should be changed in the report. As mentioned in section 4.3.3. The Best Practice is actually an interface with the ECDIS.		
121	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	No
		Comment	How will the alarm work in reality? It might become a source of distraction/annoyance.		
		MARIN response	As mentioned, every input to the ECDIS or Track-Pilot Automation should reset the timer, preventing it to be a distraction/annoyance		
122	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	No
		Comment	“Mandatory Watch Alarm” is a useless gimmick, suggesting that it would improve safety. The helmsman must be alert at all times. The routine to press a button to silence the watch alarm will not improve safety. I have demonstrated this to Marin on board. At a certain moment the Marin person silenced the alarm, without agreement of the helmsman and without checking the environment and position of the ship on the waterway. That is exactly what will happen in practice. Discipline in the wheelhouse is behavior that is part of discipline on board and cannot not be substituted effectively by a watch alarm. If the discipline is not there and people’s behavior is not to be alert, the watch alarm will not contribute to safety. For that reason the optional watch alarm is silenced on most ships. A watch alarm only contributes to getting used to alarms and not taking alarms seriously anymore		

		MARIN response	In general, the integration of automation results in a higher risk of operators (unintentionally) being out-of-the-loop, also regarding the actual performance of the automation. We therefore consider it necessary to define a mandatory watch alarm as an appropriate matter. In addition, if the skipper or helmsman is disciplined, he should be able to prevent the alarm, or even the (only visual) first stage warning from being activated without it being a threat to safety. In the end, a mandatory watch alarm is explicitly aiming at the unintentional distraction caused by the integration of automation, which can happen also to disciplined professionals. MARIN personnel silencing the alarm without agreement of the helmsman is a inappropriate action for which MARIN has to apologize.		
123	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	No
		Comment	. 1. The objective is that the helmsman stays alert and focused during his activities. A watch alarm is a mean to achieve this, but it is doubtful if this is an effective measure. Deeper investigation in how to achieve the mentioned objective effectively is therefore necessary. 2. We have to start thinking about automated emergency processes. Using a track pilot or not, what is the best way to handle if multiple alarms are ignored by the crew? Extrapolating this question to fully automated barges, it is needed to address this issue at a certain moment.		
		MARIN response	For the first observation, see comment no. 122. MARIN agrees with the second observation, but since this is outside the scope of this research, we will not add a similar comment to the report		
124	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	No
		Comment	A secondary watch alarm in the entire ship, waking up other crew who are trying to relax or sleep, will seriously threaten safety on board. Very bad idea. Join me for a trip on board.		
		MARIN response	If the first two stages of the watch alarm are being ignored, the safety of the vessel is already seriously threatened in a way other people on board should be notified about it.		
125	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	No
		Comment	Presently Track Pilots have a primary and a secondary alarm. The secondary alarm (only in the wheelhouse) will not be ignored due to its intensity and fulfills its purpose that it will not be ignored. Expanding a secondary alarm throughout the ship is a dangerous and bad idea.		
		MARIN response	See comment nr 124		
126	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	No
		Comment	Presently the advanced Track Pilot of Argonics already logs all significant data like alarms, engagements, distance to the track etc. Sometimes I can sail for hours without intervening with the track pilot and whilst being safe and alert. In case of incidents that can be seen. Not having touched the track pilot does not prove a thing about alertness. A VDR with video and sound would prove much more and would be a far more inclusive measure on wheelhouses, covering much more than the track pilot alone		
		MARIN response	MARIN agrees with the fact that a Voyage Data Recorder can provide relevant information for learning purposes, especially when data from the Track Pilot-automation is also included. But since VDR is not a common and mandatory piece of equipment, we have no other option than describe logging and storing of Track Pilot automation data as a Best Practice		
127	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	No
		Comment	The proposed measures make the use of the TrackPilot unattractive and do not affect safety in wheelhouses where people watch TV, are active with Social media, wash their cars whilst on watch or drink alcohol where a Track Pilot is not installed. It is		

			making a very useful safety device something to avoid, which is the reverse of what is intended with the TrackPilot.		
		MARIN response	See Comment No. 122		
128	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	No
		Comment	Before considering a Watch Alarm, I would insist that camera observations should be made over longer periods in wheelhouse with and without TrackPilot, with and without Watch Alarm to determine whether people are more desgtracted with a Track Pilot than without and whether a Watch Alarm contributes to better alertness. **If a Watch Alarm would make sense, it should also be installed on ships without a Track Pilot**		
		MARIN response	See Comment No. 122 and the theoretical framework in the report (Chapter 2) describing why adding any kind of automation *increases* the risk of (unintentional) distraction. Since navigation without Track Pilot-automation was not within the scope of the research, we cannot validate the benefits of a watch alarm on vessels without Track Pilot-automation.		
129	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	No
		Comment	'Best Practices, concept': The alarms for deviation of the track should be flexible: In some waters 2 meters is too much, on other waters 100 meters would not be any problem		
		MARIN response	We have considered this Best Practice from the perception of skippers and helmsman on board other vessels (predictive behavior)		
130	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	N/A
		Comment	`Beste Practices, concept': Most ECDIS related suggestions are mostly already in place, at least on my installation (Argonics with Tresco)		
		MARIN response	This is true since both systems were observed to determine Best Practices, together with systems from Shipping Technology		
131	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	No
		Comment	Education & Training': A manual on board? Reality check: Will not be read		
		MARIN response	Although this might be true (not always, as we have observed), this still can be considered as a Best Practice, also in combination with a mandatory familiarization procedure.		
132	Platform Zero Incidents	Section	-	Response accepted by Marin	No
		Comment	The standard / requirement with regard the position and size of the ECDIS screen in the wheelhouse is failing in this Best Practice. It is, in theory, possible to use a small laptop screen at a location which is not in a direct sight of the steering position. Next to the visibility from the steering position in the wheelhouse is it even possible to show the Ecdis-screen in the accommodation. So the skipper can monitor the vessel from another location than the steering position in the wheelhouse. This risk is failing in the document.		
		MARIN response	Although this observation is relevant to safe navigation, the ECDIS by itself was not within the scope of this research		
133	Platform Zero Incidents	Section	4.4.3	Response accepted by Marin	Yes
		Comment	Operation Manual to be available in Native language. Suggestion: in a language the crewmember understands. (Fe: Dutch, English, French and German) *(Noted by different commentators)*		
		MARIN response	See comment No. 50		

APPENDIX 5 LIST OF ABBREVIATIONS

List of Abbreviations	
TEN	Trans-European Network
TEN-T	Trans-European Transport Network
eTEN	Trans-European telecommunications Network
TEN-E	Trans-European Energy Network
RWS WVL	Rijkswaterstaat Water, Traffic and Environment
SA	Situation Awareness
HASO	Human Automation System Oversight
OOTL	Out-of-the-Loop loss of Situation Awareness
CCNR	Central Commission for the navigation of the Rhine
RCF	Risk Contributing Factors
TP	Track Pilot-automation
TGAIN	Track Pilot-automation
FU	Follow Up control of the rudder(s)
RoT	Rate of Turn
CTA	Cognitive Task Analysis

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