Exploitation roadmap aviation, maritime, rail

Deliverable D5.10 – WP5 – PU

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List of abbreviations and acronyms

BNWAS	Bridge Watch Alarm System
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
Euro NCAP	European New Car Assessment Programme
GoA	Grade of Automation (typically used in the rail domain)
HMI	Human Machine Interaction
OOW	Officer on Watch
SAE	Society of Automotive Engineering
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TRL	Technology Readiness Levels
TTAF	Time to Automation Fitness
TTAU	Time to Automation UnFitness
TTDF	Time to Driver Fitness
TTDU	Time to Driver Unfitness

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Preface

In MEDIATOR, different algorithms and systems have been developed to collect and integrate information from the driving context, the automated system, and the driver state. Based on this information, decisions are made on who is fittest to drive, and what actions are needed to counteract degraded driver states. These solutions are mostly targeting the automotive sector as described in MEDIATOR deliverable 5.9 (Fiorentino et al., 2023). Here, exploitation of the Mediator results is considered for other transport sectors as well. Based on the work on exploitation strategies for other transport domains, this deliverable provides an overview on the strategy and key findings relevant for the aviation, maritime and rail communities. Also, indicative road maps are described.

We would like to thank all involved authors and participants at workshops and in discussions, but also the reviewer Elmer van Grondelle (TU Delft), for valuable comments and inputs.

Anna Anund and the team from VTI.

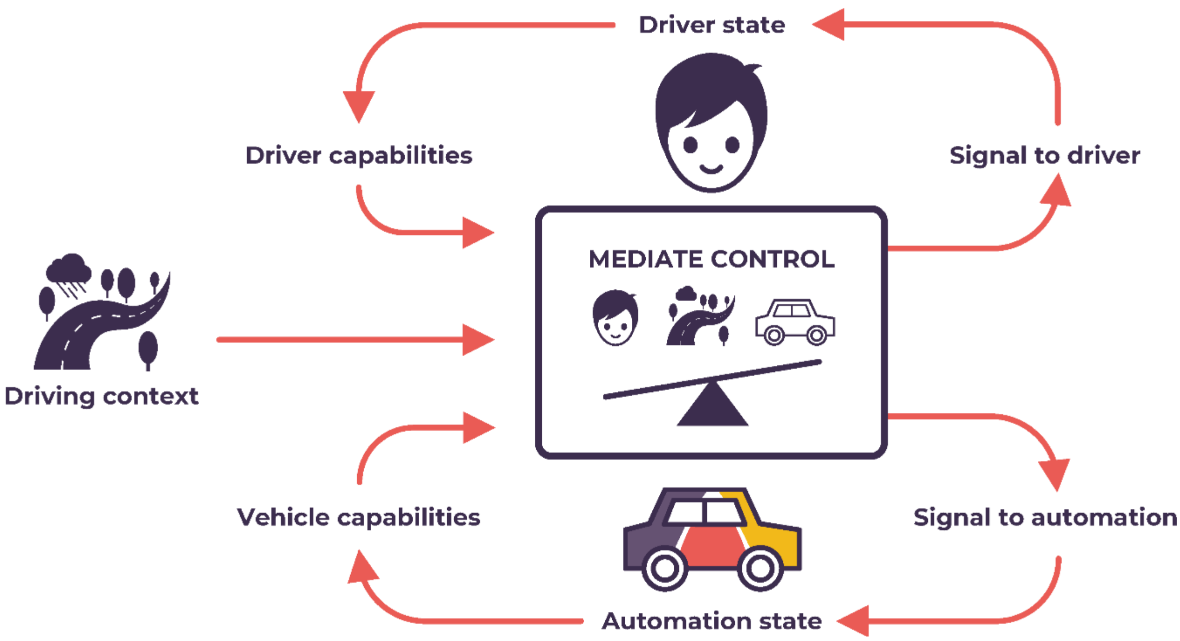
About MEDIATOR

MEDIATOR, a 4-year project coordinated by SWOV Institute for Road Safety Research, has come to an end after four years of hard work. The project has been carried out by a consortium of highly qualified research and industry experts, representing a balanced mix of top universities and research organisations as well as several OEMs and suppliers.

The consortium, supported by an international Industrial Advisory Board and a Scientific Advisory Board, represented all transport modes, maximising input from, and transferring results to aviation, maritime and rail (with mode-specific adaptations).

Vision

Automated transport technology is developing rapidly for all transport modes, with huge safety potential. The transition to full automation, however, brings new risks, such as mode confusion, overreliance, reduced situational awareness and misuse. The driving task changes to a more supervisory role, reducing the task load and potentially leading to degraded human performance. Similarly, the automated system may not (yet) function in all situations.



The Mediator system will constantly weigh driving context, driver state and vehicle automation status, while personalising its technology to the drivers' general competence, characteristics, and preferences.

The MEDIATOR project aimed to develop an in-vehicle system, the Mediator system, that intelligently assesses the strengths and weaknesses of both the driver and the automation and mediates between them, while also taking into account the driving context. It assists the timely take-over between driver and automation and vice versa, based on who is fittest to drive. This Mediator system optimises the safety potential of vehicle automation during the transition to full (level 5) automation. It would reduce risks, such as those caused by driver fatigue or inattention, or on the automation side by imperfect automated driving technology. MEDIATOR has facilitated market exploitation by actively involving the automotive industry during the development process.

To accomplish the development of this support system MEDIATOR integrated and enhanced existing knowledge of human factors and HMI, taking advantage of the expertise in other transport modes (aviation, rail and maritime). It further developed and adapted available technologies for real-time data collection, storage and analysis and incorporated the latest artificial intelligence techniques. MEDIATOR has developed working prototypes, and validated the system in a number of studies, including computer simulation, virtual reality, driving simulator and on-road studies.

With MEDIATOR we further paved the way towards safe and reliable future vehicle automation that takes into account who is most fit to drive: the human or the system.

https://mediatorproject.eu/

Executive summary

The MEDIATOR project is working towards a system that mediates between the automated functions of a vehicle and the driver/operator, ensuring that the automated driving mode balances optimally between driver fitness and automation fitness. The system aims to reduce the risks related to the transition towards full automation, a phase that still relies on the human driver taking over, either in cases where automation does not function as intended or when operating outside the automated system's operational design domain. In the project, different algorithms and systems have been developed to collect and integrate information from the driving context, the automated system, and the driver state. Based on this information, decisions are made on who is fittest to drive, or what actions are needed to counteract degraded driver states. Mediator deliverable D5.9 (Fiorentino et al., 2023) describes how these innovative solutions are best exploited in the automotive sector. Here, exploitation of the Mediator results is considered for the aviation, maritime and rail communities. Based on the work on exploitation strategies for other transport domains, this deliverable provides an overview on the strategy and key findings relevant for the aviation, maritime and rail communities. Finally, indicative road maps are described.

The deliverable includes an overview of the strategy that will describe the foreseen exploitable results that have relevance for these domains and the necessary considerations when applying these results and, if possible, a road map for further exploitation. In this deliverable, the views of experts from the aviation, maritime and railway sector have been gathered by NLR, KOG and VTI, respectively. The road map for other transport sectors has its starting point in the exploitation strategy for other transport domains that was described in the confidential Mediator deliverable D5.5 (Solis-Marcos et al., 2020).

The transfer of knowledge between transport modes regarding automation and safety are constrained by inherent differences between the different modes of transport. The level of automation differs between transportation modes, where maritime and aviation can make use of full automation during a large proportion of the trip. The time window for reaction time in cases of system failure is usually bigger in aviation and maritime, while rail and road have less time. In aviation and maritime there is a team of operators, while on road and rail there is an individual driver. The number of concurrent users on the same road is usually high, while for the other three modes it is low, except in vicinity of a terminal or a port. The quantity and quality of training required for operators differs. Plane, vessel, and train operators are rigorously and continuously trained and evaluated, while car drivers are usually not. In aviation, rail and maritime, the operators are always professionals whose main task is to control the vessel, while car drivers mainly consist of non-professionals. Despite these differences, all transportation modes are still highly dependent on operators' performance, which motivates the use of a MEDIATOR-like system in aviation, rail, and maritime operations. Adapting and implementing the mediation concept to other transport modes would however require major adaptations to most underlying monitoring and decision technologies developed in MEDIATOR.

The workshop held with experts in the respective field the first year concluded that maintaining operator alertness and performance is a challenge in all transport domains as automation levels increase. The experts considered the implementation of a MEDIATOR system as an effective solution to improve the safety and comfort of the operators, allowing them to devote more time to other work-related or not work-related tasks. However, experts also concurred that a main challenge for the implementation of this system is to adapt the monitoring equipment to operators with larger degrees of freedom to move.

A SWOT analysis was conducted for the most prioritized exploitable results identified from the initial workshop. The prioritised MEDIATOR results exploitable in the railway sector in the beginning of the project were: (i) the distraction detection algorithm extended to account for the surrounding driving environment, (ii) the algorithm to predict and output time to automation (un)fitness and, (iii) the countermeasure, including timing, to maintain or improve driver fitness. In line with the benchmarking the experts highlighted the importance of supporting drivers' situational awareness by providing timely information about the time to automation (un)fitness. Interestingly, the experts did not prioritize exploitation results aimed at detecting and predicting driver fatigue, a consistent topic in the literature. Rather, systems preventing distraction were prioritized. For the aviation domain several results were identified as potentially or highly exploitable in the aviation sector. These were clustered into the following groups: (i) Fatigue detection, (ii) Fitness/unfitness assessment and (iii) Human Machine Interface. Fatigue detection and fitness/unfitness assessment were subjected to the same SWOT analysis. Two MEDIATOR results were identified to be considered as priorities for maritime, namely, (i) the distraction detection algorithm extended to account for the surrounding environment and, (ii) the algorithm to predict and output time to automation (un)fitness.

A second workshop was carried out in the end of the project. The topic of the workshop was to discuss how the key findings from MEDIATOR could be of relevance for aviation, rail, and maritime transport. It was concluded that the technologies and designs developed in MEDIATOR would need to be modified and adjusted to fit the specific needs of each transport mode. Adapting the Mediator system for use in other sectors is not straight forward since the operator environment and traffic situation is different and the timing of when the operator needs to be in the loop varies between transport modes. Also, the requirements defining what it means to be attentive and situationally aware are different compared to road. These are all areas that require further research and/or development before the MEDIATOR results can be transferred to other domains.

The high-level roadmaps developed for exploitation of the MEDIATOR results in other transport sectors concluded that the key MEDIATOR concepts were not seen as possible to implement in a short time frame for aviation, maritime, and rail transport. Further developments of technical solutions, adaptations to less static work environments and validation were seen as important next steps.

1. Introduction

The aim of this work is to define a road map for aviation, maritime and rail communities, based on the initial exploitation strategy and the results from the use case evaluation results in MEDIATOR. The targeted exploitation is based on an analysis of market trends, potential user identification, and the financial sustainability. This work is presented in Mediator deliverable D5.9 describing the exploitation roadmap for road transport (Fiorentino et al., 2023).

In the Exploitable strategy all results have also been considered for aviation, maritime and rail. To be able to look at the exploitable results for other transport modes a simplified market analysis including a benchmarking took place. In addition, a first workshop with experts from other domains was organised, to identify the most relevant exploitable results for rail, maritime and the aviation sector. Based on this a SWOT analysis was done. Late in the project the key findings from the results achieved were presented at a second workshop with experts. Based on this, roadmaps for implementing a MEDIATOR system were created for the aviation, maritime and rail domains.

The transfer of knowledge between transport modes regarding automation and safety are constrained by inherent differences between the different modes of transport (Papadimitriou et al., 2020). Such differences must be kept in mind when defining road maps for the aviation, maritime and rail communities based on results from MEDIATOR:

- The time window for reaction time is usually bigger in aviation and maritime, while rail and road have less time.
- In aviation and maritime there is a team of operators, while on road and rail there is an individual driver.
- The number of concurrent users on the same road is usually high, while for the other three modes it is low, except in vicinity of a terminal or a port.
- The dimensions of movement are different.
- The quantity and quality of training required for operators differs. Plane, vessel and train operators are rigorously and continuously trained and evaluated, while car drivers are usually not.
- In aviation, rail and maritime, the operators are always professionals whose main task is to control the vessel. Road mainly consists of non-professionals.

This deliverable covers all parts used to identify the strategy and the road map for MEDIATOR Exploitable results, relevant for also aviation, maritime and rail domain. Its starting point is based on the idea to benefit from the diversity and commonalities in different transport domains. Diversity normally considers age and gender and is not so relevant at this point. This since still most of the professional “drivers” in aviation, maritime and rail sectors are males in the middle-aged. This is important to deal with, but not a main topic for this work.

The outline of the document starts with a description of the background including some basics on human factors aspects in general and a benchmarking of which automation technologies that are available in the aviation, rail, and maritime sectors (Chapter 2). After that, the key findings from the Mediator project are described (Chapter 3). The key findings are used as a starting point for defining exploitable results for other transport sectors. Chapter 4 describes the methods and outcomes of a first workshop and a follow up SWOT analysis done in the beginning of the project, followed by a second workshop carried out in the end of the project, exploring the potential use of the Mediator solutions in other transport domains. Chapter 5 describes the resulting road maps.

2. Background

B.1. Human factors aspects of automation

Automation has the potential to enable levels of performance and safety that would otherwise be impossible to achieve and has been applied in various ways in the transportation industries. For example, nearly all commercial aircrafts are equipped with automatic pilots that, under normal flying conditions, guide an airplane over a predetermined route by detecting changes in the aircraft's orientation and heading. Also, automatic navigation systems that operate by using radio signals from ground beacons or global navigation satellite systems are used in many ships for course directions and guidance. In the railway sector, Automatic Train Operation (ATO) systems are currently available, supporting drivers in tasks like starting/stopping, door operations and handling of emergencies, such as running a red light. Some lines of the Barcelona and Lille subways, or the Port Island Kobe in Japan are examples of trains with a very high Grade of Automation (GoA).

There are different ways to define the capabilities and responsibilities of an automated vehicle. In road transport, the commonly referred to standard J3016 suggests six levels of driver assistance technology (SAE, 2021). To understand their structure, it is important to know that automated vehicles are assumed to operate only in a pre-defined situation/environment. This environment is called the systems' Operational Design Domain. Level 0 equals unassisted manual driving. Levels 1–2 are assisted driving where the human driver still is responsible. Levels 3 – 4 represents piloted driving where the automated system is responsible within a specific domain and a human driver is responsible for all driving outside this domain. Level 5 is robot taxi; no driver involvement is needed at any point. MEDIATOR addresses automation on SAE levels 0 – 4, using the terminology defined in Table 1. A key point within MEDIATOR has been to adopt a user perspective on automation. Where SAE automation levels align with technical possibilities of automation, MEDIATOR automation levels are based on the driver's responsibilities and affordances. To illustrate, whereas SAE level 4 represents a level of automation that allows a driver to be out of the loop and that also ensures safe handling of situations where the automation cannot adequately perform the driving task, it does not consider how long one can be out of the loop. In MEDIATOR, the Time-to-Sleep mode is defined from a user perspective: it considers whether the driver can stay out of the loop for a short while or for a long time.

Table 1: Automation levels addressed in MEDIATOR (OEDR: Object and Event Detection and Response)

	driver supported			automated driving		
SAE	0	1	2	3	4	5
Automation responsibilities	warnings and momentary assistance	lateral or longitudinal support	lateral and longitudinal support	automated functions drive the vehicle within the defined operational design domain		automated driving under all conditions
Human responsibilities	driver must constantly supervise			driver is not required to drive, but must take over upon request		driver is a passenger
Euro NCAP		Assisted (shared control)		Automated (vehicle in control)		Autonomous
Automation responsibilities		OEDR and other supportive tasks		OEDR and driving. Vehicle has full responsibility		full control
Human responsibilities		OEDR and driving. Driver is fully responsible. No safe transfers		Driver can do non-driving related tasks, but must take over upon request		driver is a passenger
Mediator		Continuous mediation		Driver standby	Time-to-Sleep	
		drivers supported by automation but are responsible and must monitor surroundings and automation.		Driver must take back control upon	driver must take back control upon	

			request (order of seconds)	request (order of minutes)	
HMI	Manual	Assisted	Piloted		
	non-automated, driver is in full control	drivers are not fully disengaged and must maintain certain responsibilities. This can be steered towards a monitoring task.	Drivers monitor while automation performs driving tasks		

Usually, automation does not remove the operator from the system, but rather changes their role by relieving them from specific tasks and sometimes introducing new ones. Often, these changes may also be accompanied by other unforeseen, or even undesirable, effects on operators' behaviour and state. Consequently, operators may perform poorly when their intervention is required in safety-critical situations, e.g., sudden obstacles or system failures. Therefore, it is essential to highlight the importance to find a balance between automation and the human factor, by anticipating potential problems that arise when placing operators in passive supervisory and/or fall-back roles (Bainbridge, 1983)

In the automotive sector, automation and computerization will transform vehicles, but operators still need to remain in the loop to monitor the situation (i.e., by directly looking at the road or by checking the information presented via the HMIs), and/or to occasionally regain control when the system or the situation requires it. Disengaging drivers from the physical and cognitive control tasks has, however, the potential of turning the driving task into a monotonous and under-stimulating activity, leading to symptoms like boredom, discomfort, task disengagement and lower vigilance levels, which may also arise during the interaction with this technology (Körber, Cingel, Zimmermann, & Bengler, 2015; D.J. Saxby et al., 2008). In the literature, this task-related fatigue is called **passive fatigue**, as opposed to the **active fatigue** generated in highly complex and stimulating conditions (May & Baldwin, 2009). On-road and simulator studies in automated driving have shown that after only 20-30 minutes of driving, drivers' arousal level (Heikoop, De Winter, van Arem, & Stanton, 2018) and task engagement (Saxby et al., 2008) were reduced. Later studies have shown that under such hypo-vigilant states, drivers' ability to detect and react to unexpected events is diminished with real implications for safety (Greenlee, DeLucia, & Newton, 2018; Victor et al., 2018). In a flight simulator study, Dehais et al., (2019) observed that after prolonged periods in a flying task, pilots presented reduced neural processing of auditory signals reflected in a greater number of misses. Similarly, task-related fatigue effects have been reported in train drivers after operating in prolonged and monotonous conditions (Dorrian, Roach, Fletcher, & Dawson, 2007; Dunn & Williamson, 2012).

Another type of fatigue is sleep-related fatigue (May & Baldwin, 2009). Sleep-related fatigue is mostly influenced by circadian rhythm effects (i.e., the time of the day) and sleep pressure (i.e., prior wake duration and sleep history). Currently, the effects of automated driving on **sleep-related fatigue** development, and vice versa, remains poorly investigated. Studies in automated driving indicate that just sitting in an automated car without performing any other tasks, speeds up the development of drowsiness symptoms (Schömig, Hargutt, Neukum, Petermann-Stock, & Othersen, 2015; Vogelpohl, Kühn, Hummel, & Vollrath, 2019). Sleep-related fatigue is also a well-reported problem in other transportation modes. In railways, drivers are shift workers who often complain of insufficient or disrupted sleep patterns (Filtness & Naweed, 2017). In maritime, seafarers face 24/7 operations, long and irregular work hours and disturbed sleep (Andrei, Griffin, Grech, & Neal, 2020). And in aviation, long distance flights across multiple time zones add on the problems with sleep-related fatigue (Bendak & Rashid, 2020).

While some authors often loosely refer to the term "fatigue", even if different types of fatigue are characterized by the same indicators, it remains a fact that task-related active and passive fatigue, and sleep-related fatigue, reflect different psychophysiological phenomena and therefore require different strategies to be counteracted (Gimeno, Cerezuela, & Montanes, 2006; May & Baldwin, 2009). Thus, for example, operators with elevated active fatigue should benefit from strategies aimed at reducing their level of demand like handing the control of certain tasks over to the system. On the other hand, operators with passive fatigue may better benefit from “energizing” strategies, such as increasing their engagement level in the operational task or provide them with non-driving related tasks or NDRTs. Studies in automated driving as well as aviation have shown promising results in this respect (Caldwell et al., 2009; Neubauer & Matthews, 2014). Lastly, for drivers affected with sleep-related fatigue, strategies should be aimed at encouraging drivers to stop and take a nap or nap during highly automated driving (i.e., Level 4). This strategy is used extensively in aviation, where cockpit napping and sleeping in bunk beds are common in-flight countermeasures (Bendak & Rashid, 2020). An important prior step before implementing the best countermeasure is to reliably detect the type of fatigue suffered by the operator. This constitutes one of the challenges in the Mediator project where specific algorithms based on facial expressions, glance behaviour and physiological data were developed to distinguish these types of fatigue.

Another challenge for all transportation systems is to ensure that the operator maintains situational awareness. This problem, however, may be exacerbated when operator’s trust in the system exceeds its actual capabilities leading to an overreliance in the system. The overreliance problem in automation has been widely researched in all transportation modes as it can significantly change the way operators interact with systems. On the one hand, operators are more likely to misuse the system, that is, activating the system in contexts that exceed the system boundaries, thus increasing the probability for automation failures and requiring urgent interventions. Also, operators can drastically reduce their supervision of the ongoing situation and the system status and performance and therefore, be ill-prepared to react when a fast intervention is required (Hergeth, Lorenz, Vilimek, & Krems, 2015; Payre, Cestac, & Delhomme, 2016). Lastly, overreliance on the system may increase operators’ proneness to engage with other engaging tasks not related with the system operation, as shown elsewhere (Hergeth et al., 2015). In the automotive sector, higher proneness to engage in other non-driving related tasks have been reported, even under automation levels that requires full monitoring from the drivers (e.g., Banks, Eriksson, O’Donoghue, & Stanton, 2018; Carsten, Lai, Barnard, Jamson, & Merat, 2012; Llaneras, Salinger, & Green, 2013). Solutions to these problems should be aimed at, (i) promoting adequate attentional levels to cope with the ongoing and upcoming demands and, (ii) keeping operators situationally aware of the most relevant information.

For the former, the integration of contextual, automation fitness and operator state information is necessary to determine whether insufficient attention is being devoted to the supervision of the system and, whether specific actions are necessary to draw operator’s attention. As for the second, solutions should require the design of interfaces which combine data into meaningful information about relevant system parameters. Preferably, future states of the system should be anticipated and communicated to the operator through multiple sensory channels in a clear manner. In the rail industry, this is already happening with the migration to the European Rail Traffic Management System (ERTMS), which includes a look-ahead feature to help train drivers to plan ahead. However, by moving information from the trackside (outside the cabin) and onto a display inside the cabin, there is a worry that the drivers will lose situational awareness as they may look more and more at displays in the cockpit.

Independently of the specific source of an operator’s inability to manage the automation properly, every consideration in the field of human factors must reflect the new roles that operators are assuming. Indeed, with increasing levels of automation, drivers, pilots and seafarers will be able to gradually phase-out control over the manoeuvres and transfer it to the automated vehicle/vessel. This trend will soon enable a variety of non-driving tasks that, until now, were simply not part of the driving experience. Moreover, safety-critical issues arise in transfer-of-control scenarios, where the automated system and the human need to effectively communicate their intentions and actions between them. Therefore, new systems should not just manage, but also enhance the interactions between drivers, passengers, crewmembers, vehicles, and surrounding traffic. This perspective will have profound implications in the development of automated systems and vehicles. For professional drivers/operators, there will be possibilities to do other work-related tasks in addition to the primary task transportation task, and for non-professionals, there is a need to consider the vehicle as a living space. In both situations, humans will extensively act out-of-the-loop.

B.2. Benchmarking

To be able to exploit the results from Mediator to other transport modes there is a need to know what already exists. A benchmarking of currently available systems has been conducted along with a multi-modal workshop that took place early in the project. The knowledge gained from these activities is used to match the outcomes of the MEDIATOR project with the needs in aviation, maritime and rail domains.

2.2.1. Rail

As in other transportation modes, rail safety and efficiency are highly dependent on operators' performance, and therefore, susceptible to human factor issues due to poor driver-systems interactions. In support of this, current knowledge indicates that there exist at least two relevant problems which affect driver state and performance, that is, low situational awareness and fatigue (Fan & Smith, 2018; Young & Steel, 2017). To cope with these problems, different technological strategies have been implemented. Provided that low situational awareness and fatigue are also well-known human factor problems in automated driving, such solutions may be considered in this domain.

In the road sector, SAE levels are used to define the level of automation and the responsibility of the driver. In the rail sector the term Grade of Automation (GOA) is used instead. The levels go from 0 to 4 and is on a high level described as follows:

- GoA 0 – Line of Sight Operations.
- GoA 1 – Non-Automated Train Operation.
- GoA 2 – Semi Automated Train Operation.
- GoA 3 – Driverless Train Operation (DTO)
- GoA 4 – Unattended Train Operation (UTO)

There are different arguments for introducing automation into rail operation. One is of course to lower the cost by removing the driver, which occurs in the higher levels of automation (GoA 3 and GoA 4). However, there are also other reasons that occur already in GoA 2, like increased capacity because of a reduced speed variability when the driver is no longer responsible for the speed setting. Since the speed is no longer dependent on different driving styles, train planning can be made more accurate, which means that more trains can be scheduled on the railway.
Another argument is to be more energy efficient where topography, conditions of tracks, weather conditions etc are important optimisation factors. There is however a risk that increased automation causes driver fatigue due to boredom. In large parts of Europe, a system is tried out were the

information about how to drive to increase railway punctuality and energy-efficiency, is sent to the driver, a so-called Driver Advice System. The driver gets advice on how to drive but needs to take the decision him/herself. This system has potential to increase capacity, lower the energy-costs, but still keep the driver alert.

There are just a few main line operations above GoA 1. In the United Kingdom the Thameslink core section through Central London between St. Pancras and Blackfriars became the first route on the National Rail network that used an Automatic Train Operator system in 2018. Here the train driver is still on the train and monitors the system. The driver only acts on failures which makes it a system in the GoA 2 category. Also, GoA 3 systems are rare. This is a solution that requires a train attendance that is on board and can handle train failure, which is more seen as a step toward GoA 4. One existing service operation at GoA 4 is the Rio Tinto Autohaul system, developed by Hitachi Rail STS Railway. The remote driver monitors what happens from a control centre and can, as a fallback, take the control remotely when needed.

In mostly all trains today there is the Dead man's grip solution. This is a system classified into GoA 0 and 1. This system generally requires the driver to continuously push a pedal and/or the handgrip but it might also include a component of randomly needing to confirm that you as a driver are still in the loop. In case the driver does not grip, press or push, as expected by the system, the system will at first warn by sound and visually, and subsequently intervene by bringing the train to a full stop. Today, in GoA 1 operations the train protection system intervenes if the driver falls asleep, drives too fast or approaches a red signal. However, in some situations the train protection system does not intervene, and the driver is fully responsible for the safe operation of the train. This normally happens at low speeds (<40km/h) and examples of this are when the train approaches a stop signal, when shunting, or at various types of train or infrastructure failure (e.g., a signal failure). In such situations the driver needs to be attentive and is not allowed to speak to anyone or use communication equipment such as mobile phone etc. There are also examples of "speak aloud" solutions to support the train driver to be in the loop in these situations. The driver then needs to point at and talk through the decisions taken.

2.2.1.1. Systems to support drivers' situational awareness (SA)

Lacking updated information about the surrounding traffic situation and changes in traffic plans has been a common complaint among train drivers (Tschirner, Andersson, & Sandblad, 2013). Particularly, drivers claim that without this information they cannot adopt strategical decisions to operate the train in a way that improves speed management, punctuality and energy consumption.

To mitigate this problem, different solutions have been developed in the last decade. One example is the European Rail Traffic Management System/European Train Control System (ERTMS/ETCS), a system that ensures the interoperability of trains across borders in Europe and facilitates the continuous communication between the train and the Traffic Control Centre of information regarding positioning, speed and movement authorities. In addition, the ERTMS/ETCS includes a visual interface in the cabin where relevant information is compiled and presented to the driver, thus diminishing the need for collecting information from the wayside. Figure 1 provides an illustration of the main components of the ERTMS/ETCS driver machine interface.

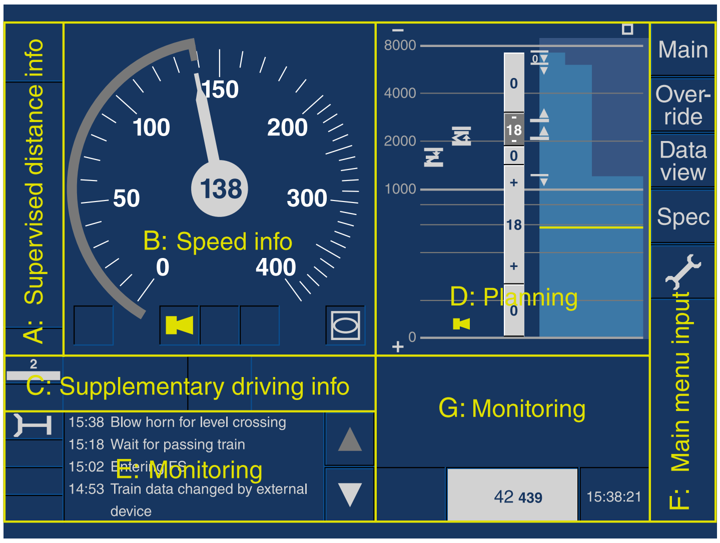


Figure 1: Screenshot of the driver machine interface of ERTMS/ETCS, highlighting the different components of the display.

Improvements in the communication systems have led to the development of a range of different Driver Assistance Systems, some of which are built into the ERTMS/ETCS, aiming to support drivers' SA and train operations. Next, a few examples are presented:

- RouteLint. This system provides information about the track segments ahead that are blocked by another train or set for his/her own train. It also informs about additional delays in the surrounding trains. Drivers may use this information to adapt the train speed to the changing conditions.
- FARE. This system collects real-time plan changes in the traffic control centre and advice drivers to increase, reduce or keep speed by means of simple symbols in the visual display. As opposed to the RouteLint, speed recommendations are already calculated and communicated to the driver.
- CATO. As compared to the previous systems, CATO provides extended information on real-time traffic planning, infrastructure information as well as speed recommendations. It also includes "target points", or points that should be passed in certain time windows.

As in the railway sector, advances in communication systems are also expected in road vehicles, due to the development of advanced vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) systems. Despite the obvious differences between trains and automated vehicles, it is expected that enhancing the information provided to the drivers, will help them improve their capacity to anticipate to upcoming events. In the literature, this is supported by several studies showing a greater drivers' ability to react and control the vehicle upon a take-over request. In the MEDIATOR system, advanced information about upcoming events will be integrated with information related to the automation and the driver state (compare to the planning component in Figure 1). As part of the system, estimations of time to automation unfitness (TTAU) and time to driver fitness (TTDF) will be made and the best action will be implemented (e.g., improve driver state or hand over control).

2.2.1.2. Systems to support driver fatigue in railways

Compared to the automotive sector, there is much less literature on fatigue in rail. The studies that exist have found elevated levels of fatigue among train drivers, mostly associated to effects of the shift work schedules such as sleep deprivation and disrupted sleep patterns. Besides, driver fatigue has also been linked to the monotonous conditions to which train drivers are often exposed (Dunn & Williamson, 2012). Under this state, train drivers tend to show a poorer speed control, commit more speed violations and increase their proneness to distraction (Anderson et al., 2006; Fan et al., 2018; Filtness et al., 2017), which is reflected in a greater probability to miss stop signals (Naweed et al., 2015). In automated driving research, this type of fatigue would correspond to the so-called "passive fatigue" which emerges after prolonged periods of under-stimulating driving conditions with the system activated (Saxby et al., 2015).

Most strategies to counteract this problem have been aimed at adopting work schedules that guarantee drivers' most optimal alertness level during their shifts. However, when it comes to train driver detection systems, state of the art remains very limited. To date, the most extended strategy in the railway sector is to counteract fatigue by a "Deadman's switch", which requires drivers to provide a response either continuously or every certain time. However, this system acts more as a sudden sickness countermeasure and is little informative of how vigilant the driver is or to support more alert train drivers. For example, this task can be performed even under drowsy states (Filtness & Naweed, 2017). So far, fatigue detection/management systems have mainly been explored in research studies. Some of examples include systems based on driving performance metrics (e.g.,Scaccabarozzi et al., 2017), driver physical parameters like eye, mouth and body movements ("Monitoring Engineer Fatigue (MEFA)," 2019) or driver's brain activity (Zhang et al., 2017). There are also tendencies to adapt state of the art fatigue and distraction monitoring systems for use in locomotive applications[1], but the main facilitator stems from previous developments in the automotive sector.

2.2.2. Aviation

In the aviation domain the need for automated flight modes developed rapidly when flight time became longer. Compared to transport on road or rail the point was that an aircraft also needs to be controlled and corrected constantly and that pilots have a really hard time to keep on doing that during long haul flights. On top of that there was the trend to reduce cockpit crew. In the 70s a Boeing 747 was often flown by a crew of five present in the cockpit. With increasing levels of automation this number has now been reduced to two. This does not apply solely to the B747. Basically, all commercial aircrafts are nowadays flown by a crew of two. A comparison that can be made with automation in road traffic is that initially the automation focused on cruise flight (to a certain extend comparable to driving on the motorway). After all, it is a phase during which the speed is high but relatively constant and comparable to the surrounding traffic. And there is a clear set of rules about how the traffic is supposed to behave.

However, increased automation is also focussing on other flight phases and on flying with an even smaller crew. For example, ACROSS (Advanced Cockpit for Reduction Of StreSs and workload)[2] is an EU funded project where the aim was to study how automation might support the situation that one or even two pilots become incapacitated and are no longer able to control the aircraft. A great deal of that project focussed on assessing pilots state continuously and to apply adaptive automation so that a flexible collaboration between human and machine would evolve. The project included scenarios where pilots are so fatigued that they need to take a nap. ACROSS is just one example of this trend.

Commercial aviation is characterised by highly procedural work and aircraft, vehicles, and obstacles are all part of coherent aviation world. A major difference with road is that road traffic is

[1] https://www.progressrail.com/en/innovation/fatigue.html

[2] https://cordis.europa.eu/project/id/314501

every now and then mixed with less professional traffic and road occupants like little children playing on the street. This mixture of a broad range of drivers and road users introduces a number of challenges that are less common in the aviation domain.

Now that higher levels of automation are, increasingly, introduced at airports, and now that aircrafts are also taxiing, controlled by automated systems, some of the challenges that are being tackled in the road domain might become quite interesting for the aviation domain as well.

Fatigued pilots remain, despite all regulation, an issue that needs to be understood better and for which mitigation means are desired. This topic clearly delivers potential for collaboration between both domains. And finally assessing whether a pilot is ready to take full control, for example after a long cruise flight at the top of descent, and when the pilot is not ready to get back into the loop, possibly with adjusted customised modes of interaction between aircraft and pilot, is still very relevant and also applicable to MEDIATOR.

Taken together, there clearly are flight phases including taxiing, where there is potential for aviation to learn more from the road, or at least to exchange experiences.

2.2.3. Maritime

The primary cause of maritime accidents is human error (Dominguez-Péry et al., 2021). The root main causes involve human resources and management (issues in inter ship communication, safety culture, bridge resource management, none-compliance with legislation etc.), socio-technical information systems (misuse of instruments or automation), and individual or cognitive errors (fatigue, stress, insufficient situational awareness, etc.).

While fully autonomous vessels have yet to be realized in the commercial sector, modern bridge systems have subsystems that employ varying degrees of automation (Wright, 2020). These include propulsion control, power distribution and control, bridge watchkeeping, alarm monitoring and damage control. Note that even when aided with high autonomy, seafarers must still interact with these systems to assess their operational status.

It should also be noted that maritime transportation can be very different from automotive and aviation in terms of traffic behaviour, traffic density and legal requirements. Concerning behaviour, large commercial vessels behave differently from planes and automobiles in that they move slowly and have extremely long reaction time. There are similarities with trains, but here, routes are planned hours if not days ahead, course corrections require miles to complete, and full stops can take as long as one hour. In terms of traffic density, maritime traffic is very diverse. One might encounter 2000 vessels while transiting the Singapore Strait but not encounter a single vessel while crossing the Indian or Pacific Ocean. Under-stimulation is often an issue on a bridge. Finally, vessels have legal requirements for departure, transit and arrival that result in the captain diverting attention – often at the critical times of arrival and departure to a port area – in order to submit reports. Many accidents have been linked to inattention to navigation due to reporting obligations.

One should also note that safety is only one of the factors driving automation in the maritime sector. Class A vessels are very expensive to operate. One significant expense is the bridge team, as a ship's bridge must be manned 24/7. Reducing operating expense (OPEX) is a significant driver for automation in the maritime sector. At the same time, automation must be achieved safely, so, to address the challenges as outlined above, the following types of systems have been developed:

- Dynamic Positioning and Propulsion: a computer-controlled system to automatically maintain a vessels position and heading. Position reference sensors, combined with wind sensors, motion sensors and gyrocompasses, provide information to the system about the vessels position and the magnitude and direction of environmental forces affecting its position.
- Automatic Route Keeping.
- Fail-to-safe mode of operation: built-in self-diagnostic facilities to monitor the entire control system by pre-determination of system responses with respect to internal or external faults.
- Bridge Watch system: an automatic system which sounds an alarm if the watch officer on the bridge of a ship falls asleep, becomes otherwise incapacitated, or is absent for too long a time. Impairment is assumed if the bridge officer fails to respond to a flashing light.

3. Exploitable results from Mediator

In MEDIATOR there are sensors/systems/software for detection/prediction of the driver's and the vehicle's capability to drive. There is also an HMI making sure that the transition between human and vehicle is done in an efficient way. This chapter describes the background and the concept of the exploitable results of the MEDIATOR project.

MEDIATOR works towards designing a system that mediates between the automated functions of the vehicle and the driver/operator, by handing control to the agent (human or system) that is estimated to be fittest in the ongoing situation, but also in the near future.

MEDIATOR have the following key concepts:

- A central mediation concept to intelligently assess the strengths and weaknesses of both the driver and the automation and mediate between them, while also considering the driving context, ensuring that the fittest one is operating the car.
- Initiation of timely and safe take-overs when needed, i.e., in case of reaching the end of the automation operational design domain or in case of degraded driver fitness.
- Prevention of drivers to become unfit (due to e.g., fatigue or distraction) when no higher levels of automation are available.
- A user centred approach
    - Revised levels of automation taking a user centred perspective.
    - Prevention of driver degradation (in addition to correction of degraded driving).
    - Suggestions to hand over control to automation to increase driver comfort.
    - Preserved driver autonomy, always allowing the human to take back control from automation.

MEDIATOR aims to solve some of the well-known driver-vehicle interaction problems occurring at intermediate automation levels (SAE levels 2–4), such as impaired driver states, overreliance and/or poor take-over performance. To achieve this goal, a broad range of systems have been developed, implemented, and integrated to continuously capture relevant information from outside (e.g., traffic situation), and inside the vehicle (e.g., driver state) and decide who should be in control or how to improve driver state.

MEDIATOR's composition of sensors, systems, and software aims to assess and predict human and automation fitness, mediating the vehicle control via a decision-making component coupled with different HMI strategies. MEDIATOR has generated exploitable results in the form of technologies (hardware and software), applied to different demo platforms.

The work in MEDIATOR, mediating between the automated functions of the vehicle and the driver/operator, is well aligned with Euro NCAPs new assisted driving assessment protocols in the sense that the technical competencies of the system (automation monitoring) are balanced (the Mediator system) against driver capabilities (driver monitoring) while being supported by safety backup, the car's safety net in critical situations (see Figure 2). The Mediator work also aligns well with the amendment of Regulation (EU) 2019/2144 of the European Parliament and of the Council with technical requirements and test procedures for type-approval of motor vehicles regarding driver drowsiness and attention warnings.

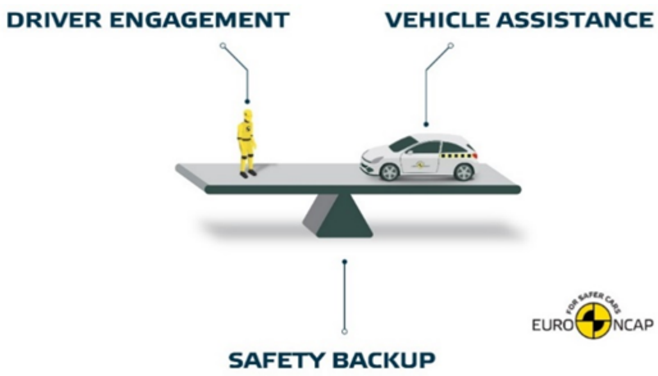


Figure 2: Euro NCAPS test protocols principle for assistance competence. (Source: https://www.euroncap.com/en/press-media/press-releases/euro-ncap-launches-assisted-driving-grading)

MEDIATOR has been tested in lab and on-road conditions with reference to three automation modes and ten use cases see Mediator deliverable D1.4 Decision logic and criteria) (Cleij et al., 2020). The studies are summarized in D3.5 Integration of Evaluation Results from the MEDIATOR Studies (Rauh et al., 2023). The automation modes were defined from a human perspective, where the human either has a continuous monitor and/or control task, needs to be ready for takeover in the order of seconds, or could be out of the loop completely and even fall asleep. The ten use cases included comfort as well as safety related scenarios, such as takeovers to human when automation is no longer available, mitigating degraded driver fitness or comfort related scenarios, such as actively proposing a takeover when automation becomes available.

The MEDIATOR system is designed to achieve four key enablers, namely:

- assessment/prediction of human fitness,
- assessment/prediction of automation fitness,
- mediation control component (or decision-making component)
- HMI to communicate and monitor the implemented actions.

B.1. Assessment/prediction of human fitness

Impaired driver states and degraded performance are detected via different sensors monitoring drivers' behaviour and physiological activity, via for example heart rate sensors and IR cameras. Based on these measurements, drivers' ongoing and predicted state is estimated and compared against information about the automation level and status and the driving context. For the Mediator system, the detection of task- and sleep-related fatigue, inattention and discomfort are prioritised based on their well-known effects on manual and automated driving performance and on acceptance of automated systems. All driver-related information is integrated and used to estimate the Time to Driver Unfitness or Fitness (TTDU and TTDF). The TTDF is useful in SAE Levels 3 and 4, when after periods of disengagement, drivers need several seconds or minutes to regain a sufficient level of fitness. The TTDU serves to make predictions about when driver performance may start to degrade in automation levels in which attention and readiness for intervention are continuously required (e.g., SAE Levels 0-2) or within seconds (e.g., SAE Level 3). This information is communicated to the central mediation component for integration with other sources of information and decision making. The component for assessment/prediction of human fitness is specifically comprised of the following Mediator software:

1) Distraction assessment: Software that extracts gaze direction and Non-Driving Related Task (NDRT) engagement from video streams. The output is merged with information about the driving context in a modified version of the AttenD algorithm (Ahlstrom et al., 2013). This provides a continuous measure of the inattention level of the driver that can be used to determine the distraction-related contribution to TTDU and TTDF.
2) Sleepiness and fatigue assessment: Software has been developed that extract deep features resembling gaze direction, eyelid aperture, blink frequency, pupil size and facial expressions based on face videos and context information that is based on forward-facing videos. The developed algorithm is based on earlier work by Bakker et al. (2021). Physiological fatigue indicators were extracted. Look-up tables that make use of the real-time fatigue estimate were developed to determine how sleepiness and fatigue contribute to TTDF and TTDU.
3) Driver comfort assessment: general principles regarding preferred moments to switch to automation and preferred switch frequency are defined offline are considered in the decision logic as comfort affecting parameters.

B.2. Assessment/Prediction of automation fitness

To determine automation fitness, gathering contextual information from ongoing and upcoming traffic conditions is crucial. In MEDIATOR, data directly collected via cameras, radars, LIDAR systems, or provided by other communication systems are integrated and fused to provide a high-resolution perception and understanding of the context. Relevant information from factors affecting automation fitness is collected like, for example, type of the road, road state (e.g., surface quality), road layout (e.g., curviness), traffic status (e.g., dense traffic, vulnerable road users), weather and light conditions, and potential obtrusive objects in the trajectory. This information allows to estimate whether the current automated system/mode is fit for the present and upcoming driving context and whether the driver attention and/or intervention is required. Based on collected data, estimations are made for Time to Automation (Un)Fitness (TTAU/TTAF).

B.3. Central mediation component

This is the core component of the Mediator system, where information from the driving context and the driver state is integrated and subjected to a decision logic process to determine the best action. In human-automation systems, there is a strong focus, coming from amongst other the military industry, to design human-machine cooperative systems, and to take strengths and weaknesses of both into account to facilitate optimal cooperation. Current automotive automation often mainly focuses on what the automation can do and assumes the driver does the rest. Also, the strongly related human-centred design approach is becoming more and more important. This is included in the Decision Logic by optimising not only for safety, but also for comfort and considering the capabilities and needs of the driver when making the trade-off on who is fittest to drive. The Decision Logic component is comprised of three sub-components:

1) Driving context: where all relevant driving contexts are integrated.
2) Decision Logic: where the "best" actions are selected.
3) Gateway, which works as a bridge to allow for proper information exchange between all other main components.

The Mediator system uses information from the automation state, driver state and context modules to determine if switching from automation to human or vice versa is required or might improve comfort or if the driver fitness needs to be improved. To communicate these actions to the driver, the Decision Logic estimates the best time to do so, based on the input from driving context and driver state. For example, it is not advisable to communicate with the driver when the driver is in a curve or just accelerating or braking relatively strongly or about to merge into the highway, thus any communication will be done before or after such road sections.

B.4. HMI

The Mediator HMI was designed to overcome the main challenges related to vehicle automation by mediating between the driver and the vehicle/system. The HMI software receives inputs from the decision logic component regarding the driver's and the automation's current and near future state as well as actions to be evoked. This information is then conveyed to the driver in a trustworthy and understandable manner to ensure drivers are aware of the system mode and of what is expected of them. The amount, type and modality of the information presented by the HMI depend on the automation level and the urgency of the situation and the driver state. Besides conveying information, the interface makes it possible for the driver to provide inputs when required by the system. Different existing HMI guidelines and the lessons learnt from aviation, and maritime sectors were considered in the development of this component.

The main challenges related to vehicle automation that are addressed with the MEDIATOR HMI are:

- Transfers of control
    - Generic three-stage transfer of control rituals were developed.
    - Automation is proactively proposed when the driver is distracted or when automation becomes available.
    - Mode awareness (by transparency)
- HMI to support mode awareness with minimal effort for the driver, e.g., coloured lighting that can be perceived in the periphery. In the holistic approach HMI elements cooperate to communicate with the driver instead of relying on a single element such as an icon on the dashboard.
    - Communication of time budgets that continuously inform the driver on the time left in the current automation mode to support self-regulatory behaviour.
    - Communicate underlying reasons for transfer of control and warning messages to increase system transparency.
- Keeping the driver in the loop
    - Corrective and preventive measures to reduce distraction and fatigue.

The MEDIATOR HMI uses ten different HMI components that cooperate to communicate the driving mode, time budgets and related responsibilities for the driver instead of relying on a single element such as an icon on the dashboard, Figure 3. The HMI components include:

- ambient lighting and led strips to communicate automation mode and the remaining time in this mode (time budget) and to naturally work towards transitions between modes (transition of control).
- light and sound sensors facilitating signal intensity adaptation to the constantly changing context.
- custom shifter to switch between (driving and automation) modes with force feedback to discourage ill-advised modes.
- haptic feedback devices which are used to correct or alert a driver with degraded fitness in the form of
    - inflatable cushions in the driver seat.
    - vibrating and retracting seatbelts.

- the availability of infotainment systems varies between the modes. When the driver is allowed to be out of the loop, more infotainment is offered, and less driving related information is displayed.

Figure 3; Mode awareness through Ambience, clockwise from top left: Manual, Assisted, Piloted (Driver standby) and Piloted dark mode (Time-to-Sleep).

B.5. Exploitable results for aviation, maritime, and rail transport

To be able to create exploitation roadmaps for a MEDIATOR system in aviation, maritime and rail transport, a subset of exploitable results was selected for further investigation of their relevance for these transport domains. The concepts considered to be most relevant for other domains were:

- Maintaining mode awareness
  - Supporting mode awareness through HMI design.
  - Keeping the driver in the loop
  - Corrective actions: Distraction and fatigue warnings.
  - Preventive actions: Time budget information to support NDRA self-regulation.
- Predicting fitness
  - Real-time, real-world prediction of upcoming automation availability (Using HD map data, navigation, and weather information).
  - Understanding fatigue development.
- Switching between human and automation
  - Guiding transfers of control from automation to human
  - Propose higher automation level when:
  - Degraded driver performance is detected.
  - A higher level of automation becomes available.

These concepts were discussed in a workshop with experts from the aviation, maritime, and rail domains towards the end of the project, see section 4.B.3.

4. Workshops and SWOT analysis

Two focussed workshops with external experts from the aviation, maritime and rail communities were conducted in the project. The first workshop took place in the beginning of the project, in Gothenburg on October 8th, 2019 (Figure 4). The aim was to gain knowledge on how other transport domains manage and cope with human factors and degraded human performance issues, performance of automation and decision making, and HMI design. Based on the early insights, a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was performed.

The second workshop took place towards the end of the project and was arranged as an online meeting on March 15th, 2023. The aim was to discuss the roadmaps for exploitation of a selection of key results from MEDIATOR by different transport modes and identify opportunities as well as potential barriers. The text and the results presented in the two workshop chapters reflects the opinions from the workshop participants and might not be anchored in scientific findings.

B.1. First workshop with focus on strategy

4.1.1. Method

This first workshop was organized as a full-day satellite event the day before the 2nd Mediator general assembly. The workshop was open to all Mediator partners and attended by 42 participants. This workshop took place in the beginning of the project before the system were developed.

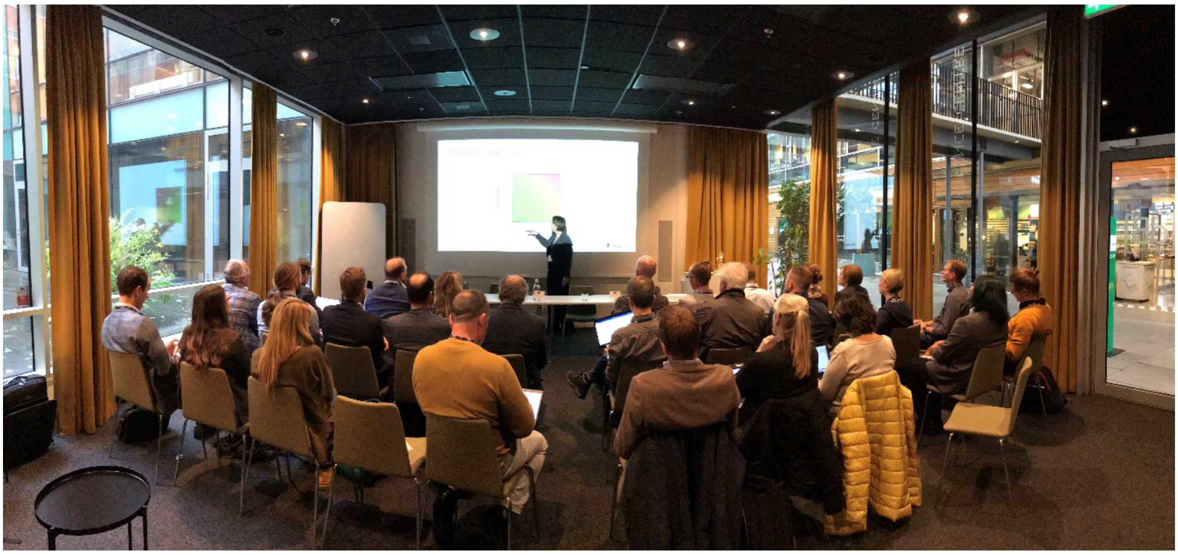


Figure 4: Workshop in Gothenburg 2019.

The agenda consisted of three parts, focusing on (i) human factors and degraded human performance, (ii) automation and decision making, and (iii) HMI design. Each session started out by a state-of-the-art presentation prepared by different MEDIATOR partners. This was followed by a panel discussion where representatives from the aviation, maritime and rail communities gave their view on the state-of-the-art in their respective domains, focusing on lessons that have been learnt and how this can be exploited in the MEDIATOR work.

Invited experts/panellists in the human factors and degraded human performance session were representatives from the Royal Netherlands Aerospace centre, the Swedish National Road and Transport Research Institute, and the Norwegian Centre for Transportation Research. In the automation and decision-making session, the invited experts were from Transrail and Kongsberg Maritime. Finally, in the HMI design session, the invited experts were from SAAB Aeronautics, the Rail Safety and Standards Board, and Norwegian University of Science and Technology. Hence the representation for each Transport domain was as follows: Aviation - 2 experts, Maritime - 3 experts and Rail - 3 experts.

4.1.2. Outcome of the 1st Workshop

4.1.2.1. Human factors and degraded performance

The human factors and degraded performance session focussed on five topics; the new role of the driver, how to maintain human performance and situation awareness, safety measures, maintaining skills, and driver monitoring.

The new role of the operator

The introduction of automation changes the role of the driver or operator, from active participation to passive monitoring.

Most pilots with a good flight control system limit their hand-flying to take-off and landing, simply because the autopilot does such a nice job of everything else. The autopilot is not used for take-off. Many airliners can use the autopilot for landing, but most landings are done manually. Except for take-off and landing, most of a flight is flown with the autopilot engaged. This allows the pilot to focus on other important tasks such as navigation, communication, and systems operation.

Modern maritime auto-pilot systems are capable of being synchronised with the Electronic Chart system (ECDIS), which reduces the need of manual course changes and alterations as the system will follow the courses and alterations, laid out in the voyage plan. However, maritime automated systems do not dynamically adapt to new situations and rely heavily on operator override. And most ships are still controlled manually. Ships are very different from cars. They trust the operator to have enough situational awareness, and the human is expected to be a reliable fall-back. Another difference is that the operator does not always have to be highly alert.

There are four levels of automated trains. Level 1 is fully manual, level 2 is partially automated with a driver in the cabin, level 3 has no driver but there are attendants onboard, and level 4 is completely unmanned. Level 4 automation is already in use in closed systems, such as the metro, but regular train lines with the tracks not sealed off are still working towards level 2. There is a concern that automation takes the skill out of the situation and the automation does too much for the driver.

A difference between car drivers and operators in other domains is that pilots, captains, and train drivers are professional operators. This means that it is easier to use laws, guidelines, regulations, and company policies that control how and when automation is used. For example, drive and rest regulations can be used to avoid excessive fatigue, and education can make sure that the operator understands the automated systems. Another difference between car drivers and operators of other domains is that in other domains such as rail and aviation there is a traffic controller who has an overview of the traffic system and can manage the traffic systematically. This means that conflicts are solved on a system level. This is a major challenge for car automation where each vehicle is independent.

Maintaining human performance and situation awareness

Another issue closely related to the new driver role is maintaining alertness and performance in automated driving. Fatigue is perhaps one of the most major concerns in the context of automated driving and drivers' ability to take manual control when being asked to do so.

The maritime domain has been fighting to maintain human performance, regardless of the ship being automated or not. Checklists is a common concept to keep the crew in the loop. Motivation factors are important. Each ship is unique, there are 8 or 9 different screens on the bridge. Along the cruising path there are sections considered as requiring high levels of attention and other parts which require low levels of attention. In trains, there is a “Deadman’s” switch that makes sure that the driver is physically in position. This is obviously a necessity to be able to gain and maintain situational awareness, but not a guarantee that this happens.

In a mediation system i.e., when the automation and the operator work as a team, it is important that everything that the automation does is communicated to the operator. In aviation, if the state of the automation changes, this must be communicated to the pilot. In maritime this is called “fatigue proof concept”, and the system will prepare the crew to get back into the loop. The rail industry has a system that constantly rewards the driver. Focus is maintained with for example gamification. It looks like fleet managing systems. Also, a car driver needs to be prepared before taking back the control, to have the possibility to build up sufficient situational awareness. How much time that is needed, is driver state and situation dependent. Estimations range from 3 to 6 seconds. It is difficult to design a system that makes sure that there is enough time to get the driver back in the loop. In aviation, the HMI adapts to the urgency of the situation, to get the pilots full attention when needed.

From the navy it has been noticed that when the cockpit and the HMI was stripped from clutter, with the objective to free up resources, the crew became insecure about which systems were working and which were not. It is important to communicate the state of the automation.

Safety measures

What steps have been taken in various transport modes in terms of design of in-vehicle systems, regulations, infrastructure to ensure safety as automated systems have been integrated?

There should always be an override button though, so that the human can take over control. There are however examples when pilots have taken over control and crashed, where the aircraft would have been more capable of dealing with the situation. The automation should act as a butler who solves problems and then disappears again. One thing is clear though, if the operator does not respond to a take-over request, the system must be able to avoid a crash. Humans are not always able to make this decision though. A safety procedure that is used in aviation is to have two pilots. This is perhaps not possible in a car.

In trains, just as in cars, automated functionalities are turned off if drivers apply the brake. In the automated system, the train driver is always allowed to override. Apart from with emergency braking.

Maintaining skills

Automated driving is targeted at relieving drivers from many of the driving tasks which raise major concerns regarding knowledge and skill retention. Furthermore, in a few years young drivers might learn to drive a vehicle with various automated functions and may not have the proper skills to drive manually when needed.

Rail have scheduled sessions when the drivers must drive manually to uphold their competence. This usually occurs on Sundays when the rail network is less busy. This is enforced by the system and cannot be skipped. For aviation this is also the case when it comes to landing manually. Pilots also use flight simulators to train and uphold their skills. Maritime also do training and the crew must show that they have required skills. We share the ocean with everyone, and everyone needs to interact. Digitalization in the maritime domain is progressing as we speak, and the staff continuously complains there is lack of time to learn new systems. So, maintaining, and updating skills is an area that needs to be considered in all transportation modes, including amateur car drivers.

Driver monitoring

Being able to determine driver state is an important part of the Mediator system.

Driver and pilot monitoring have much in common. Both are seated and sitting relatively still, so camera-based systems such as eye tracking are feasible solutions. These can be used to estimate the vigilance and attentional level of the operator. Head mounted eye tracking has also been used in maritime, but the sensor is obtrusive and conditions are rough and data quality is an issue. In future cars with high levels of automation, it is expected that the driver will be out of position, for example when working on a laptop on a fold-up table temporarily replacing the steering wheel. This will make it more difficult to use remote cameras for driver monitoring, as is currently the case on the bridge of ships and in trains. These operators have much larger degrees of freedom as they can stand up and walk around.

By and large, monitoring of the crew would be very useful in the maritime domain since there are major problems with fatigue. However, this is not done, partly due to the lack of robust and accurate systems. In rail, there are issues with acceptance of camera-based driver monitoring systems due to privacy issues. However, after a tram accident in the UK, there is now more acceptance on monitoring the face of the driver.

4.1.2.2. Performance of automation and decision making

The automation and decision-making session focussed on the topics: problems that automation encounters, cooperative automation, task division, and the availability of automated functionalities in aviation, maritime and rail.

In automotive, already on SAE level 1, these systems are not unequivocally accepted. 23% of users do not like lane keep assist and complain because unexpected automation failures arise due to rare objects on the road, unclear or unusual road markings in cities or during constructions, and unpredictable behaviour by surrounding road users. In aviation, in contrast, it must be proven beforehand to a much larger extent that the automation will work for the use cases specified.

Overreliance is also a huge problem in cases where humans do not understand the system. Even if you tell the human that they always need to monitor the surroundings, they will still get distracted and fall asleep. Both automation and human factors need to be taken in to account when designing the systems. However, in other transportation domains, the operators are trained to know what the automation can do and what they should do when the automation fails. Professional operators are thus less prone to over-rely on automation and they are more likely to intervene before a situation turns critical. That is probably a difference compared to normal car drivers. It is recommended that driver training is required also when driving semi-automated cars; and that great care is given in HMI design to make both responsibilities and limitations of the automated systems clear to the driver.

A general problem across domains is that engineers automate what is easy to automate rather than the difficult situations in which humans need help. This leads to the problem that a passive operator always needs to be vigilant. In rail, it has been noted that if a correct and optimal automated decision somehow feels strange to the operator, it is better to offer a suboptimal solution that is more aligned with the operator's expectations. It is important to explain the context as to why a certain behaviour occurs or is requested. The general lesson here is that the decision making by the automated system should be sufficiently aligned with the "mental model" that the human user/driver has.

As to whom has the final say in decision making, in rail, the train driver will not accept to be a silent bystander. In an automated system, the train driver will always be allowed to override the automated system. Apart from the exception in emergency braking, but a train driver would find it a disgrace if automated braking is always activated.

In maritime, the captain typically wants to see raw data to always have a clear view on important underlying parameters, despite perhaps far-reaching automation. At the same time, information is scattered on many different screens on the bridge, all with different sensor data and different HMIs. A system that integrates various sources of information and turns it into actionable intelligence would be considered useful for the operators. This is especially true in so-called "scramble" situations, where things threaten to go wrong, and decisions have to be made at very short notice. This lesson can be and probably should be considered also for semi-automated driving, when decision making is shared between automation and the human driver, and the human driver is relied upon in such "scramble" situation.

It is argued that, in general, in maritime the automation will likely never have full situation awareness so there will always be an override option for the captain, except when it comes to emergency braking. It is considered important that the automation always leaves enough leeway for "good seamanship". If the same is true for automotive application, the same conclusion may apply.

In both maritime and rail, the automation needs to be at a strategic/planning level. Large ships and trains are heavy and cannot be controlled on a short term. In maritime, prediction of future movements is important in this respect, and warnings should be given based on limitations and restrictions constrained by which movements are possible. The system needs to be able to see further ahead, and the automation is always better on strategic planning than a human operator could, for example due to longer sensor range. In rail, strategic advance planning is what the automation does best, whereas new knowledge is better handled by the operator. Everything is essentially present, and the Automatic Train Protection (ATP) system ensures the safety. All automation needs to be transparent for the operator. Decisions altered plans and operator corrections should always contain a message explaining the underlying reasons for the change.

If systems are only semi-automated and if it is expected that the operator should be on standby and ready to resume control, it is important that people are given enough time to do so in a safe way. In maritime they give the operator 20 seconds before they expect him or her to handle the controls. The speed of the ship is also reduced to give the operator extra time. It is not appropriate to do as the automotive industry currently does, for example to just turn of lane assist abruptly with no advance warning. Even the 5 to 10 seconds minimum take-over time by the human driver in current level 3-type automation designs is very short, in fall-back scenarios in which automation foresees it can soon no longer operate safely.

4.1.2.3. HMI design

The HMI session focussed on the design process, safety and trust, training, and the effect of passive monitoring.

Aviation highlights the importance of the right information at the right time. Sensor and data fusion are important concepts to enable to achieve this. However, pilots also want to be able to learn more and want to have access to the raw data upon request. This facilitates situational awareness and system understanding. The HMI elements presenting fused information should be adaptable and situation aware. For example, in the panic or scramble situations, essential and directly actionable information should be highlighted. A less radical example are the adaptations made to the HMI in landing mode, with predictable but detailed information tailored to the task at hand. Similar desires were raised from the maritime representative. An example was given where a captain became uneasy when the detailed information with raw sensor data outputted as scrolling text was removed, because that was his way to know that the system was working.

From an HMI point of view, in aviation, head up displays have been very useful and have become an important way to provide information to the pilot. An important issue is to make sure that the messages written are designed to fit the user and not as it is today by engineers without confirmation and involvement by the operators.

For the rail sectors graphics are created to inform the drivers without increasing the driver or operator workload. This is somewhat problematic as the new systems such as ERTMS/ETCS move information from signs and signals on the wayside (outside the cabin) to a display (inside the cabin), which may lead to deteriorated situational awareness and initially also increased workload. At the same time all regulations need to be regarded – a task that is not easily solved. There is an intention and a need to harmonise the HMI toward a trustable and useful system.

The “backward compatibility” was highlighted to be an important issue to consider, and also mental models need to be considered. During this work it was highlighted that this also needs to be aligned between human and automation, and different HMI representations need to be aligned as well.

Good design principles promoting intuitiveness, effective colour schemes, stereotypical designs, etc., are essential in all domains.

An overall important aspect, when learning from other transport modalities, is that those other modalities are in principle driven and maintained by professionals, while automobiles are driven by amateurs. The difference between professionals and amateurs has impact on HMI design. While professionals will undergo training to learn specific interfaces, an automobile interface may not require specific training. Learning must as much as possible be intuitive. To facilitate that the design must build on existing affordances (like the aforementioned ‘backward compatibility’).

The difference between professional and amateur drivers also raises the issue of driver autonomy. In amateur situations it may be more likely that a driver has a different preference towards the automation level. The HMI must facilitate these ‘negotiations’ between driver and automation. An ethical issue derived from that, is the choice for or against a driver-override option. While in aviation there are examples of accidents because a pilot was not able to override the automation, which would be an argument to allow pilot-override, in an amateur driven vehicle a proper driver response seems more questionable.

Regarding maintenance an ethical question arises. While it may be assumed that, given the complexity of the modern automobile, maintenance is generally done by professionals, initiating the maintenance is an owner’s, i.e., the amateur’s responsibility. Hence, a vehicle owner is partially responsible for proper functioning of the system.

B.2. Strengths, Weaknesses, Opportunities, and Threats

A SWOT analysis was conducted for the most prioritized exploitable results identified from the 1st workshop. The insights gained from the SWOT analysis may aid in the exploitation of the results and create awareness about potential critical issues that could impact negatively on the final achievements and results, and to seek out opportunities and counteract threats.

Each of the most promising identified exploitable results were ranked from 1 (highly exploitable), 2 (exploitable) to 3 (maybe exploitable) for the rail, maritime and aviation domains. The ranking was made by VTI for rail, NLR for aviation and KOG for maritime.

4.2.1. Rail

The prioritised MEDIATOR results exploitable in the railway sector in the beginning of the project were: (i) the distraction detection (AttenD algorithm) extended to account for the surrounding driving environment, (ii) the algorithm to predict and output time to automation (un)fitness and, iii) the algorithm for decision on most appropriate countermeasure, including timing, to maintain or improve driver fitness. In line with the benchmarking the experts highlighted the importance of supporting drivers’ situational awareness by providing timely information about the time to automation (un)fitness. Interestingly, the experts did not prioritize exploitation results aimed at detecting and predicting driver fatigue, a consistent topic in the literature. Rather, systems preventing distraction were prioritized. For those three selected exploitable results the SWOT analysis were done.

4.2.1.1. Distraction detection (AttenD algorithm) extend to account for the surrounding driving environment.

By continuously tracking drivers’ glance behaviour, this system ascertains whether drivers have looked at (and therefore are aware of) inside or outside information that is relevant for the train operation in a given moment. If no gaze to the relevant information were detected, a specific action, such as issuing a warning or highlighting the information on the display, would then be activated to draw driver’s visual attention to the information.

Given the distraction detection system greatly relies on the performance of the eye-trackers in the cabin, most concerns highlighted in the SWOT analyses relate to its reliability under changing conditions in lightning or driver position, among others (See Table 2). On the other hand, coupling driver glance behaviour to the relevancy of the information at each moment, is perceived as a good solution to detect distraction behaviours in an unobtrusive manner.

For the successful implementation of this algorithm in trains it should be considered that, by contrast to drivers in road vehicles, train drivers have a greater freedom to move within cabin. This implies that multiple cameras should be installed to better capture drivers' glance behaviour as well as head and body movements. Moreover, to determine whether drivers have looked at the relevant information, specific definitions for what information is priority at a given moment are necessary.

Table 2: Rail SWOT analysis for "Distraction detection (AttenD algorithm) extended to account for the surrounding driving environment".

Strengths	Weaknesses
• Unobtrusive measurement of drivers' glance behaviour. • Consistency of gaze direction analysis. • Detection of various driver states via pupil size and eyelid measurements (e.g., overload, or fatigue).	• Poor performance due to miscalibrations, head movements, driver postures and type of glasses. Train drivers have larger degrees of freedom to move around in the cabin that needs to be covered with multiple cameras. • Different train control systems require different definitions on which information is relevant for the driver and where this information can be acquired (wayside or in the cockpit).
Opportunities	**Threats**
• Increasing performance of new eye-tracking systems. • Glances to priority information can be ascertained automatically. • The influence of surrounding traffic and also the limited degrees of freedom of a train is less complex compared to road transport, which makes it easier to develop context sensitive inattention monitoring.	• Poor quality of tracking due to external conditions like lighting or that the eyes are not visible to the cameras.

4.2.1.2. Algorithm to predict and output time to automation (un)fitness.

Most trains today require drivers to be always attentive; however, Automatic Train Operator (ATO) systems are available supporting drivers in tasks like starting/stopping, doors operations and handling of emergencies.

A SWOT analysis has been performed for the prediction algorithm of automation (un)fitness considering the different GoA. Overall, predicting automation fitness or unfitness and outputting this to the driver was perceived as a promising strategy for managing drivers' task-related fatigue, and most particularly, sleep-related fatigue (in GoA 4). Also, the implementation of this algorithm will be feasible in trains equipped with the ERTMS/ETCS, as this system provides the infrastructure needed to communicate in real-time changes in the traffic plans, or potential events that could affect the performance of the automation level.

Most concerns in the SWOT analysis relate to difficulties in monitoring driver state and behaviour while freely moving inside or outside the cabin (in higher GoA), and the need for clear interfaces to avoid mode confusions in the driver (See Table 3). As the main threat, the SWOT analysis highlighted the need for developing robust automated systems to cope with abrupt events during the automated driving period, where drivers will not be available for intervention.

For the successful implementation of this algorithm in trains it should be considered that, depending on the GoA, some tasks will need to be performed by the driver and others by the system. Consequently, automation (un)fitness algorithms must clearly identify and output which and when each specific automated task will become fit or unfit depending on the upcoming traffic situations. In addition, existing ERTMS/ETCS systems provides the infrastructure necessary to communicate TTAU and TTAF to the driver. However, to avoid potential mode confusions, intuitive interfaces need to be developed. Since, under certain automation modes, drivers are allowed to move freely within, and even outside the cabin, such interfaces should be designed to reach the driver regardless of his/her location in the train (e.g., wearable interfaces).

Table 3: Rail SWOT analysis for "Algorithm to predict and output time to automation (un)fitness".

Strengths	**Weaknesses**
• Support drivers in task prioritization (e.g., postpone a task until automation is fit again). • Effective support for driver fatigue (see opportunities). • Time to focus on other operational tasks while driving automated, e.g., communication or navigation. • Technology for continuous communication between the train and the traffic control centre is available today (e.g., ERMTS/ETCS).	• Extra infrastructure equipment will be necessary. • Driver monitoring systems should adapt to freely moving drivers who are allowed to leave the cabin, sleep or engage in other tasks. • Information on TTAU should be communicated considering driver location in the train and driver state (e.g., via wearable systems). • Information on TTAU should be conveyed considering drivers preferences and needs, e.g., time needed to get back in to the loop. • Mode confusion. The driver does not know what automated tasks are becoming fit or unfit.
Opportunities	**Threats**
• Possibility to compensate for task-related fatigue by engaging in non-driving related tasks (GoA 2-4).	• Sudden events during the automated driving need to be handled by the system, as the driver might not be available.

• Possibility to compensate for sleep-related fatigue by taking naps in GoA 4. • The ERTMS is a good framework to implement the algorithm.	

4.2.1.3. Algorithm for decision on most appropriate countermeasure, including timing, to maintain or improve driver fitness.

The SWOT analysis revealed that supporting driver fitness would greatly contribute to avoiding negative human-factors related effects on safety and efficiency during train operation (e.g., poor speed management and energy consumption). However, the SWOT analysis also warns about potential inaccurate driver state detections leading to inappropriate countermeasure deployment, as well as the need to adapt the countermeasures to the driver' characteristics (see Table 4).

For its successful implementation, this algorithm should adapt to the inter-individual differences in drivers' needs for time to become fit again after prolonged periods of inactivity, and preferences for countermeasures strategies. Likewise, the detection systems must be able to accurately detect the driver state and deploy personalised countermeasures.

Table 4: Rail SWOT analysis for "Algorithm for decision on most appropriate countermeasure, including timing, to maintain or improve driver fitness".

Strengths	Weaknesses
• Effective way to support driver fatigue throughout the shift. • Deployment of optimal countermeasures.	• Effective countermeasures vary among people. Personalisation is necessary. • Time to become fit again varies from person to person.
Opportunities	**Threats**
• Improved safety for operators and passengers. • Improved speed management of the train and energy consumption. • Reduce the number of human factors related mistakes. • Possibility to delay impaired states until it is possible to take a break or a nap (next station)	• Driver state detection is not accurate enough, which leads to inappropriate countermeasure deployment. • Managers use the technology to extend shift duration.

4.2.2. Aviation

For the aviation domain several results were identified as potentially or highly exploitable in the aviation sector in the beginning of the project. For simplicity, these have been clustered into the following groups: 1) Fatigue detection, 2) Fitness/unfitness assessment and 3) Human Machine Interface. The former two groups, i.e., fatigue detection and fitness/unfitness assessment, were subjected to the same SWOT analysis.

4.2.2.1. Fatigue detection

Knowledge about fatigue in real time and in such a way that it can also anticipate, i.e. provide fatigue assessment prior to actually reduced capacity of the operator would be very welcome in aviation. Please be aware of that “driving performance” is consider as “flying performance”. In fact, all sources of information that can be applied to get a better assessment should at least be considered.

4.2.2.2. Fitness/unfitness assessment

Under this group, the following exploitations results were included: i) algorithm to predict and output overall time to driver (un)fitness, taking all driver states from above into account and ii) algorithm to predict and output time to automation (un)fitness.

These two bullets were taken together because driver (pilot) and automation can be seen as a team (Table 5). For both a continuous assessment of the “fitness” can be applied to create the best team performance. There are situations that both are not optimal fit, but that one of the two is still fitter than the other. Therefore, both assessments are seen, by us as one system.

Table 5: Aviation SWOT analysis for “algorithm to predict and output overall time to pilot (un)fitness, and algorithm to predict and output time to automation (un)fitness.

Strengths	Weaknesses
• Solid assessment of fatigue based upon multiple data sources. • The system can measure more than just fatigue. • Mostly unintrusive / unnoticeable by the operator.	• Equipment needs to be built into aircraft, which is expensive and a big “hassle” in general in aviation. • Assessment will not be 100% correct. • Detection of fatigue is not enough to solve a problem, so additional work is needed. • Privacy issues when recording personal data. • Uncertainty about what is measured (fatigue, fitness, attention).
Opportunities	**Threats**
• Regulators may want to install such a system in all commercial a/c.	• Not everyone (unions) will agree with such a system. • Potential overreliance, or misuse issues.

• It may even contribute to "happier" pilots, since fatigue becomes something acceptable and can be discussed. • Combine with other tech developments like higher levels of automation, to decide how to inform pilots dependent on the state of the pilot.	• Airlines and manufacturers might show some reluctance given that these systems may also lead to less flexibility for the operation.

4.2.2.3. Human Machine Interface

The following exploitation results were included as HMI interface: i) HMI component to communicate the time to automation (un)fitness, ii) HMI component to communicate the time to driver (un)fitness, iii) HMI to prevent driver degraded performance and iv) HMI to correct driver degraded performance.

The "overarching" principles of how the system works will be the same for driving a car and flying an aircraft. In particular, how psychophysiological sensor data is processed is very comparable. However, adaptations are needed as well. For example, vehicle data and environment data are very different between both domains.

Also, the locations of sensors are different, so once the ideal locations for sensors in cars are established, there might be a huge difference with aircrafts. The same goes for HMI, communication and preventive / corrective actions. An Aircraft is very different from a car. Communication principles remain the same, but the rules of thumb for when to communicate how to communicate, and also to whom (after all an aircraft has two pilots) may vary a great deal. Taken that all together the principles are the same and therefore both domains can learn from each other. However, where the sensors may be basically the same the actions and communication styles can only be used as source of inspiration between different domains and can most likely not be copied without any adaptations. Also, the stakeholders are very different. In cars there are unions that need to be convinced. And for private cars it is up to the driver to use a system as long as it is accepted by the authorities.

Table 6: Aviation HMI SWOT.

Strengths	Weaknesses
• Timely and effective communication allows to mitigate a situation prior to incidents or accidents happen.	• Uncertainty in the data coming from the sensors might result in giving the wrong advice / taking the wrong action.
Opportunities	**Threats**
• Safety will increase. • If the system is really good more traffic can come nearer. I.e. the capacity of airports / runways may increase. • In theory operations with one pilot may become possible.	• Communication may come at an inappropriate time resulting in more damage than support. • Preventive or corrective actions ate inappropriate.

• Lessons will be learned that may be applicable to fully (with no pilot at all) automated systems.	• The system might offer its output (communication plus actions taken) to the authorities / employer of the operator.

4.2.3. Maritime

Two MEDIATOR results were identified to be considered as priorities for maritime, namely, (i) the distraction detection (AttenD algorithm) extended to account for the surrounding driving environment and, ii) the algorithm to predict and output time to automation (un)fitness. The SWOT analyses for these exploitation results, as well as the specific adaptations needed for their successful implementation were done.

4.2.3.1. Distraction detection (AttenD algorithm) extended to account for the surrounding driving environment

While bridge systems already have alert systems to ensure the bridge team is alert, namely by sounding an alarm if silent alert goes unacknowledged, extending this alert to take account of nearby vessels or proximity to land would add value. However, for the successful implementation of this algorithm specific adaptations are needed to support multiple simultaneous users and to support weather and sea state awareness (Table 7).

Table 7: Maritime SWOT analysis for "Distraction detection (AttenD algorithm) extended to account for the surrounding driving environment".

Strengths	Weaknesses
• Potential ease of implementation due to the singular nature of bridge systems – each subsystem gets its own display, potentially reducing the complexity of eye tracking required. • This is a silent, unobtrusive solution	• Multiple bridge team members could complexify and overwhelm the technology. • Poor performance due to miscalibrations, head movements, driver postures and type of glasses. The crew have larger degrees of freedom that needs to be covered with multiple cameras on the bridge or head mounted eye trackers.
Opportunities	**Threats**
• Increased system and automation resilience. • Improved safety at sea	• Poor performance due to extreme variations of light during a 24-hour period. • Poor performance due to movement of the bridge itself during rough sea conditions

4.2.3.2. Algorithm to predict and output time to automation (un)fitness

Fully autonomous vessels in the near future will be remotely monitored by Shore Control Centres (SCC). These SCCs will monitor several vessels, intervening only when a vessel has encountered an uncertain situation either in its environment (such as an unavoidable conflict on its route) or is experiencing equipment failure. This algorithm for evaluating whether the automation system is up to the task, based on input from sensors, is a potentially valuable assessment and one that is not currently employed (Table 8). However, the message size will need to be evaluated as communication carriers will be limited to satellite for long periods of time.

Table 8: Maritime SWOT algorithm to predict and output time to automation (un)fitness.

Strengths	Weaknesses
• Ensures a more robust and solid system. • Includes the context of operation, not just the technical likelihood of a specific component failing.	• Could be an expensive system, depending on the communication carrier. In many ocean areas, only satellite communication is possible. • The learning period for the algorithm could be painful.
Opportunities	**Threats**
• Potential for re-use in other areas, such as bridge systems, USVs and AUVs. • Increased system and automation resilience.	• Only as good as the weakest link. Communication carrier with the ship system will be critical.

B.3. Second workshop with focus on road maps

To discuss the roadmap for exploitation of the MEDIATOR result for aviation, maritime and aviation, a second workshop was organised. The workshop focused on identifications of opportunities as well as potential barriers.

4.3.1. Method

The second workshop took place on the 15th of March 2023. The workshop was done as an online video meeting. The aim was to present the key findings from the 4 selected exploitable results.

In total 10 experts participated together with the moderators and presenters (4 persons). The 10 experts represented Maritime (4 experts), Rail (3 experts), and Aviation (3 experts).

The workshop started with a presentation of the MEDIATOR project and the four selected key findings that were outlined already in section 3.B.5:

- Maintaining mode awareness
- Keeping the driver in the loop
- Predicting fitness
- Switching between human and automation

For each of them four questions were introduced:

- Would the concept be relevant for other transport modes?

- What are the challenges in adopting this concept in other transport modes?
- What additional R&D would be needed to adapt to other modes?
- What is the timeline for implementation for implementation in other transport modes?

A digital Whiteboard, see Figure 5, was set up so the participants could write their reflections during the discussion. The moderator introduced each of the key findings, and for each of them leading the discussion through the questions.

Maintaining mode awareness Supporting mode awareness through HMI design	**Aviation**	**Rail**	**Maritime**
Would the concept be relevant for other transport modes?			
What are the challenges in adopting this concept in other transport modes?			
What additional R&D would be needed to adopt to other modes?			
What is the timeline for implementation in other transport modes?			

Figure 5: Whiteboard outline simplified for one of the Mediator results.

After the workshop a link to a web-based survey was distributed. The survey included questions about the exploitable results from the project. The objective was to explore the exploitability of the four concepts that were developed and presented at the workshop, giving the participants the opportunity to express their own view, but also to collect their view on the road map (Chapter 5).

The survey covered the same key findings as the discussion: 1) Maintaining mode awareness, 2) Keeping the driver in the loop, 3) Predicting fitness and 4) Switching between human and automation. The survey questions can be found in Appendix 1. For each of the exploitable results, four initial questions:

- Is it relevant for the transport mode?
- Is implementation feasible?
- Are drivers or pilots willing to accept it?
- Will it would improve safety?

The fifth question, in case implementation was deemed desirable:

- How long will it take to make each exploitable result ready for market in the different transportation domains?

4.3.2. Outcome of the 2nd workshop

In general, since the first workshop was very informative there were not so much new information received from the second workshop. However, in the following text some new reflections and insights are described.

A main comment that is relevant for all exploitable results was that the role of the driver is very different in aviation, rail and maritime operations compared to road transport. One of the main differences is that in these transportation modes, the driver is most often a professional driver. There are occupational regulations that determine hours of operation and working conditions and there is an employer-employee relationship to take into consideration. Regulations and privacy issues are more challenging in commercial vehicles.

In maritime operations, a MEDIATOR system would possibly be more relevant in coming autonomous ship operations. High Speed Vessels (HSV) have the most similar working environment as in a car, but there are typically two operators, like on an aircraft. Except from HSV the operator is not always sitting or standing on the same position all the time which makes, for instance, driver monitoring more challenging. Auto-docking, in which case the vessel is docking autonomously, but the operator needs to be ready to takeover in seconds, is a relevant scenario for a Mediator system. Timing is also different in maritime operations with less need for immediate action but on the other hand a need to act in due time as e.g., stopping a large vessel takes time and needs to be planned.

4.3.2.1. Maintaining mode awareness

In general, it was clear from the discussions that there is an important difference between a private car driver and a professional driver of an aircraft, vessel, or train. For a professional driver, regardless transport mode, it is not possible to “drop out” of the control as in a private car. It was underlined that this is a job and hence not possible to compare with driving a car. Said that, there was an agreement that it is still important with automation awareness.

Comments from the whiteboard

However, it may still be useful to apply the principles from the Mediator system regarding mode awareness. For train drivers it is also very relevant to get feedback about which mode is active, but automation status was not seen any different than other information relevant to the current task. For rail as for aviation and maritime, there is a challenge to get information about automation status presentable, in relation to other vital information that also needs to be communicated. Supporting mode awareness could also be relevant for maritime operations and communication of automation modes is currently used in maritime to indicate vessel control modes.

In aviation, there are several levels/types of automation, not a simple increase in automation levels, like the SAE levels from 0 to 5. With many different levels of automation using many different systems, a MEDIATOR system designed for aircraft would need to be much more complex. The system would need to be able to handle and communicate many types of mode changes. When it comes to HMI, using ambient lighting of different colours is not easy to implement to facilitate automation awareness as light conditions are often challenging. It can be very, very bright on the flight deck due to sunlight. In maritime, there would be a need to adapt HMI and sound to fit maritime operations.

Aviation

For the aviation domain it was especially underlined that the role of the pilot is very different compared to that of car drivers. This is also important when it comes to the background that they bring with them in terms of, for example, training. In addition, it is also important to understand that (commercial) pilots are not only flying the aircraft but also communicate with air traffic control and adjusting both vertical and horizontal navigation. The experts said that it is relevant to know which systems are active. On the other hand, there are so many different levels of tasks to handle that it was not clear what the MEDIATOR approach would add. It was also mentioned that the role of the pilot is not always including the planning, as this could be done by someone else. The pilot's task is more to check that everything is done as planned. When it comes to awareness this is not enough for a pilot. They also need to know how to get up and down. In general, in an aircraft, information about which systems are activated is available. The problem is when some parts are changed. How is it communicated to the pilot? An identified risk for aviation is that you might miss a mode. The risk is that if you get a signal of a mode change, the implication might differ depending on the situation. Important to realise is that aviation is developing. Higher levels of automation are introduced. With increasing levels of automation, monitoring operator state and using that in the HMI becomes more relevant.

Maritime

When ships are on autopilot (heading keeping) or autotrack (following a pre-planned route) the automation will tell the officer on watch (OOW) when it is time to take back control. Regulatory requirements[3] IMO Resolution MSC.128(75)) requires a Bridge Watch Alarm System (BNWAS) that monitors the OOW when in automatic steering modes. This is done by motion detectors or that the OOW must operate buttons located on various locations on the bridge, which must be activated within specified time intervals to acknowledge that the OOW is attentive. Even if the ship is in an auto sailing mode, the OOW is required to be attentive and have good situational awareness. If the OOW does not respond in predefined time, a bridge sounding alert will sound, and further alerts will sound in officer cabins and in the end on the public announcement system if no human response is registered. These systems are already integrated in the legalisation for this type of automation products There are also systems available that show if there is a conflict in understanding if the automation is activated or not. This is handled by HMI. This includes both confirmations from the automation and the human.

In case of the OOW taking manual control of automation, just a single button operation is required and for some ship notations, a movement of more than 5 degrees on the helmsman's wheel will terminate automatic steering. The time to stop a ship is long and the information to act needs to be on a tactical level.

Rail

The experts from the rail sector highlight that the challenge is that the information toward the driver is so overwhelming. A mode awareness information is an extra level of information to handle, and this is seen as a challenge.

4.3.2.2. Predicting fitness

Comments from the whiteboard

Predicting fitness, especially prediction of pilot fatigue, was seen as relevant for the aviation domain. For single pilot operations, it was seen as crucial to know and predict the pilot's level of fitness. Fatigue is a big issue in aviation and there are different types of fatigue (high workload vs. underload vs. jet lag, etc). Aviation would need to rely on remote sensing of pilot fitness as you cannot use steering wheel sensors. There is currently much ongoing in this area in aerospace. Predicting fitness could be relevant in maritime, but similar solutions are already taken in account in existing systems and planned in coming systems. Larger ships have a BNWAS which is used to alert the crew if a navigator is not responding. There have, however, been incidents due to unresponsive crew members despite having BNWAS. There are means to detect if the mariner is present and using cameras may be difficult due to an operator's location on the bridge (standing, sitting, moving around).

[3] IMO Resolution MSC.128(75), performance standards for a Bridge Navigational Watch Alarm System

The rail sector pointed out that there are privacy issues in driver monitoring and unions will likely be against such systems. In aviation, poor fitness to fly could lead to a loss of their license, which is a potential secondary consequence of monitoring.

Accuracy of the sensing systems was mentioned as a major challenge and especially false positive readings was seen as an issue. Time budget and sensors must be modified and adjusted to maritime operations. Technical development would be needed to transfer from laboratory equipment to robust operational equipment, integrated in the entire aircraft, train or vessel.

Aviation
There was a strong view that Fatigue is an issue in aviation. Even if the pilot is moved to a remote operation the problem of fatigue might remain. For aviation, there is an HMI solution that will warn the pilots when they fail to respond to topics asked for by the aircraft. This is seen as useful.

Maritime
Also, the experts in maritime claim that they already have state detection to some degree. One question discussed was around how they communicate about how long they can drive in automation. The simple answer is that in maritime there is no need for manual operation during long periods of time. It is mostly in emergencies that the skipper needs to take over. There are already vessels that are fully automated. For this type of operation, the vessel for example predicts what can be done during different weather conditions such as waves, during docking etc. The system then most often tells the driver to be ready, but the vessel itself normally handles the situation. The exploitable results on how to alert the driver might be useful.

Rail
For train driving there is a system called a dead man's grip. This is a system that requires not only a hand on, but also that you push and respond continuously. This will of course not solve the problem with driver fatigue but will help to avoid critical situations when it happens. When you drive a train without responding to signals, the system will take over. This could be seen as a fall-back solution.

For the rail domain it is mentioned that fitness before they start to drive is very important. The driver needs to complete the protocol before. The decision of fit-to-drive is however done by drivers themselves. No measurements are done on the drivers. A system for real-time monitoring might be helpful. That said, there is a need for more tools to understand how fit the train drivers are while driving. The risk is that the driver is more and more out of the loop. Here, new knowledge is needed to develop this.

4.3.2.3. Keeping the driver in the loop

Comments from the whiteboard
For all modes of transportation, it was stressed that the more automation that is introduced, the higher the risk that the driver will be out of the loop. Adding new tasks to keep the driver in the loop was, however, not seen as a good solution for any mode.
In aviation, time on task is the biggest issue during for instance trans-Atlantic, and Pacific flights, especially at night. The change in pace of operation is an issue when you do nothing for 8 hours, crossing the ocean and then everything happens at once as you approach the destination (air traffic, complex arrival procedures, etc). This change in pace usually happens when the pilots are most fatigued. Sleepiness and fatigue are common, as well as problems related to jet lag. On short haul flights, keeping the pilot in the loop is not a big problem.

Aviation
Keeping the pilot in the loop is an issue. They fly many hours, and their task is to a high degree monitoring. A system for keeping the pilot in the loop might be accepted by them. However, the most critical thing is when they go from low cognitive load to high load, when they reach the coast, or in particular the destination airport, when the pilot needs to be super alert. This moment, called top of descent, is also the time when the pilot might be most fatigued. The shift between high and low cognitive load is demanding. In that case, the effort on getting the pilot back into the loop could be useful. Hence, action to prepare the pilot for the time budget until this happens, might be useful. The pilots are aware that the time to be more active will come and they also try to prepare themselves beforehand by stretching, caffeine intake, etc. However, there is nothing in the HMI that supports this.

To avoid fatigue during long haul flights additional flight crew is sometimes added, so that others can rest in bunks. This is good, but also a bit problematic when the resting crew should start their work and get back to flight. There is a risk for sleep inertia and the handover situation needs to follow a clear protocol.

Railway
For railway the first comment is that they already have the dead man’s grip, foot or pedal or hand. The system asks the driver not only to have their hands on the switch, but they also need to push it down to tell the system they are still there. The dead man grip is however not a support to increase alert driving, it is rather a system that takes over when the driver fails to keep alert.

The more you are implementing automation, the more tasks you need to add on to make sure that the drivers are still in the loop. This can be seen as contra productive and there is no system available the contribute to keeping the driver alert.

Maritime
The main problems with driver impairment are due to the type of shift they work (for instance 6 hours on - 6 hours off or 4 hours on - 6 hours off). Already, there are solutions for monitoring both the automated systems on the ship and the crew and give some advice. It is not clear what Mediator will bring that is new.

4.3.2.4. Switching between human and automation

Comments from the whiteboard
In aviation, medium to long-haul flights are usually operating at the highest level of automation most of the time and the need for switching is limited. During single pilot operations, however, when the pilot becomes really incapacitated, switching to higher automation could be beneficial. The problem in aviation is usually that the pilot must switch down a level (not up), like a hand-over in car driving. Air Traffic Control asks the pilot to do something that cannot be done via the Flight Management System, so the pilot must do it via a lower level of automation, interacting directly with the autopilot systems by using the mode control panel. Challenges are deciding what the system should do exactly and determining that it is safe to give control to the system.
The currently available automated systems in rail and maritime are not of the same level as the ones in passenger cars. It is therefore difficult to foresee the benefit of a Mediator system to suggest who is fittest. Significant technical development would be necessary. In maritime operations, the current automated systems will terminate in case of a sensor alarm or an operator action but there is work in progress to meet autonomous requirements within two years.

Aviation
The discussion was not very positive to the proposal on switching to higher automation if the pilot is impaired. This type of support was not seen as useful. A lot of tasks are already automated.

Maritime
It was discussed that this already exist in maritime, the most crucial aspect is to convince the officer on watch to use it. There is a system that supports the human to take back the control if the vessel cannot keep the ship in position. This is seen as positive.

Rail
Rail is far from automation. The speed handling is coming. However, is this a risk? Driver advisory systems with information from the traffic control is also a more common solution. Still, this is not solving the problem, rather moving it.

One main railway line with automation is the Rio Tinto line in Western Australia, transporting iron ore from mines to the port for shipping. The human drive the last part into the mine. They have a kind of remote solution if needed.

4.3.2.5. Results from the survey

The survey was completed by five experts, two had their main expertise in aviation, two in rail and one in maritime. It was possible for all experts to give ratings related to all transportation domains in the survey.

All exploitable results were rated as fairly relevant for all modes of transportation. Most ratings were 4 or 5 on a scale from 1 = not at all relevant to 5 = very relevant. Experts from the aviation domain gave more inconsistent ratings about the relevance of these concepts for aviation.

The judgements on whether it would be feasible to implement the MEDIATOR concepts in other transport domains varied more than the ratings of relevance. Switching between human and automation was considered most feasible to implement for all transport modes. Ratings were 4 or 5 on a scale from 1 = not at all feasible to 5 = very feasible, with only one exception (one expert’s rating was that it is not at all feasible in aviation). The other concepts had ratings between 3 and 5.

It was anticipated that drivers and pilots would be least willing to have a system for predicting fitness (all ratings were 2 or 3 on a scale from 1 = not at all to 5 = very much). Maintaining mode awareness had the highest ratings for willingness to have (all ratings were either 3 or 5).

The experts thought that a MEDIATOR system could improve safety to some extent for all domains (most ratings were 4 or 5). Again, a few ratings were low for the aviation domain.

The experts were in general very unsure of how long it would take to reach market (Technology Readiness Level, TRL9). Most of the answers were “don’t know” on these questions.

4.3.3. Examples of HMI solutions from Maritime area inspired by MEDIATOR concept.

For the maritime sector the inspiration from the MEDIATOR results were used and implemented in the environment for the operators. This is in detailed described in Appendix 2 and 3.

5. Road maps

In the following section potential roadmaps for a MEDIATOR system in aviation, maritime, and rail domains are presented. The exploitation roadmaps are based on the foreseen exploitable results of the MEDIATOR system that have relevance to aviation, maritime, and rail transport communities, also with reference to a potential market for the MEDIATOR system. The main objective of the MEDIATOR Roadmaps is to provide a stakeholder view on the long-term development of systems like MEDIATOR in Europe. The methodological approach used to develop exploitable roadmaps has been based on the project's development and validation activities, and feedback from the MEDIATOR stakeholder workshops. Data about the identification and management of intellectual property for other domains are not a part of this work. In the project this is done for Road only and described in Mediator deliverable D5.9 (Fiorentino et al., 2023). All MEDIATOR results will be described hereafter in a common structure, based on design needs in terms of further development of Mediator subcomponents:

- Technological needs to cover the evolution of vehicles and technologies in the next years.
- Validation needs to increase scenarios and trustworthiness of systems like Mediator.
- Future needs have been summarised in roadmaps relating to short, medium and long terms.

The roadmaps for aviation, maritime, and rail are designed in a similar way as the roadmaps for road transport but with different time intervals. The roadmap tables are intended as a timeline with increasing time to market from left to right. Exploitable results that have a short time to market are on the left (high TRL) and concepts that need research and development are to the right (low TRL) as they have a longer time to market.

B.1. Aviation

The principles / the technologies that were developed in MEDIATOR may be applicable in the aviation domain as well. Nowadays in commercial air transport it is common to fly aircraft with a crew of two. However, modern concepts of operation like extended minimum crew operations or single pilot operations, rely on the principle that one pilot can, at least during parts of a flight, operate an aircraft alone. Important for those concepts is that pilot workload and situational awareness are good during the whole flight, also during non-nominal situations or emergencies. Often technological (AI) solutions are sought to support the pilot. To support or enable such systems it seems very logical that the aircraft needs to assess the pilot state constantly and adjust its interface and information presentation accordingly. The MEDIATOR approach towards assessing driver state and deciding who is better at operating the system - the car or the aircraft - seems a promising approach that builds further upon the MEDIATOR approach. After all, with those new concepts for flying aircrafts with just one pilot, with extensive automated support, is that the pilot might be distracted, bored, fatigued, just like in the MEDIATOR concept.

Also, the MEDIATOR approach towards informing a driver about the mode in which the car is operating might be relevant when aircrafts become more automated. Methodologies to inform the pilot in an intuitive and timely manner when his/her attention will be needed again might be very relevant in the future cockpit.

Putting both ideas into a solid roadmap is not so straightforward. One opportunity arises with EU funded projects that have already started to explore feasibilities of monitoring the pilot, and using that information to optimise information presentation to the pilot accordingly. The intention of the Royal NLR is to start by introducing both ideas from MEDIATOR in these EU funded projects and so see how the different ideas will be received.

Further, the ideas will be distributed within the NLR, where several designers, and evaluators of design might get access to these principles. Via this approach the MEDIATOR design principles will not only reach the civil flight cockpit, but also air traffic control and the military domain.

B.2. Maritime

Maritime operations are quite different from driving a car, but the concept of mode operation has been used for a long time. This have been mainly managed by manual procedures and in more recent years, by digital procedures. HMIs have to some extent been used to inform about current operation mode (transit, approach, dynamic position, diving etc.). These modes are usually based on the capability of the ship and manning and it has been important that current operation mode is well known.

Even if maritime already has some features that are similar to MEDIATOR built-in to different products, they are not necessary looked at in a holistic manner as done in MEDIATOR, which is somewhat new.

The maritime industry is now developing new automation systems for autonomous ships and shore-based control centres are built to monitor these types of ships. A holistic approach as demonstrated in MEDIATOR can improve and ensure good situation awareness for these information centres. The first-generation autonomous ships are newbuilds which are fully electric and are designed for shorter transport distances (feeders). Such ships are already built and are sailing, however with a very small crew. New software is developed to replace the human onboard and is gradually to be implemented and tested. They are planned to be fully ready within two years.

Table 9: Roadmap Maritime.

Maritime roadmap	<2 years (Production)	3-5 years (Innovation)	>5 years (R&D)
Design	Operative prototypes for real-world testing	Finalized UI and UX	New UX concepts for monitoring several ships from one operations centre workstation
Technology	New sensors under development and testing	Components ready for production	New sensors for Inland waterways. Concepts for communication between ships and autonomous vessels
Validation	Regulatory, Approvals	Class approved	

B.3. Rail

Train operation is different from car driving in several aspects. For instance, the automation levels are different, the traffic situations are not at all similar to road traffic, you only control the longitudinal situations, the vehicle fleet is relatively old, the driver is a professional and the driving task is different. Therefore, the MEDIATOR system and concepts would need to be modified to fit the rail domain. Some of the concepts discussed could, however, be relevant also in rail operation. The general roadmap for implementing a MEDIATOR system in rail is presented in Table 10. Taking the GoA levels to the MEDIATOR perspective MEDIATOR system cover GoA 1 and GoA 2. The development and implementation of rail automation is a prerequisite for the need of a MEDIATOR system in this domain. These developments are included in the table even if they are not directly related to the MEDIATOR exploitable results.

Table 10: Roadmap *Rail.*

Rail roadmap	<2 years (Production)	3-5 years (Innovation)	>5 years (R&D)
Design	Ensure privacy and data protection related to driver monitoring.	Compliance with international standards. MEDIATOR HMI solutions adapted to the rail domain.	
Technology	Rail automation implementation (GoA 1.5). MEDIATOR driver state detection system development for rail (stand-alone systems since trains are very different in age and matureness).	Rail automation development (GoA 2). Development of more sophisticated automation fitness monitoring.	Development of the central mediation component and decision logic for rail.
Validation	Simulator trials of driver monitoring. Real-world trial for automation (GoA 2).	Real-world trials for driver monitoring.	

With an increased use of automation in the rail domain, it is foreseen that there might be a need to support the driver in maintaining mode awareness. In many cases, the train fleet will not be replaced with new vehicles. A challenge is therefore to develop stand-alone systems that can be retrofit into old trains. The developed system would need to be modified to handle the specific types of automation used in the rail domain.

The need for keeping the driver in the loop is mainly relevant in low-speed situations like passing stop signals, when shunting, and various types of train or infrastructure failure (<40 km/h). The need for fast reactions by the driver is more crucial in those situations as this is where the driving actions (e.g., braking) will have more immediate effect. Some solutions are already used or being developed for keeping the driver in the loop in the rail domain, such as the dead man's grip. Further developments here could be monitoring if the driver has seen and acted upon signals (i.e., through gaze detection). For example, the system could be used to confirm that the driver is aware of an upcoming stop signal.

The automated systems, developed for rail, generally do not adjust the level of automation based on environmental or traffic conditions. In one perspective, the traffic situation is much more predictable and the ODDs for automation are well defined. However, weather conditions, topography, type and weight of goods, number of passengers etc., are factors of importance for how to drive the train optimally. These factors influence efficiency, safety, comfort etc. More sophisticated monitoring of automation fitness could thus be relevant also in the rail domain. The roadmap for rail thus includes development of a system that warns if the train automation is not working optimally and lowers its speed or hands over control to the human.

Monitoring of human fitness is a more delicate question in the rail domain. Driver unions are strong, and it is foreseen that driver monitoring for detecting fatigue and distraction could be seen as a privacy issue. As for the other concepts discussed, a stand-alone system tailored for the train environment would need to be developed. Driver monitoring technology applied in MEDIATOR could be modified to fit the various train designs currently used.

Based on the developments and modifications of the MEDIATOR technology needed to fit the rail domain, a central mediating system for switching between human and automation would require time for research and development.

6. Limitations and further research

From the benchmarking we learned that new systems should not just manage, but also enhance the interactions between drivers, passengers, crewmembers, vehicles, and surrounding traffic. This perspective will have profound implications in the development of automated systems and vehicles.

Another area for further research is related to training and skills. The more automated operations the less training the operators get. How to make sure you keep the competence with less training is important to address in the future. It is also important to be aware that for professional drivers/operators, there will be possibilities to do other work-related tasks in addition to the primary transportation task, and for non-professionals, there is a need to consider the vehicle as a living space. In both situations, humans will extensively act out-of-the-loop.

Comparing driving a car and being an operator in maritime, aviation or railway context there are many differences, including traffic behaviour, traffic density and legal requirements, but also behaviour and the need of skill and the training provided. One crucial issue is related to the speed they move in and when the driver/operator needs to be in the loop and when they are allowed to be out of the loop. This is a topic that makes it difficult to easily transfer results from the road sector to other sectors. Doing so would require major adaptations of most underlying monitoring and decision technologies developed in MEDIATOR.

The road sector is more mature when it comes to research about fatigue detection compared to other sectors that mostly looked at this from a research point of view up to now. However, adapting state-of-the-art fatigue and distraction monitoring systems for use in other sectors is not straight forward since the operator environment is different. Especially in rail and maritime, operators can move around. Also, the requirements defining what it means to be attentive and situationally aware are different compared to road. This is an area that requires further research.

The work suffers from some limitations. For example, the text in the deliverable is based on the results achieved at two workshops. It reflects the opinions from the workshop participants and might not be anchored in scientific findings. In order to be able to generalise the results further investigations are needed.

In what way the system communicate is important to focus on to keep the driver/ operators trust to the system. From the workshop results, there is a wish to always be able to override the system. However, this cause a risk if the driver/operator is unfit, or does not have enough situational information, to take over. The only issue that can be agreed on is when the operator does not respond to a take-over request, then the system must be able to avoid a crash. This area is also interesting for less time critical situations in other sectors for which different thresholds and strategies needs to be developed.

7. Conclusion

The goal of this document has been to identify the most relevant exploitable results from the MEDIATOR project to support operators from other transport domains. For this purpose, various experts from the aviation, maritime and rail sectors have collaborated in the writing of this deliverable. Specifically, the experts have provided information on the most relevant human factors problems in their sectors as well as on the existing systems to support operators in their tasks. They have been involved in the first workshop in the beginning of the project providing an early insight into what might be possible exploitable results from the project to their domain. Based on this the SWOT analysis took place. They have also been involved in the second workshop in the end of the project giving their view on a selection of some key findings.

Initially, the main exploitable results across domains were covering the area of (i) the algorithms to predict the time to automation (un) fitness, (ii) the algorithms to detect and predict fatigue and inattention, and (iii) the associated HMI components to communicate the outcome of the algorithms to the operator so that preventive or corrective actions can be taken. As a main advantage, the experts consider the inclusion of these systems as an effective solution to improve the safety and comfort of the operators, allowing them to devote more time to other work-related or not work-related tasks. However, experts also concur in that a main challenge for the implementation of this system is to adapt the monitoring equipment to operators with larger degrees of freedom to move. This is the case in today's ships, where the crew can move freely between different stations, but also in the railway sector, where the increasing automation will enable train drivers freely move inside and outside the cabin.

From the initial workshop it was clear that there are situations or scenarios in all transport sectors with a potential to learn more from the road domain, or at least to exchange experiences. In the second workshop looking at the key findings the discussions were more critical in relation to relevance for other sectors and clear limitations were identified. One important aspect to consider was the fact that in all transport domains, except for road, is operated by professional drivers This cause a major difference both in terms of education, experience, legislation and possible business models. The key findings presented were not seen as possible to implement in a short time for the other sectors. Further developments of technical solutions, adaptations to less static work environments and validation were seen as important.

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Appendix A Survey after the 2nd workshop

Do you find the concept **maintaining mode awareness** relevant also for other transport domains?

	Not at all 1	2	3	4	Very relevant 5	Don't know
Aviation	○	○	○	○	○	○
Rail	○	○	○	○	○	○
Maritime	○	○	○	○	○	○

Do you find the concept **maintaining mode awareness** feasible to implement in other transport domains?

	Not at all 1	2	3	4	Very feasible 5	Don't know
Aviation	○	○	○	○	○	○
Rail	○	○	○	○	○	○
Maritime	○	○	○	○	○	○

Would the concept **maintaining mode awareness** be something the drivers/pilots/operators are willing to have?

	Not at all 1	2	3	4	Very much 5	Don't know
Aviation	○	○	○	○	○	○
Rail	○	○	○	○	○	○
Maritime	○	○	○	○	○	○

Would the concept **maintaining mode awareness** improve safety in other transport domains?

	Not at all 1	2	3	4	Very much 5	Don't know
Aviation	○	○	○	○	○	○
Rail	○	○	○	○	○	○
Maritime	○	○	○	○	○	○

How long would it take to make the concept **maintaining mode awareness** ready for market (TRL9) in other domains?

	2 years or less	3 years	4 years	5 years	6 or more years	Don't know
Aviation	○	○	○	○	○	○
Rail	○	○	○	○	○	○
Maritime	○	○	○	○	○	○

Appendix B Maritime - similarities and differences compared to road

This chapter reports on similarities and differences between automated systems used in maritime and road transport that is related to the work done in the MEDIATOR project.

B.1. Similarities and difference between automated systems on cars and ships

There are many differences between automotive and maritime. On cars there is a fixed driver position with input devices like steering wheel, pedals, gear shifter, handles, switches, touch-displays etc. organized around the driver. Gear has for long been automated and cost for this option has been reduced so now more and more cars are delivered with an automatic transmission. With the new wave of electric vehicles brought to the market there are no gear anymore, just a fixed ratio on the transmission. Adaptive cruise control has been available on premium cars for decades and is now almost standard in most cars. Steering and Lane Control Assist is becoming more and more available in cars. For some car brands, when driving in Level 1 and 2 activated, the automation also takes control of the window wipers. On most cars the driver controls the wiper, but when L3 and L4 ADAS systems are getting available, these systems must also control the wipers and headlights. In darkness Adaptive Headlights will control the headlamps and automatically switch between high and low beam. There are many levels and types of automation in cars already. Many drivers are unfamiliar with the available Level 1 and 2 systems in their cars and do not trust the system enough to use it. With upcoming Level 3 and 4 systems, there is definitely a need for a Mediator system.

Cars are mostly driven on shorter trips with all types of drivers. Longer tours are done in weekends and vacations. A few of them use their car in their daily work (taxis, delivery cars etc.). On ships there are always professional mariners. The vessel trips can be short as for some ferries but can also last for days or weeks. Some vessels do offshore operations and can be in operation for months and even years. There are normally two or three crews with a shift schedule for 2 to 4 weeks or longer. The shifts can vary in length and are typically; 4 hours on duty and 8 hours off, 6 hours on and 6 hours off or 12 hours on and 12 hours off. Fatigue is here a different issue than in a car.

Another difference is that there is only one steering position on cars.
On ships there are normally two mariners on the bridge or three on some vessel types. In some cases, only one needs to be on duty. The bridge is typically equipped with two workstations, where one is dedicated for manoeuvring and navigation. The other is set up for monitoring but can take command of the manoeuvring if needed. These two workstations are placed at the forward bridge. In addition, there are workstation for manoeuvring and navigation on the bridge wings. These are typically used when docking. Vessels performing offshore operations has often an aft bridge with typically two or more workstations, see Figure 6.

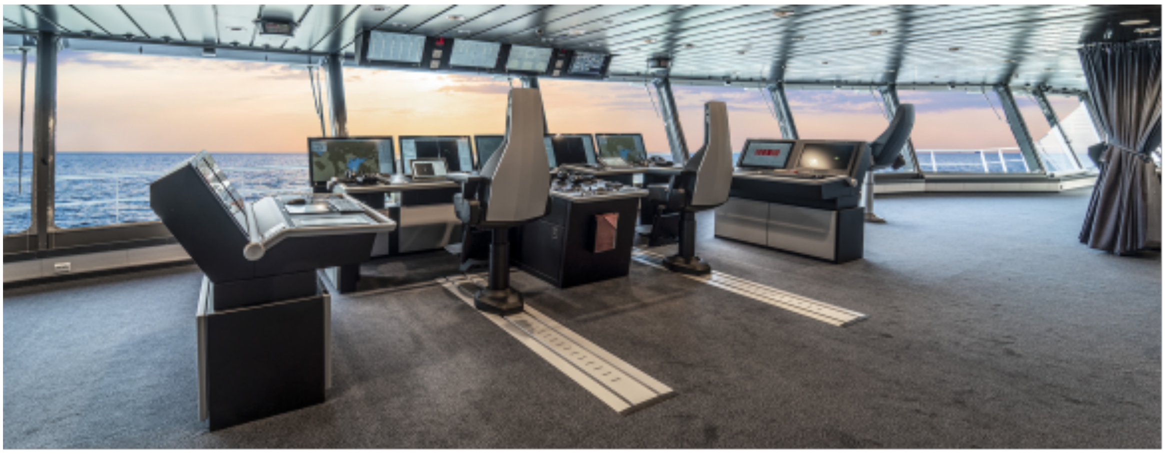

Figure 6: Colour Hybrid bridge with one workstation for manoeuvring and navigation, and one for monitoring.

For ships, **Auto Pilot** has been available for a long time. This device keeps the given heading and the automation adjust the rudder(s) or azimuth pod(s) to maintain this heading. The vessel speed is also set and does not need to be held in position by the mariner except for on high-speed vessels (HSV) where the speed and heading is typically controlled by a joystick with spring-back.

The Auto Pilot system is mainly used on open sea with smaller vessel traffic. The mariner can walk away from the workstation for manoeuvring and navigation and do other tasks on the bridge but is still responsible for the sailing. The vessel can maintain heading, but still drift off from the route due to impact from wind and current.

A more advanced type of Auto Pilot is the **Track Pilot**. This will keep the vessel on the track given by the selected route. It will sail the vessel to the next waypoint where the vessel takes a defined turn and continue to the next waypoint. The vessel will sail by itself, but do not use any sensors to detect other ships, land, shallow waters, banks etc. It needs a mariner to overview the situations and do necessary actions.

B.2. Auto Docking

Auto docking is an automated system used on pendulum ferries going frequently between mainly two, but sometimes more harbours on a regular schedule, transporting cars and people. The bridge is typically placed centrally on the vessel with good view to the main deck and gates at each end. The sailing direction is changing after each trip. Here the mariner is sitting more like in a car with all needed input devices and visual display units around. When entering the harbour, the mariner can choose to activate Auto Docking by pushing a button. The ferry will then follow a defined track and dock automatic. It will adjust position, steering and speed and the mariner is sitting stand by and can take over manual control if needed. This is comparable to L3 in ADAS systems.
In Figure 7 a system operation overview is presented.

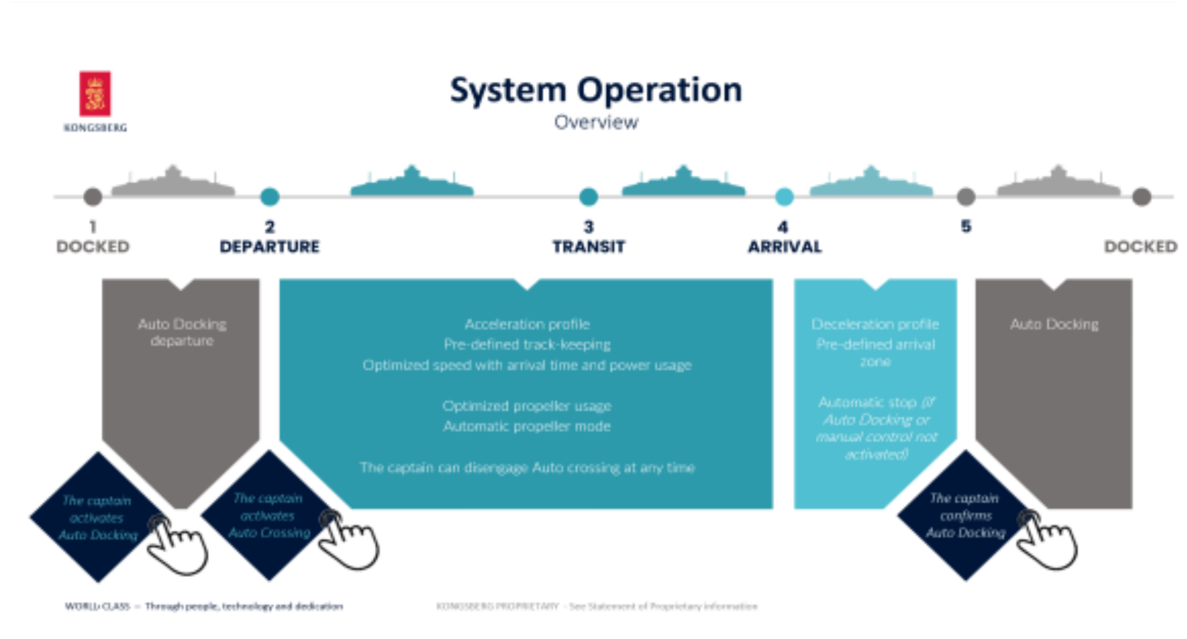

Figure 7: System operation overview.

Figure 8: Bastø Electric docking at Horten ferry quay in Norway.

The Time Budget concept could be incorporated for this type of ferries. Informing the mariner during the crossing of how long time there is until autodocking can be activated. As this trip is well-known and repeated several times a day, the need for this additional information can be seen as unnecessary information. It could be an option, but testing and evaluating of a Time Budget concept is of interest.

B.3. Mediating between ROC-operator and automation

Remote Operation Centre (ROC) is an onshore control centre, overviewing one or several autonomous vessels. The level of automation will decide how many vessels one operator can overview at one time. The goal is to have L5 automation by which the vessel knows what to if something unexpected occurs, but Level 4 is where the focus is now. The operator must then be available for taking over and manoeuvre the vessel manually from his remote position, see Figure 9.

Figure 9: Workstation at Remote Operation Center in Horten, Norway.

The vessels will sail autonomous parts of the route, depending on the degree of sensors and their availability to function under all circumstances and conditions. Each monitored vessel could have a Time Budget as in Mediator, displaying how long they can sail autonomously, and when the operator needs to take over manual steering. When monitoring several vessels, the logistics can get more complex. Having a Time Budget can give a list of which vessels to take over first and last. Having some kind of Mediator system that negotiate who should sail, the automation or the ROC-operator, could also be useful. The case is not if the operator is just fit, he also needs to have the capacity to take over the vessel control at the desired time or at a sudden time if something unexpected happens. The Mediator system must then be able to slow down or hold back the affected vessels.

Communication

Unlike cars, vessels communicate between each other on radio (VHF) and agree on who should turn, slow down etc. when they are on potential collision courses. How this communication should be between a traditional manned vessel and an unmanned autonomous vessel, must be looked further into. How autonomous vessels should communicate between each other is another topic to solve. For a start the ROC-operator should be able to do the communication between the different vessels.