Exploitation roadmap road transport

Deliverable D5.9 – WP5 – PU

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List of abbreviations and acronyms

AB	Advisory Board
AD	Autonomous Driving
ADAS	Advanced Driver Assistance System
AI	Artificial Intelligence
API	Application Programming Interface
AV	Automated Vehicle
DMS	Driver Monitoring System
ERTRAC	European Road Transport Research Advisory Council
Euro NCAP	European New Car Assessment Programme
GSR	Global Safety Regulation
HF	Human Factors
HMI	Human Machine Interaction
IAM	Integrated Assessment Models
KER	Key Exploitable Results
KPI	Key Performance Indicator
LIDAR	Light Detection and Ranging
MER	Main Exploitable Result
MRL	Market Readiness Level
NDRT	Not-Driving Related Task
ODD	Operational Design Domain
OEMs	Original Equipment Manufacturers
RRL	Regulatory Readiness Level
SAE	Society of Automotive Engineering
TRL	Technology Readiness Levels
TTAF	Time to Automation Fitness
TTAU	Time to Automation Unfitness
TTDF	Time to Driver Fitness
TTDU	Time to Driver Unfitness
TUC	Chemnitz University of Technology
V2X	Vehicle-to-everything
WoOz	Wizard of Oz

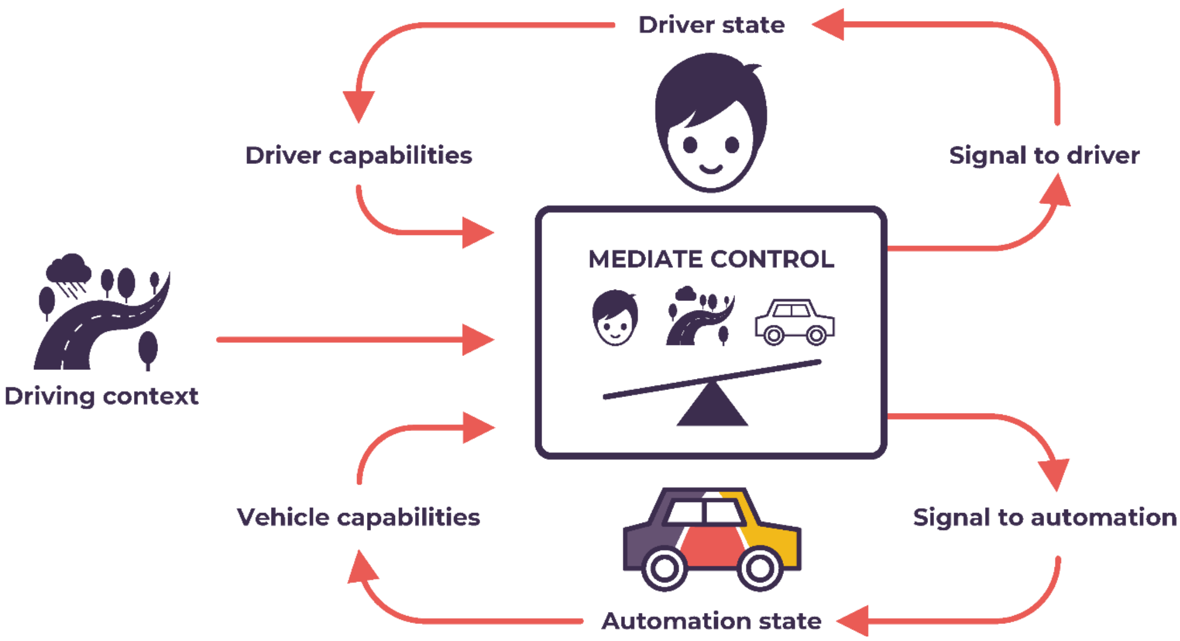
About MEDIATOR

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

This public Deliverable report describes the MEDIATOR results from an exploitation perspective to make sure that solutions are accepted, adopted and ultimately implemented in road transport.

The current deliverable is part of the MEDIATOR Dissemination & Exploitation activities and aims at disseminating the project's activities and results, expressing them in terms that are readily understandable to the various stakeholders; as well as furnishing roadmaps for further exploitation by the road transport community.

The main exploitable result from MEDIATOR is the Mediator system. It is composed of sensors and software components capable of: (1) assessing/predicting human and automation fitness/unfitness, (2) mediating the vehicle control via a decision-making component, (3) implementing several actions adapted to each use case by using different Human Machine Interface (HMI) strategies.

The Mediator system has been tested in lab and on-road with reference to three automation modes and ten use cases. The automation modes were defined from a human perspective, where the human either has a continuous monitor and/or control task (Continuous mediation), needs to be ready for takeover in the order of seconds (Driver StandBy), or could be out of the loop completely and even fall asleep (Time to sleep). The ten use cases included safety related scenarios, such as take-overs 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.

To ensure feasibility of MEDIATOR solutions for market implementation in transport, stakeholders from the automotive industries were involved in addition to the industrial partners within the consortium. For this purpose, different approaches were used: (1) The Industrial Advisory Board was consulted regularly right from the beginning of the project; (2) At the end of the project, three MEDIATOR workshops (Netherlands, Italy and Germany) were conducted to involve all possible interested stakeholders (e.g., academia, tier supplier, engineering companies). During the workshops, feedback regarding MEDIATOR outcomes (automation, human factor, HMI and Central mediation component) were collected and discussed (Word Café approach).

To maximise the impact of MEDIATOR results, the deliverable reports four roadmaps based on the foreseen exploitable results of the MEDIATOR system that have relevance to road transport communities. Further a potential market for the MEDIATOR system will be referenced.
The roadmaps, linked to the main logical components of Mediator system, ensures that MEDIATOR results can feed into their domains and thus be further exploited –with mode-specific adaptations. The roadmaps for exploitation of the MEDIATOR results identify opportunities as well as potential barriers.

1. Introduction

This chapter describes the exploitable results of the MEDIATOR project. These exploitable results contribute to MEDIATOR exploitation strategy.

The exploitation activities are based on the exploitation of the MEDIATOR results with the goal to that solutions are accepted, adopted and ultimately implemented in transport solution.

To make sure that MEDIATOR solutions were feasible for market implementation in addition to the industrial partners within the consortium, stakeholders from the automotive industries were involved in different ways:

- from the beginning with the Industrial Advisory Board
- at the end of the project with three MEDIATOR Workshops in Netherlands, Italy and Germany, to: (1) involve all possible interested stakeholders (academia, tier supplier, engineering companies, etc.); (2) collect their feedbacks about MEDIATOR outcomes (automation, human factor, HMI and Central mediation component) also with their direct involvement in discussion (Word Café approach).

The topics automation, human factors and HMI are already well defined in other transport modes. For this reason, a continuous cross-fertilisation between other transport modes and road transport communities is pursued during MEDIATOR Exploitation activities, In order to set the MEDIATOR activities, a first workshop was organised during the first stage of the project. The workshop aimed to answer the following question: *"How can the other transport modes support MEDIATOR?"* It was useful to understand how other transport modes deal with monitoring of the automated system without increasing the cognitive workload, and which interface enables a human to do other things without having particular attention. The second workshop took place towards the end of the project. The scope 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. For further details about the workshops refer to Anund et al., (2023).

Figure 1.1 summarises the global exploitation strategy and the very close link (also called "cross fertilization area") between the exploitation of the MEDIATOR results targeted at road communities and the exploitation of the MEDIATOR results targeted for ither transport modes (rail, aviation and maritime). In details inputs from other transport modes were used to identify the main MEDIATOR innovations. A SWOT analysis was done, followed by an analysis of market trends, allowed to identify the most relevant exploitable results and related roadmaps. Late in the project the key findings from the MEDIATOR results achieved were discussed with experts to implement roadmaps for other transport modes.

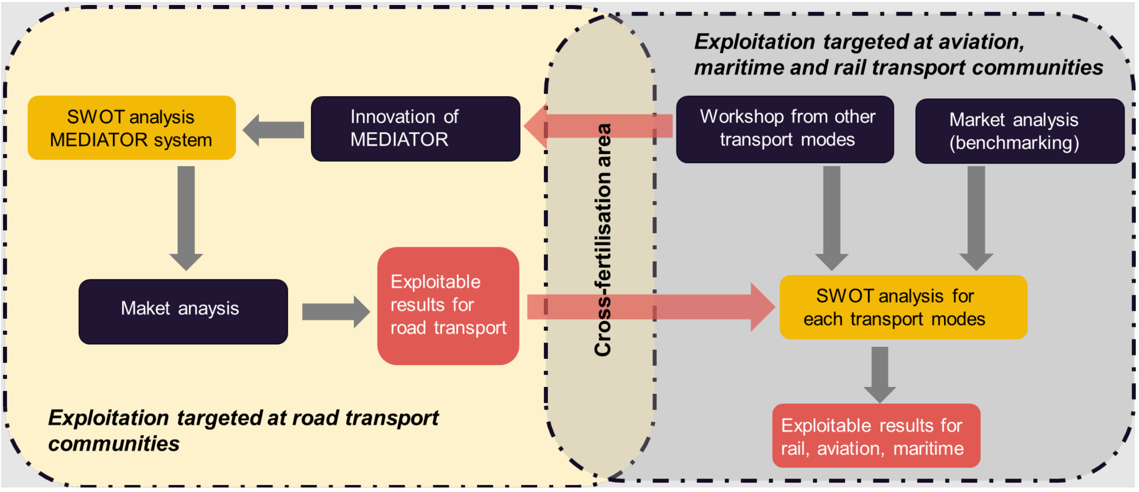


Figure 1.1 Global exploitation strategies related to road transport communities and targeted at aviation, maritime and rail transport communities.

To maximise the impact of the MEDIATOR results and to point out the needs for future developments, the deliverable reports appropriate roadmap plans to support the exploitation of the MEDIATOR project's outcomes targeting the road communities.

1.1. Aim and structure of the deliverable

The scope of this work is to define the MEDIATOR Exploitation roadmap related to road transport. The exploitation roadmaps on road transport are based on the foreseen exploitable results of MEDIATOR system that have relevance to road transport communities, also with reference to a potential market for the MEDIATOR system.

As a starting point, Chapter 2 describes the exploitable results of the MEDIATOR project, contributing to the MEDIATOR exploitation strategy. Results are related to: Human fitness/unfitness, Automation fitness/unfitness, Central mediation component and HMI.
A market impact analysis has been performed, for each exploitable result, by using an Integrated Assessment Model (IAM) for the assessment of both regulatory and market constraints. The market analysis as well as the maturity levels of the exploitable technologies are described in Chapter 3.

The MEDIATOR Workshop Café was organised to receive suggestions for the MEDIATOR exploitable results, delivering roadmaps for further exploitation by the road transport communities. The methodology adopted comes from the World Café that is an innovative way to allow interaction between the project consortium and stakeholders using an interactive way to listen to stakeholders' needs and suggestions / feedback / ideas. Results are in Chapter 4 together with the suggestions received from the Advisory Board in several meetings held during the MEDIATOR project.

Chapter 5 contains the four MEDIATOR exploitation roadmaps related to human fitness, automation fitness, HMI, and central mediation component.

1.2. Relevance of Human factors in automated vehicles

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 understimulating 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; Saxby et al., 2008).

One of the most relevant human factors problems highlighted in the literature is driver fatigue, which is estimated to cause 20% of traffic accidents worldwide. (European Commission, 2021; Zhang et al., 2021). Multiple factors contribute to fatigue development during driving. Some of these factors are linked to task characteristics such as task duration or task complexity and lead to the so-called task-related fatigue. Recent studies (Körber, Cingel, Zimmermann, & Bengler, 2015) have shown that automated systems can also generate fatigue-related symptoms like boredom, discomfort, task disengagement and lower vigilance levels. This should translate into the implementation of detection systems capable of discriminating different types of fatigue[1] suffered by the driver and activating suitable strategies. For drivers with active fatigue, for example, strategies aimed at reducing task load, such as increasing automation level, should be suitable. In passive fatigue (, however, drivers may benefit from "energising" strategies, such as take-over certain driving tasks or engage in non-driving related tasks (NDRT). As for drivers affected with sleep-related fatigue, strategies should be aimed at encouraging drivers to take a nap in specific areas on the road, or during highly automation levels (i.e., Level 4).

Research has also shown that relieving drivers from the driving tasks increase drivers' proneness to engage in other NDRTs (e.g., Banks, Eriksson, O'Donoghue, & Stanton, 2018; Carsten, Lai, Barnard, Jamson, & Merat, 2012; Llaneras, Salinger, & Green, 2013). Although this is permitted in level 3 and higher levels, such behaviours may slow down drivers' reaction to a take-over request. In particular, the greater proneness to engage in NDRT is, to some extent, related to the automation overtrust problem (Hergeth et al., 2015). Trust is defined as the "attitude that an agent will help achieve an individual's goal in a situation characterised by uncertainty and vulnerability" (Lee and See, 2004). While a sufficient level of trust is necessary to ensure that drivers use the system and benefit from its capabilities, excessive level of trust may lead to overreliance and misuse of the system. This means that drivers tend to delegate too much responsibility to the automation system, and even activate it in conditions it was not designed for. Management of reliance in automation is mainly related to provide continuous trustworthy feedback to the driver and give him/her the possibility to adjust the level of automation based on his/her preferences (Lee and See, 2004). With increasing levels of automation drivers will be able to gradually phase-out control over the manoeuvres and transfer it to the automated vehicle. This trend will 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.

1 There are different types of fatigue:

- Mental fatigue can be divided into active fatigue and passive fatigue. Active fatigue is caused by tasks that require continuous coordination of perceptual activity. Passive fatigue is caused by tasks requiring few perceptual activities and long-term monotonous reactions (Zhang et al., 2021).
- Sleep-related fatigue (May & Baldwin, 2009) 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

Therefore, new systems like Mediator should enhance the interactions between drivers, vehicles, and surrounding traffic.

1.3. SAE Levels of Automation and Mediator terminology

There are different ways to define the capabilities and responsibilities of an automated vehicle. 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 (ODD). 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 1.1. 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 1.1: Automation levels addressed in MEDIATOR (OEDR: Object and Event Detection and Response).

<table>
<tr><td></td><td colspan="3">driver supported</td><td colspan="3">automated driving</td></tr>
<tr><td>SAE</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Automation responsibilities</td><td>warnings and momentary assistance</td><td>lateral <u>or</u> longitudinal support</td><td>lateral <u>and</u> longitudinal support</td><td colspan="2">automated functions drive the vehicle within the defined operational design domain</td><td>automated driving under all conditions</td></tr>
<tr><td>Human responsibilities</td><td colspan="3">driver must constantly supervise</td><td colspan="2">driver is not required to drive, but must take over upon request</td><td>driver is a passenger</td></tr>
<tr><td>Euro NCAP</td><td></td><td colspan="2">Assisted (shared control)</td><td colspan="2">Automated (vehicle in control)</td><td>Autonomous</td></tr>
<tr><td>Automation responsibilities</td><td></td><td colspan="2">OEDR and other supportive tasks</td><td colspan="2">OEDR and driving. Vehicle has full responsibility</td><td>full control</td></tr>
<tr><td>Human responsibilities</td><td></td><td colspan="2">OEDR and driving. Driver is fully responsible. No safe transfers</td><td colspan="2">Driver can do non-driving related tasks, but must take over upon request</td><td>driver is a passenger</td></tr>
<tr><td rowspan="2">MEDIATOR</td><td></td><td colspan="2">Continuous mediation</td><td>Driver standby</td><td>Time-to-Sleep</td><td></td></tr>
<tr><td></td><td colspan="2">drivers supported by automation but are responsible and must monitor surroundings <u>and</u> automation.</td><td>driver must take back control upon request (order of seconds)</td><td>driver must take back control upon request (order of minutes)</td><td></td></tr>
<tr><td rowspan="2">HMI</td><td>Manual</td><td colspan="2">Assisted</td><td colspan="2">Piloted</td><td></td></tr>
<tr><td>non-automated, driver is in full control</td><td colspan="2">drivers are not fully disengaged and must maintain certain responsibilities. This can be steered towards a monitoring task.</td><td colspan="2">drivers monitor while automation performs driving tasks</td><td></td></tr>
</table>

2. Mediator Exploitable Results

This chapter describes the exploitable results of the MEDIATOR project. These results contribute to MEDIATOR exploitation strategy.

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

MEDIATOR key concepts are the following:

- Central mediation concept to intelligently assess the strengths and weaknesses of both human and automation to mediate between them, while also considering the driving context, ensuring that the fittest one is operating the car.
- Initiating timely and safe take-overs when needed, i.e., in case of reaching the end of the automation operational design domain (ODD) or in case of degraded human fitness.
- Preventing humans to become unfit (due to e.g., fatigue, distraction) when no higher levels of automation are available.
- Revised levels of automation taking a user centred perspective
- Not only focus on correcting degraded driving but rather focus on preventing human degradation
- Comfort scenarios where Mediator actively proposes to handover control to 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 (e.g., fatigue or inattention), overreliance and/or poor take-over performance. To achieve this goal, a broad range of sensors and systems have been developed, and partly integrated into different simulators or in-vehicle prototypes throughout the project 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 generates exploitable results in the form of technologies (hardware and software), applied to different demo platforms. There is no prototype with the complete Mediator system, but that each prototype / demo platform focused on specific parts of the Mediator system: automation, driver monitors, fatigue and HMI module. All the results will influence further research activities in the field of human factors and with regard to driver-vehicle-interaction problems occurring at intermediate automation levels. The developed technologies will be set as a new basis for the further development processes of systems like Mediator.

Mediator system is composed by sensors, and software components capable of: (1) assessing/predicting human and automation fitness/unfitness, (2) mediating the vehicle control via a decision-making component, (3) implementing several actions adapted to each use case by using different HMI strategies.

MEDIATOR has been tested in lab and on-road with reference to three automation level modes and ten use cases. 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 safety related scenarios, such as take overs 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 allows optimising the safety potential of automated vehicles, especially during the transition from the human driver to full automation.

2.1. MEDIATOR sensors/software components

MEDIATOR involves a broad range of sensors to continuously capture relevant information from the driving context, automation state and driver state. The decision-making component of the system mediates between the automated functions of the vehicle and the driver, by passing control to the agent that is assessed to be fitter to drive in the current situation. The HMI component provides/acquires information to/from the driver in such a way to prevent interaction problems occurring at intermediate automation levels.

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

- assessment/prediction of human fitness/unfitness,
- assessment/prediction of automation fitness/unfitness,
- central mediation component (also called decision logic component)
- HMI to communicate and monitor the implemented actions.

Figure 2.1 shows the information flow between the main components of the Mediator system.

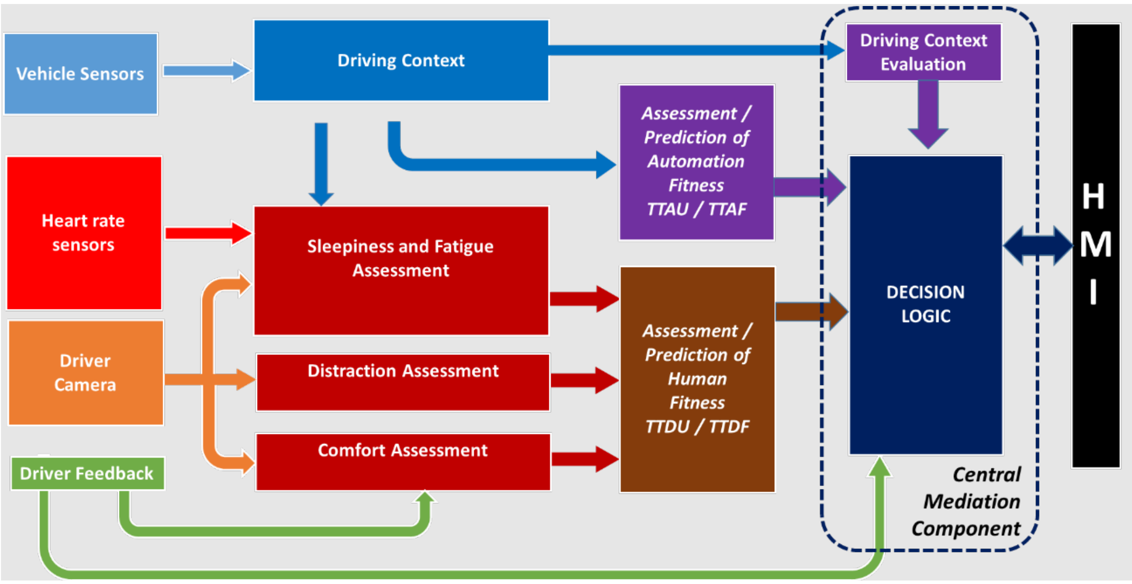


Figure 2.1 Information flow between the main components of the Mediator system.

The above Mediator key enablers have been integrated as reported in the following.

2.1.1. Assessment/prediction of human fitness/unfitness

Impaired driver states and degraded performance are detected via different sensors monitoring drivers' behaviour and physiological activity. This is done by using sensors developed within MEDIATOR, like the heart rate sensors embedded in the steering wheel and the seatbelt, as well as off-the-shelf sensors as IR cameras. Based on these measures, drivers' ongoing and predicted state is estimated and compared against information about the automation level/status and the driving context. In 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. 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 Level 3 and 4, where, after periods of disengagements, drivers need several seconds or minutes to regain a sufficient state and awareness. The TTDU, however, serves to make predictions about when driver performance may start to degrade in automation levels where his/her attention and readiness for intervention are continuously (e.g., Levels 0-2) or within seconds (e.g., Level 3) required. 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 software:

- Distraction assessment: Software that extracts gaze direction and Not-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. 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.
- Sleepiness and fatigue assessment: Software that extracts deep features resembling gaze direction, eyelid aperture, blink frequency, pupil size and facial expressions based on face videos and context information based on forward-facing videos is developed. Physiological fatigue indicators are extracted.
- Driver comfort assessment: preferred moments to switch to automation and preferred switch frequency defined offline were considered in the central mediation component as comfort affecting parameters[2].

2.1.2. 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 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 path (like highway exit, roundabout, construction zones, etc.). This information allows to estimate whether the current automated system is fit for the present and upcoming driving context and whether driver attention and/or intervention is required. Based on collected data, estimations are made for Time to Automation (Un)Fitness (TTAU/TTAF).

2.1.3. Central mediation component

This is the core component of the Mediator system where information from the driving context, automation state and the driver state are 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

2 An extensive literature research was conducted to identify driving situations in which driving comfort might be impaired and driving automation might be preferred by drivers (Rauh et al., 2023).

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 Central mediation component by optimising not only for safety but also for comfort and taking into account the capabilities and needs of the driver when making the trade-off on who is fittest to drive. As detailed in the architecture of the Mediator (see Figure 2.1) system the central mediation 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 respective 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, and any communication will be done before or after such road sections.

2.1.4. HMI

The MEDIATOR HMI is addressing main challenges related to vehicle automation; the HMI, to mediate between the driver and the vehicle/system, is based on a holistic user centric design.

The HMI software receives inputs from the central mediation component regarding human and automation's current and near future fitness as well as actions to be implemented. 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 it is expected from them. The amount, type and modality of the information presented depend on the automation level, 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 MEDIATOR HMI uses several design principles to address main design challenges related to vehicle automation. The main design principles used for the MEDIATOR HMI design are:

- Holistic approach: HMI is designed to integrate all interactions between the vehicle and the driver, as well as the interaction with other sources, which require the driver's attention.
- Designing for user acceptance: In all situations, the system could facilitate driver preferences. Driver-autonomy is likely to be the highest scope of the system, where there is no Mediator system preference towards the level of control by either driver or vehicle. Driver preferences are not considered in urgent or emergency scenarios for safety reasons.
- Designing for industry acceptance: Brand identity, i.e., brand-specific design of the HMI, is crucial for market penetration. As above, variation in design is unwanted in urgent or emergency scenarios. In all other situations, however, car manufacturers have design freedom to create brand-specific variations. Design freedom is likely to be the highest scope of the system, where there is no Mediator system preference towards the level of control by either driver or vehicle.

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 requested when the driver is distracted or proposed 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 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. The HMI components (see Figure 2.2) range from (1) ambient lighting for communicating the driving mode, (2) led strips for communicating automation mode and remaining time in this mode ((3) time budget) as to naturally work towards transitions between modes (transition of control), (4) a custom shifter to switch between (driving/automation) modes and haptic feedback devices in the form of (5) inflatable cushions in the driver seat and (6) vibrating/retracting seatbelts which are used to correct or alert a driver with degraded fitness. Furthermore, on the (7) instrument panel 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 2.2 Mode awareness through ambience, clockwise from top-left: manual, assisted, piloted and piloted dark mode.

3. Market analysis of the MEDIATOR results

In this chapter, a market impact analysis has been performed, for each exploitable result, by using an Integrated Assessment Model (IAM) for the assessment of both regulatory and market constraints, also taking into account systems and technologies actually available on the market or potential competitors.

Within the development process of the MEDIATOR innovative results, the maturity levels of the exploitable technologies are being assessed. Therefore, this document presents the detailed description of the “Technology Readiness Levels” (TRLs) of each innovation in the form of a TRL roadmap for each technology, developed in the form of algorithms, sensors or communication systems.

3.1. MEDIATOR results

The main exploitable result from MEDIATOR is the Mediator system; algorithms and sensors, generated throughout the project, are the MEDIATOR Key Exploitable Results (KERs).
For those exploitable results, a market impact analysis has been performed by taking into account systems and technologies already available on the market or potential competitors. MEDIATOR KERs and the results of this impact analysis are summarised in Table 3.1.

Table 3.1 Impact analysis on MEDIATOR exploitable results.

	MEDIATOR Exploitable result	**Systems and technologies actually available on the market**
Human (un-)fitness	Real-time fatigue detection based on physiology, camera data and driving performance	Driver Monitoring System (DMS) and many wearable monitoring devices
	Algorithm to predict and output time to driver alertness/fatigue, considering the current fatigue level and context, traffic and automation level/state	Not available on the market. Research in progress.
	Distraction detection extended to account for the surrounding driving environment	Not available on the market. Research in progress.
	Body pose and object detection algorithms to detect NDRT engagement	Many generic software libraries, but very few are specialised for driving
	Algorithm to predict and output time to driver (in)attention, taking context, traffic and automation level/state into account	Not available on the market. Research in progress.
	Algorithm to predict and output overall time to driver (un)fitness, taking all driver states from above into account	Not available on the market. Research in progress.
	Sensors in the steering wheel to detect physiologic data (heart-activity)	Some potential competitors

Automation (un-)fitness	Algorithm to predict and output time to automation (un)fitness	Not available on the market. Research in progress.
Human Machine Interface	HMI conventional Manual Human Input components include physical input technologies for the driver to interact with the vehicle (HMI and DL).	Not available on the market. Research in progress.
	HMI manual input for autonomous mode selection (shifter)	Research in progress
	HMI automated retractable steering wheel	Research in progress
	HMI Auditory Human Input Components.	Research in progress.
	HMI Visual Specific involves technologies that communicate specific information to the human.	Some systems provided as standalone devices
	HMI Visual Abstract involves technologies that attract the attention of the human or communicate non-specific information to the human	Commercially implemented on a large scale
	HMI Auditory Specific involves technologies that communicate specific information to the human	Commercially implemented on a large scale, almost exclusively navigation instructions
	HMI Vibro Abstract involves vibrational devices in seatbelt	Some applications in seating commercially available
	HMI Passive Ambiance involves technologies that manage the human perception of autonomous driving mode..	Some laboratory testing done but no commercial application
	HMI technology integration, allowing for an integral design of the whole system rather than working with multiple suppliers of closed systems.	Not available on the market. Research in progress.
Central mediation component	Algorithm for the decision on who is most capable of driving (driver or automation)	Not available on the market. Research in progress.
	Algorithm for the decision on the most appropriate countermeasure, including timing, to maintain or improve driver fitness	Not available on the market. Research in progress.
	Algorithm to adapt decisions based on personal preferences and characteristics	Many generic profiling systems, with some that are specialized for driving

3.2. MEDIATOR exploitable results and TRL

To assess the maturity level of a specific technology, the "Technology Readiness Level" (TRL) has been used. The TRL scale classifies nine different levels (HORIZON 2020 – see also Figure 3.1):

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)

- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies)

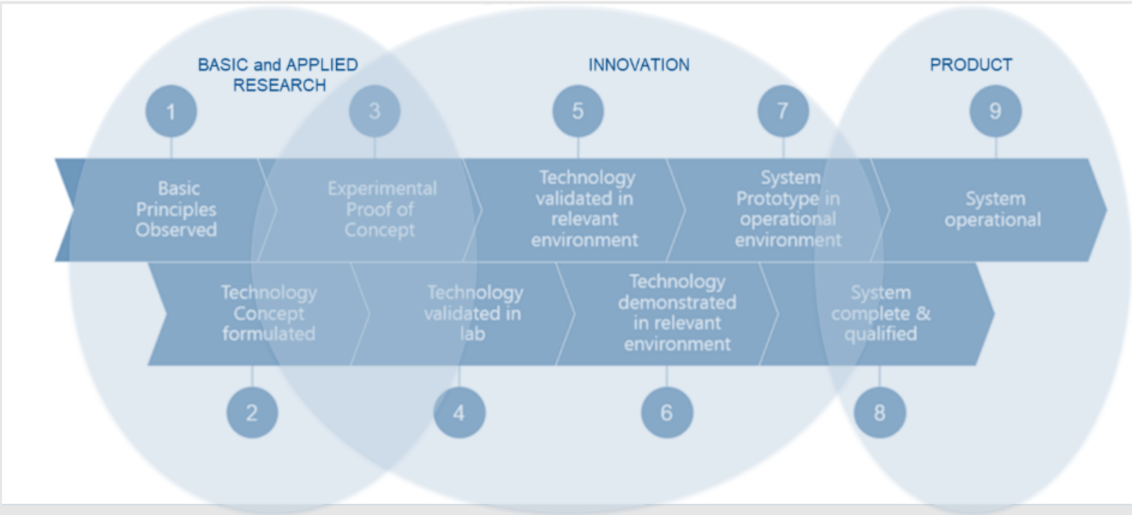


Figure 3.1 Technology readiness levels (TRL), according to EU Horizon 2020 classification (European Commission Decision C(2017)2468)

Based on the proposal of the project, the TRLs for the technical enablers and their MEDIATOR innovations has been monitored during the whole project runtime and adapted during the development process of the project. The development phase, as well as the test and evaluation of all technologies, allowed to have an estimation of the final TRL.

The main exploitable result from the project is the Mediator system; it started from TRL 2 and reached TRL 5. Based on the design and development activities (Bakker et al., 2022), and on the testing and evaluation studies (Rauh et al., 2023) in Table 3.2 the TRL description related to the Mediator system is reported.

Table 3.2 TRL related to the development of the Mediator system.

TRL level	MEDIATOR activities
TRL 2 – technology concept formulated	Technical design and development of Mediator system.
	Definition of the overall Mediator architecture in terms of components and main interactions between components. The technical software communication framework underlying the interaction between the components, each of which was designed as a modular component to be connected by a centrally designed API (Application Programming Interface) using a carefully designed set of API messages.
	Results and knowledge qualifying this TRL: • Driver state component • Automation state component • HMI component • Central mediation component

TRL 3 – experimental proof of concept	First experimental tests to evaluate Mediator central mediation component.
	Calibration of Mediator central mediation component. Required data for conceptual experiments are defined. Suitable metrics are identified and specified to measure outcome of the experiments.
	Results and knowledge qualifying this TRL: • Computer Simulation Study. Technical evaluation, simulation and evaluation High-Level Decision Logic (also called Central mediation component), based on data from the on-road study in Sweden with TI in-vehicle prototype
TRL 4 – technology validated in lab	First experimental tests to evaluate the human fitness detection of the Mediator system conducted using driving simulators. First evaluation of technology complete.
	Customisation of different driving simulators to evaluate the functionality of Mediator system. Implementation on different demo platforms and experimental setup are completed. This includes correctness tests of the implementation and input/output validation of the technology concept in several use cases mainly based on fatigue, distraction and comfort.
	Results and knowledge qualifying this TRL: • Driving Simulator Study on Fatigue. Effects of preventive & corrective actions on fatigue + hazard perception, longer term effects over 2 distinct sessions • Driving Simulator Study on Distraction. Effects of preventive actions on distraction + hazard perception, longer term effects over 2 distinct sessions • Driving Simulator Study on Comfort. Comfort, Transition of control, HMI, automation degradation, driver characteristics, user evaluation
TRL 5 – technology validated in relevant environment	In vehicle prototype to test on-road Mediator components in different Use Cases.
	In-vehicle prototypes implementation. Real recorded data from a vehicle required. Statistical analysis of on-road data.
	Results and knowledge qualifying this TRL: • On-road study in Italy with HF in-vehicle prototype to test HMI (take over requests, automation levels, manual driving) and user evaluation • On-road study in Sweden with HF in-vehicle prototype to test functionality and user evaluation, fatigue and distraction, degraded automation, HMI (referring to Mediator system and a baseline) • On-road study in Sweden with TI in-vehicle prototype to test the Mediator components (Automation module, Decision Logic module, Driver State components and HMI)

3.3. MEDIATOR exploitable results and Integrated Assessment Models

To adequately quantify and develop a method to incorporate time delays due to technology development, removal of regulatory barriers and market adoption, a framework is used that explicitly includes both regulatory and market constraints when assessing technology development and rate of market application.

This framework brings a new capability to Integrated Assessment Models (IAMs) because it supports the identification of technologies that should have enough regulatory support and appropriate market acceptance to become a widely applicable commercial product. Furthermore, this framework allows for a side-by-side comparison on which technologies competing for a similar market space may achieve market acceptance before the others (Eljasik-Swoboda et al., 2019).

Figure 3.2 illustrates the underlying theoretical framework adopted, based on the classical 'pyramid' design related to:

- Technology Readiness Level (TRL), representing, in a scale between 1 to 9, the degree of a technology to be used safely by users in the predicted user environment;
- Regulatory Readiness Level (RRL), indicating, in a scale between 1 to.5, how much regulations are supportive of Automated Vehicles (AVs) use and place few restrictions on when, where and how testing of AVs may occur and takes into account institutional investment and number of funded projects on the topics;
- Market Readiness Level (MRL), measuring, in a scale between 1 to 5, the maturity of an emergent need or demand in the envisaged market, considering the potential issues related to competitors and economic or societal resistance.

The pyramids reported in Figure 3.2, start to the lower level (TRL1, RRL1, MRL 1), to the top level (TRL9, RRL 5, MRL 5).

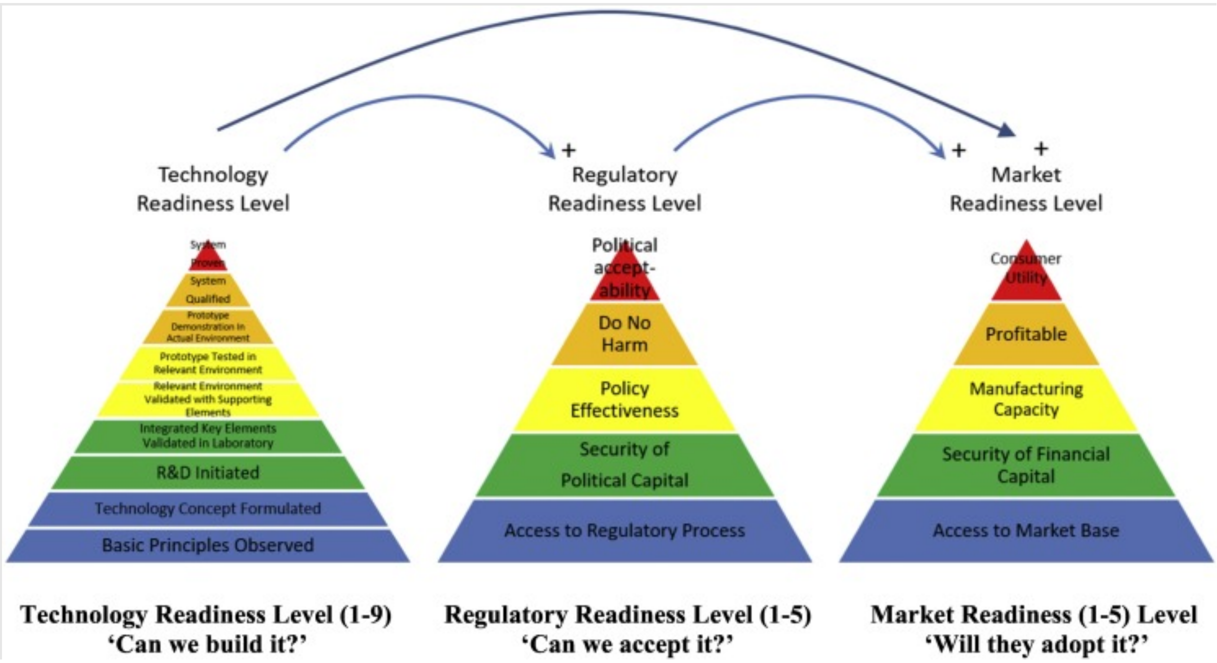


Figure 3.2 Relationships between Technology Readiness Level (TRL), Market Readiness Level (MRL) and Regulatory Readiness Level (RRL) – From: Kobos et al., 2018.

Even if the main exploitable result from MEDIATOR is the Mediator system, each of the MEDIATOR KERs have been grouped in the four Main Exploitable results (MER), related to Mediator main components (Human fitness/unfitness, Automation fitness/unfitness, Human factors and HMI, Central mediation component). For each of these main exploitable result, different TRL, RRL and MRL scales were defined, according to the MEDIATOR activities, from the point of view of development and evaluation activities (Rauh et al., 2023), regulatory aspects encountered in testing systems like Mediator (Fiorentino et al., 2023) and state of the implemented technologies.

*Table 3.3 TRL, MRL and RRL for the main MEDIATOR exploitable results.*Table 3.3 shows the results of evaluating RRL and MRL for the main MEDIATOR exploitable results.

Table 3.3 TRL, MRL and RRL for the main MEDIATOR exploitable results.

Main exploitable results	TRL (see Table 3.2)	Market Readiness Level (MRL)[3]	Regulatory Readiness Level (RRL) (see Fiorentino et al., 2023)
Human fitness/unfitness	**5**	**4**	**4**
Automation fitness/unfitness	**3**	**3**	**2**
Human factors and HMI	**6**	**4**	**4**
Central mediation component	**3**	**3**	**2**

Both TRL and MRL assessment show a more maturity for HMI and Human fitness/unfitness, with TRL and MRL that are both highly rated and represents the basis for a successful market-entry. Automation fitness/unfitness and central mediation component need to solve issues related to technology and regulatory framework to be placed into the right market window at the right time.

These results are plotted in a bubble chart (see Figure 3.3) to represents regulatory and market factors that could help to provide a new approach for technological forecasting and policy assessment efforts and could benefit from an integrated analysis applied throughout the framework on the probability of meeting specific readiness levels within a given timeframe.

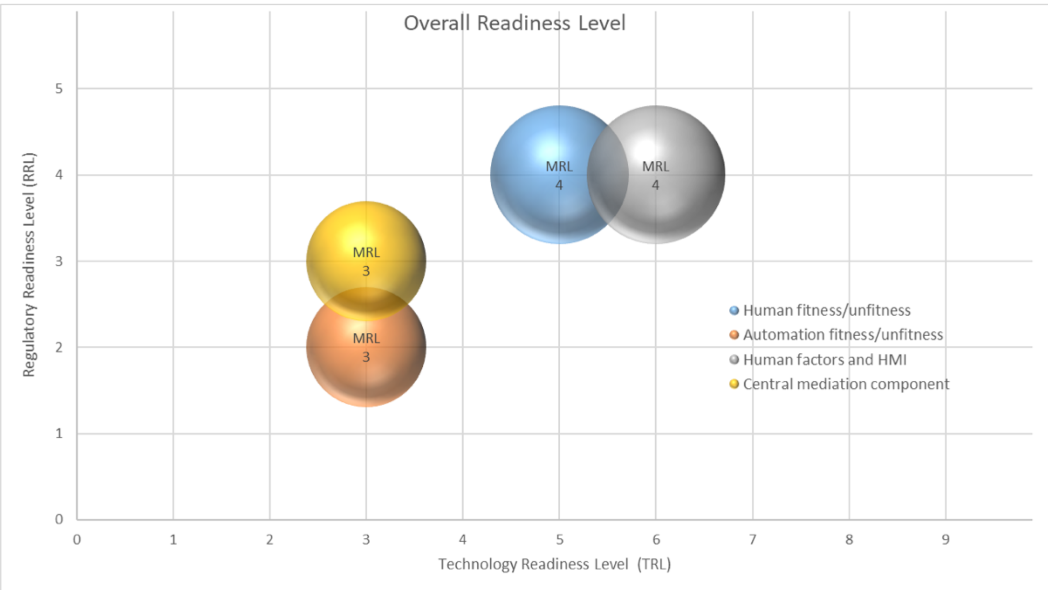


Figure 3.3 Integrated Assessment Model (IAM) for the overall readiness level of main exploitable results of MEDIATOR.

With reference to MEDIATOR's main exploitable results, the following tables (Table 3.4 to Table 3.7) summarise the impact of the new technology on the market and features about how to target the appropriate level of research, address the regulatory process governing the technology moving into

3 MRL was estimated based on partner's experience and inputs received by external stakeholders (Industrial representatives at Advisory Board and external experts).

the market and engage the desired market adoption factors, required to achieve a good level of market penetration.

Table 3.4 MER Human fitness/unfitness

Main exploitable result (MER)	MER Human fitness/unfitness
Description of the Result	**Human fitness**
Problems you are addressing	Management of inter-and intra-subject variability
Product/Service Market Size	Automotive Market
Market Trends/Public Acceptance	High customer propensity to unobtrusive monitoring
Legal, normative, or ethical requirements (need for authorisations, compliance to standards, norms, etc.)	Restriction in collecting biometric data that allow a univocal identification of the subject
Competitors/Incumbents	Many devices from biomedical field, Seeing Machines, Nauto, Lytx, Affectiva
Cost of implementation – bringing product/service to the "market."	Medium
Time to market from the end of the project	1-2 years
Foreseen Product/Service Price	Camera-based distraction and fatigue detection, and prediction product (hardware + software), possibly aided by optional extra low-intrusive physiological sensors (heart rate, heart rate variability, etc.). Price range: 200 – 2000 euro per device.

Table 3.5 MER Automation fitness/unfitness

Main exploitable result (MER)	MER Automation fitness
Description of the Result	**Automation fitness**
Problems you are addressing	Judging the capabilities of the vehicle automation in the current context
Product/Service Market Size	Automotive Market
Market Trends/Public Acceptance	Drivers quite high confidence and trust in automated decision systems (Rauh et al., 2023)
Legal, normative, or ethical requirements (need for authorisations, compliance to standards, norms, etc.)	Authorities are ensuring that AVs will be safe, both mechanically and in terms of data security Standard authorisation for on-road test
Competitors/Incumbents	Existing automakers with experimental Autonomous Driving (AD) functions and rolled-out Advanced Driver Assistance System (ADAS) systems
Cost of implementation – bringing product/service to the "market."	Unknown; depends on specific sensor and modelling costs, the targeted maturity level and the ODD
Time to market from the end of the project	4 and more years
Foreseen Product/Service Price	Unknown

Table 3.6 MER Human Machine Interface

Main exploitable result (MER)	MER Human Machine Interface
Description of the Result	**Human Machine Interface**
Problems you are addressing	Individual components that are being considered for the HMI are for the larger part commercially available, albeit not always up to automotive standards. Some technologies have implied a significant modification in the interface subsystem. The final integration of all components into one integrated system is also likely to require modification of the interfacing, both in software as hardware. The HMI holistic approach requires a change of mentality from OEMs side because they have to approach this kind of HMI as system integrator.
Product/Service Market Size	Markets related to all transportation modes
Market Trends/Public Acceptance	New HMI technologies could take time to be accepted, specifically by drivers with strong habits to classic interfaces. Designing for learned affordances and driver autonomy are crucial design requirements to accelerate acceptance. Actually people's acceptance changes quickly. In studies conducted during the project, participants mentioned that they would prefer a touchscreen to select driving modes. One reason may be that the shifter is not in a comfortable position behind the real shifter. But also in the four years of Mediator a lot of new cars have touchscreens and Head-Up display, so people are getting used (Grondelle at al, 2023).
Legal, normative, or ethical requirements (need for authorisations, compliance to standards, norms, etc.)	Compliance Automotive Standards
Competitors/Incumbents	Many small companies are developing HMI device and systems for AVs, but mainly for infotainment. Because in MEDIATOR, infotainment systems were fully integrated into the HMI, forming new business alliances.
Cost of implementation – bringing product/service to the "market."	Low for individual components, high for changing the vehicle HMI architecture.
Time to market from the end of the project	2 and more years
Foreseen Product/Service Price	Compared to a conventional HMI, new additional components will increase the overall vehicle price. In theory, however, a well-designed integrated sub-system (instead of many individually interfaced components) could balance this out.

Table 3.7 MER Central mediation component

Main exploitable result (MER)	MER Central mediation component
Description of the Result	**Central mediation component**

Problems you are addressing	Making a trade-off on who is fittest to drive based on data with uncertainties and predictions of “future states.”
Product/Service Market Size	Markets related to all automated systems
Market Trends/Public Acceptance	Increasing focus on human-automation cooperation supporting systems.
Legal, normative, or ethical requirements (need for authorisations, compliance to standards, norms, etc.)	Legislative, ethical and infrastructure barriers restrict the number of environments where tests can be undertaken.
Competitors/Incumbents	Toyota Guardian concept
Cost of implementation – bringing product/service to the “market.”	Medium. Decision logic is by itself mostly software-based with limited computation requirements, but it requires an extensive testing campaign
Time to market from the end of the project	4 and more years
Foreseen Product/Service Price	Software component that operates at meta-level in partially automated vehicles, monitoring simultaneously human and automation performance, and advising HMI on recommended automation turn-on/turn-off suggestions to be presented to the driver.

4. Stakeholders’ involvement in MEDIATOR exploitation

This chapter describes the suggestions received from the Advisory Board (AB) meetings as well as from the MEDIATOR Workshop Café in Italy and from other two final workshops at SWOV and Chemnitz University of Technology, to exploit the MEDIATOR results and to deliver roadmaps for further exploitation by the road transport communities.

Three AB meetings were organised during the MEDIATOR project. During these meetings, the AB members supported the Consortium partners to orient the MEDIATOR project development towards reachable results, to specialise the MEDIATOR project development activities and the exploitation strategies, to set-up finalization, execution and analysis of the evaluation trials and their integration into the impact assessment.

Three workshops at the end of the project were organized to discuss with policy makers (at SWOV), with the scientific community (at Chemnitz University of Technology) and with industrial stakeholders (in Italy at Capgemini Engineering) on the MEDIATOR exploitable results, delivering roadmaps for further exploitation by the road transport communities. Each workshop had a specific organisation, manly based on the target audience, to obtain the maximum involvement of the participants; common to all workshops was the presentation of MEDIATOR project concepts and results. The innovative approach of World Café was used during the Italian workshop to obtain the maximum involvement from the industrial stakeholder.

4.1. Advisory Board

The MEDIATOR Advisory Board is composed by Scientific and Industrial representatives that provide input and feedback on intermediate results as well as on the expected outcomes of all technical activities respectively for scientific relevance of the research (Scientific Advisory Board) and for the industrial exploitation (Industrial Advisory Board). The Industrial component into the AB is represented by European OEMs and suppliers; they advise the consortium on whether chosen approaches and solutions are feasible and acceptable for market implementation and provide input on relevant international market and technological developments.

The following Industrial organisations are, today, members of the AB:

- BMW group
- Euro NCAP (European New Car Assessment Programme)
- IAV automotive engineering
- Volvo Car Corporation
- Veoneer
- Valeo

According to the aim of this deliverable only the contribution of the Industrial representatives at Advisory Board is reported.

4.1.1. 26th November 2019

During the first AB meeting, on 26th November 2019, the industrial representatives gave special support to the MEDIATOR research questions. In detail, they indicated that the MEDIATOR project should focus more on common driving scenario's and less on, often rare, extreme scenarios, such as emergency stops. While the system should also be able to deal with such extreme situations, a more important goal of the MEDIATOR system is to prevent any unsafe situations and improve the driver experience and safety all throughout their driving trips. The first AB meeting allowed the consortium to orient the MEDIATOR project development towards reachable results.

Figure 4.1 MEDIATOR first AB meeting.

4.1.2. 24th November 2020

The second meeting was organized in two different dates, according to the availability of the industrial and the scientific members. The meeting with the Industrial representatives was held on 24th November 2020 and allowed the consortium to specialise the MEDIATOR project development activities and also the exploitation strategies. The discussion during the meeting was very useful for the MEDIATOR consortium because topics under development like use cases, human factor detection, HMI, and validation procedure were discussed. The comments and suggestions allowed to specify the MEDIATOR exploitation plan and the related exploitation activities.

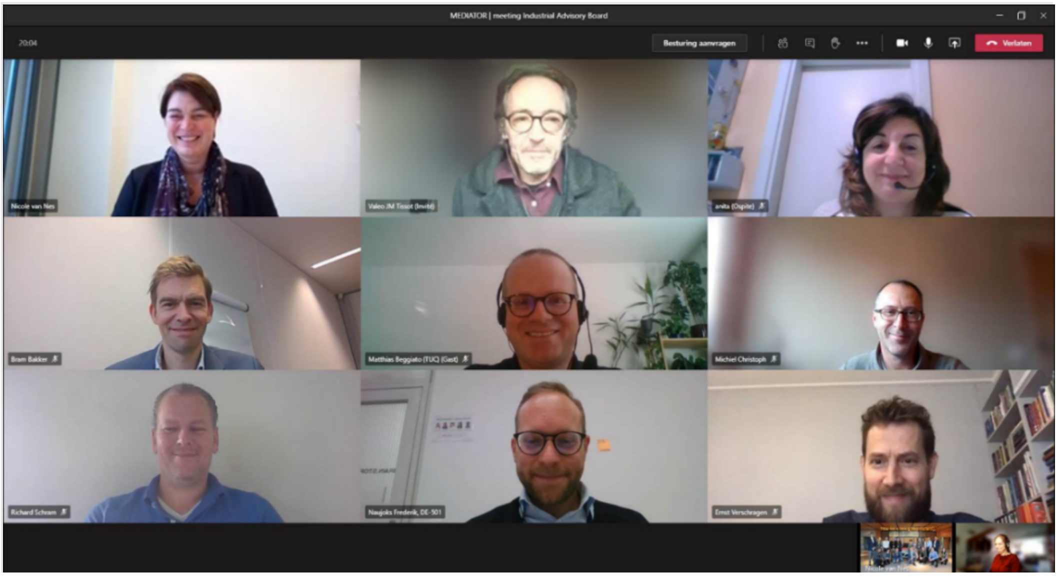


Figure 4.2 MEDIATOR second IAB meeting.

4.1.3. 16th November 2021

The third AB meeting, on 16th November 2021, allowed the consortium to set-up finalization, execution and analysis of the evaluation trials and their integration into the impact assessment. It was a very successful meeting resulting in valuable recommendations for refocussing and scoping the evaluations trials and subsequent Mediator system assessment. The AB members were highly engaged in the discussions and committed to providing constructive feedback, keeping in mind the current stage of the project.

Due to different member availability meeting was organized in two sessions (morning and afternoon). The recommendations and conclusions were similar.

- Evaluation trials. The main recommendation was to look at the bigger picture and draw general conclusions about the Mediator system using the results from the different studies. To do so HMI designs and measurements should be as similar as possible between studies and the evaluations trials should be kept simple.
- Impact assessment. The recommendation was to keep the safety impact assessment simple and to use Key Performance Indicators (KPI) from previous EU project.

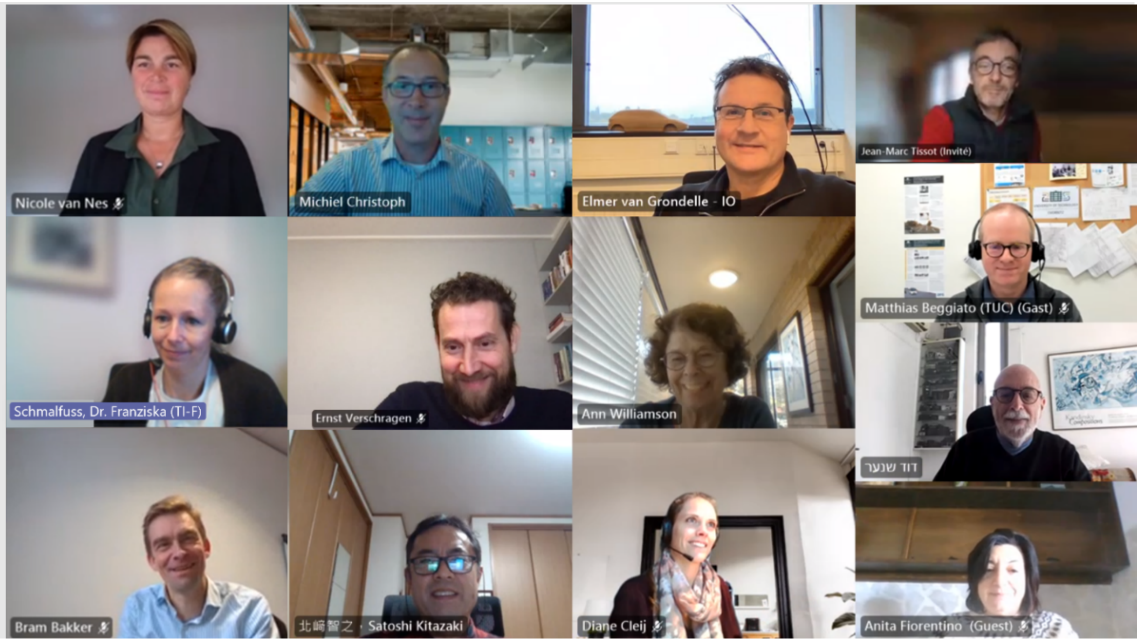


Figure 4.3 MEDIATOR third AB meeting – morning session.

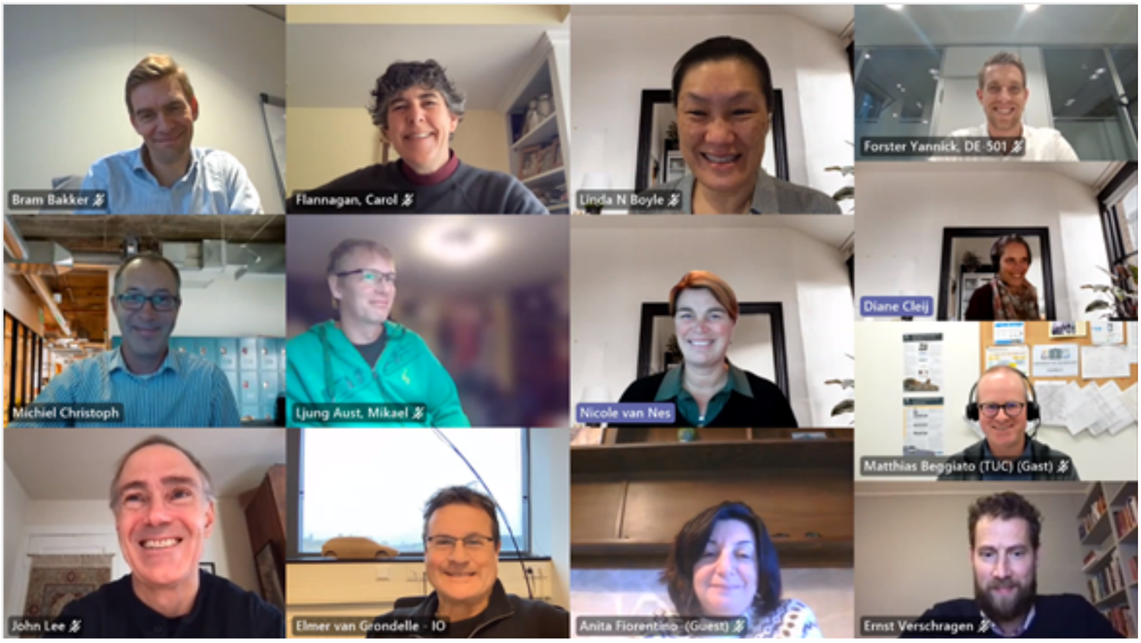


Figure 4.4 MEDIATOR third AB meeting – afternoon session.

4.2. MEDIATOR Workshop Café

The World Café is an innovative way to allow interaction between the project consortium and stakeholders and an interactive way to listen to stakeholders' needs. It is a dialogue that favours the transmission and evolution of the ideas of the participants who influence each other, feeling part of a whole (cross pollination). It gathers a diversity of points of view, encourages their expression and favours understanding and acceptance of what cannot be changed and the concentration of energies towards what can be changed for the better.

4.2.1. Methodological approach

The World Café workshop methodology fosters an environment that develops good conversations. The approach is designed to get authentic dialogues started. This encourages the sharing of ideas in a relaxed, informal and creative atmosphere. The basic principle consists in the contamination and intersection of knowledge, of everyone's experiences (see Figure 4.5).

Figure 4.5 World Shop Café main principles (Source: theworldcafe.com, and www.slideshare.net).

The following seven World Café design principles are an integrated set of ideas and practices that form the basis of the pattern embodied in the World Café process.

1. Clarify the Context. Knowing the purpose and parameters of the meeting enables to consider and choose the most important elements needed to reach the goal(s): e.g., who should be part of the conversation, what themes or questions will be most pertinent, etc..
2. Create Hospitable Space. Café hosts around the world emphasise the power and importance of creating a hospitable space - one that feels safe and inviting. When people feel comfortable to be themselves, they do their most creative thinking, speaking, and listening. Generally, the “environment” is modelled giving the impression to stay in a café: Small round tables covered with a tablecloth (preferably that can be drawn/written upon), as shown in Figure 4.6. In addition, some extra paper, post-it notes, coloured pens, could be added. Ideally, there should be no more than four or five chairs at each table, to facilitate the moderation action and to create an informal atmosphere that encourage everyone to contribute.

Figure 4.6 Example of hospitable space with tablecloth that can be drawn/written upon (Source: theworldcafe.com).

3. Explore Questions that Matter. Knowledge emerges in response to compelling questions. Each round is prefaced with a question designed for the specific context. Therefore, the questions or issues that are chosen for each table should be relevant for the engaged participants. Consequently, the same questions can be used for more than one round or table.
4. Encourage Everyone's Contribution. The process begins with more conversation rounds. Participants are encouraged to write, doodle and draw key ideas on their tablecloths, also with the help of post-it.
5. Connect Diverse Perspectives. The opportunity for the participant to move between tables, meet new people, actively contribute thinking. As participants carry key ideas or themes to new tables, they exchange perspectives, greatly enriching the possibility for surprising new insights.
6. Listen together for Patterns and Insights. The quality of listening is perhaps the most important factor determining the success of a Café. It is important to encourage people to participate at the discussion without be impressed by other participants.
7. Share Collective Discoveries. The last phase of the Café, often called the "harvest", consists in inviting to a few minutes of silent reflection on the patterns, themes and deeper questions experienced in the small group conversations and then in sharing with the larger group to help in the cross-fertilization of ideas. In this way patterns are then identified, collective knowledge grows, and new possibilities for action emerge. After the last round of conversation, people can return to their home (original) tables to synthesize their discoveries. Or, they may continue travelling to new tables, leaving the same or a new host at the table. Sometimes, after the last planned round, the facilitator may choose to introduce a new question that helps to deepen the exploration for a final round of conversation.

4.2.2. The MEDIATOR Workshop Café on 9th March 2023

The MEDIATOR Workshop Café aimed to **discuss on the MEDIATOR exploitable results, delivering roadmaps for further exploitation by the road transport communities**. According to these specific goals the invited participants were the MEDIATOR possible stakeholders: academia, OEMs, tier suppliers, engineering companies, and small/medium enterprises.
The selected location was a meeting room appositely prepared with independent tables, at Capgemini premises in Turin. Several support material, software demo and videos about the Human Factors (HF) in-vehicle prototype and the Technology Integration in-vehicle prototype were prepared to give to the participant opportunity to learn more about MEDIATOR.

For the MEDIATOR Workshop Café three questions were defined with the specific aim to analyse the MEDIATOR exploitable results in terms of design needs, technologies and validation phase and to estimate for each of them the level of maturity for the central mediation component (Mediator system as a whole), for the human fitness, for the automation fitness and for the HMI. The questions were as follows:

- **DESIGN Needs**: *Which actions are still required for an Industry (automotive) adoption?*
- **TECH**: *Which enabling technologies (SW/HW) are essential?*
  - Ready to be use
  - Missing
  - R&D needed
- **VALIDATION: Define the key challenges for a next generation of tests:**
  - Technical validation
  - User validation

Figure 4.7 shows an example of the above questions prepared for the participant at the table related to the central mediation component, to clearly inform the participants how they contribute.

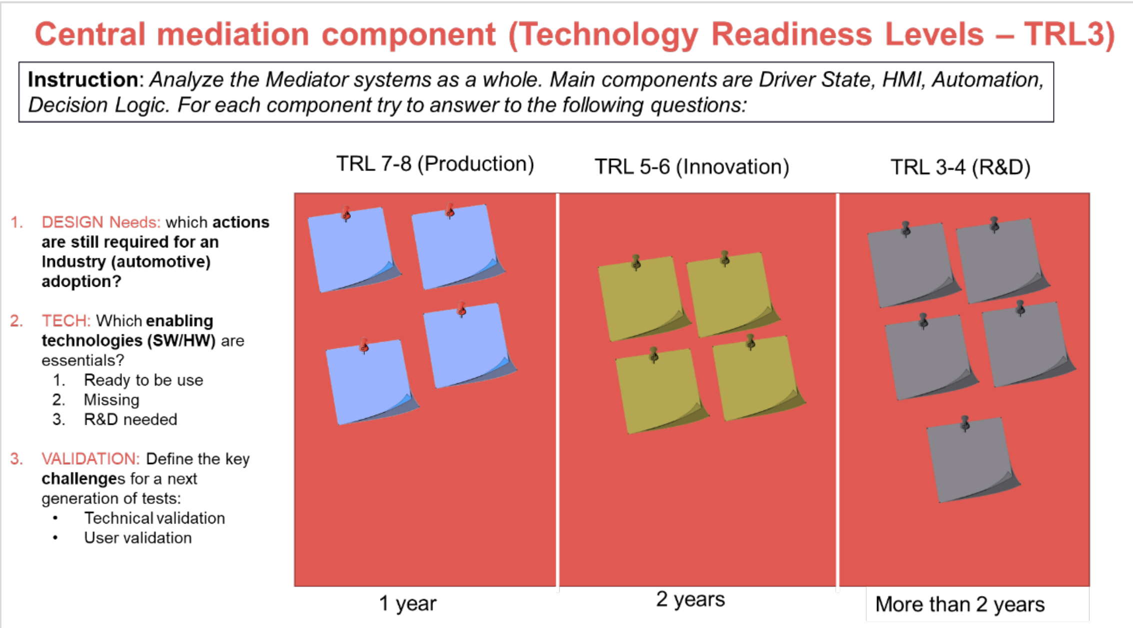


Figure 4.7 Questions for participants at the table related to the central mediation component.

4.2.2.1. Agenda

The MEDIATOR Workshop Café was planned to allow the participants to have a one-day travel. The agenda of the workshop was the following:

09:30 10:30 - Welcome (Capgemini)
Workshop Café (A. Fiorentino – FCA Italy)
MEDIATOR Overview and final results (M. Christoph – SWOV)
- MEDIATOR HMI design (E.D. van Grondelle – TU Delft)

10:30 13:00 - Team work
13:00 14:00 - Lunch
14:00 15:00 - Wrap up and networking.

Figure 4.8 shows the preliminary phase of the MEDIATOR Workshop Café with the presentation of the MEDIATOR key concepts and results.

Figure 4.8 Presentation of the MEDIATOR overview and final results at the MEDIATOR Workshop Café.

4.2.2.2. Participants

The participants at MEDIATOR Workshop Café were 27 (in addition to the consortium partners). In Table 4.1 the participant's list is reported for organisation, type of organisation, skills and numbers of participants for each organisation.

Table 4.1: Participant's list.

Organisation	Type of organisation	Skills	Participant's number for each organisation
Delta Koigo Tech	Tier 1	Seats and Driver state	2
Drivesec	Engineering Company	Automotive cybersecurity	1
Gran Studio	Engineering Company	Design	3
Ital design (IDG)	Engineering Company	ADAS and AD Systems	3
Politecnico di Milano (PoliMI)	Academics	Autonomous driving driving simulators.	3
Politecnico di Torino (PoliTO)	Academics	Automotive engineering	3
Proma Group	Tier 1	Seats	1
Re-Lab	Engineering Company	Human Factor	2
SAPA Group	Tier1	Plastic trims	1
Stellantis	OEM	Driver State Autonomous driving HMI	3
Teoresi	Engineering company	Vehicle-dialogue interaction HMI Driver State	3
Università di Napoli (UniNA)	Academia	Autonomous driving	2

4.2.2.3. Operative Organisation

The operative organisation of MEDIATOR Workshop Café was the following:

- 5 discussion tables were formed
  - 2 tables related to the «Central mediation component (Mediator system as a whole)»
  - 1 table related to «HMI»
  - 1 table related to «Human fitness»
  - 1 table related to «Automation fitness»
- Participants were initially distributed on the tables according to their specific skills or interest, avoiding that participants of the same organisation stay at the same table at same time
- Participants don't know each other; to facilitate discussion and to discourage embarrassment, linked to different skills and background, only at the end of the workshop to create networking, the participants present themself
- Post-it and colored pens to populate a billboard with the individual feedbacks were furnished
- 5 members of the MEDIATOR consortium (the "Mediators") moved between the tables, to mediate the discussion, also giving more details on the MEDIATOR achieved results
- HMI demo and MEDIATOR videos at request in the meeting room were showed
- Synthesis of the main MEDIATOR results was on each table
- Coffee and cakes were at disposal of the participants

Figure 4.9 shows the discussion tables and the participants distribution. For each table a seat was unoccupied to allow the Mediators to seat at different tables when they turned.

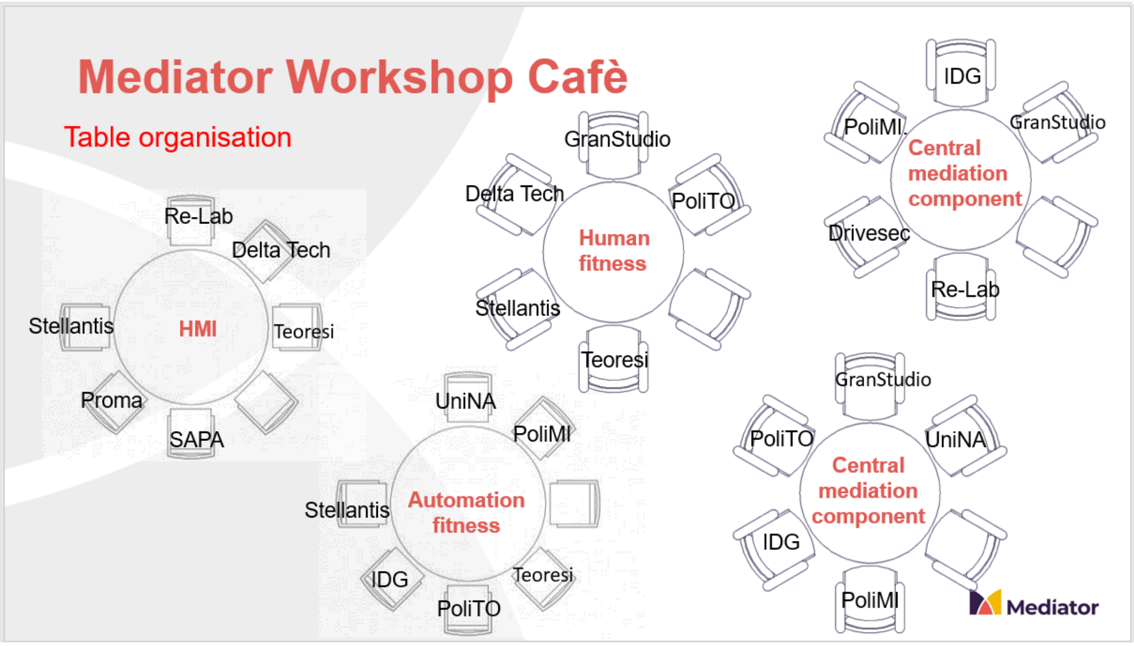


Figure 4.9 Discussion tables and participants distribution.

4.2.2.4. Results

Suggestions from the participants were collected on a billboard which was divided in three time slots related to the TRL and in terms of design needs, technologies and validation phase, as shown in the following figures.
Suggestions with TRL 3-4 mean they are at an early stage of maturity (Research level), requesting more than 3 years to be developed; suggestions with TRL 5-6 mean they will contribute to

innovation, requesting 2 years to be developed; suggestions with TRL 7-8 mean they are ready for production, requesting 1 year to be developed.

Central mediation component tables

The discussion at the central mediation component tables focused on the whole Mediator system, also analysing the link with other components and also discussing on the new rules expected to OEMs that have to enlarge their specific skills moving from engineering specialist (mechanical, electronic, etc) toward to system integrator engineering.

In terms of design needs several comments were received, mainly on the integration of Mediator Central component into the automotive vehicle development process. Below are listed the main design needs to embrace mainly in the medium- and long-term:

- New vehicle architectures with a central domain
- Zero defects for SW components
- Recovery action in case of system fault
- automotive standard (functional safety) and cybersecurity

Similarly, were discussed the technology needs; the experts pointed out that the Mediator systems run in parallel to the progress done on automotive field and more in general on connected and automated vehicles. The main evidence was related to the opportunities to use new technologies to better specialise the Mediator main components:

- the driving context could be improved with information coming from the infrastructures or from other connected vehicles (V2X)
- human fitness could work with a holistic approach based on the data fusion of different technologies of driver monitoring and driving context
- HMI should be specialised including voice assistant, personalisation and standardised colours.

Finally, the group discussed on the validation needs, that at the moment are the most challenge issue to solve, because regulatory testing isn't similar in all EU countries, there are ethical issues to solve, and the involvement of different user categories could be interesting to assess in terms of acceptability. Sharing the testing knowledge could also be pursued. Below are listed the main validation needs:

- Large scale validation in different countries
- Increase validation on real road with different user category and user age
- Increase the testing in urban and extra urban area,
- Increase training for the professional driver involved in the tests, also with support od fringing simulators
- Use driving simulators to reduce the on-road test validation campaign.

Figure 4.10 and Figure 4.11 report the post-its on the billboard according to needs and time (related to the TRL). In general, suggestions are mainly referred to TRL 3-4; no suggestion were given for technology and validation at TRL 7-8.

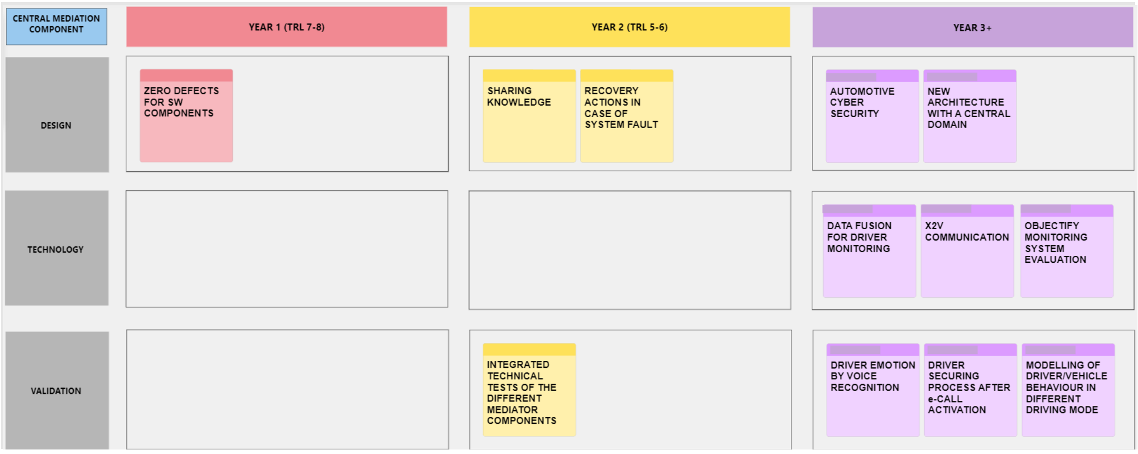


Figure 4.10 Participants' suggestions from the first Central mediation component table.

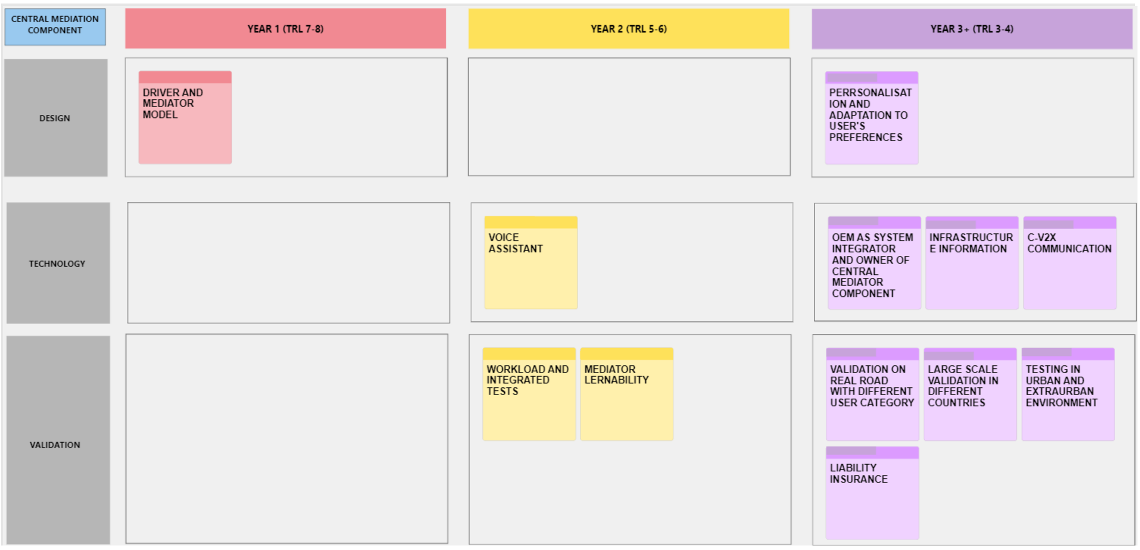


Figure 4.11 Participants' suggestions from the second Central mediation component table.

HMI

The discussion at the HMI table was focused on the whole Mediator system, also analysing the new task expected from OEMs mainly related to integrate different new components (inflatable seat, seatbelt, LED, etc.) in a common vehicle architecture.

The discussion at the HMI table focused on the developed holistic HMI, on the new prototypal components that were developed (shifter, inflatable seat) and on the need to have an HMI with standard colours to avoid misunderstanding when driver changes vehicles (i.e., shared mobility).

In terms of design needs several comments were received, mainly based on the integration of Mediator HMI component into the automotive vehicle development process. Below are listed the main design needs in short-, medium- and long-terms:

- HMI components complaint to automotive standard
- HMI standard colours and icons
- Customisation of HMI

- new automotive choices related to modify/simplify some components, like the steering wheel or the gear lever.

Similarly, were discussed the technology needs; experts pointed out that the Mediator systems ran in parallel to the progress done in automotive field and for this reason several components need to be specialized according to the automotive choices: large display; inflatable seats; integration of an external display; retractable steering wheel; driving mode selector.

Finally, the group discussed on the validation needs. These are mainly related to test the proper integration of HMI components into the vehicle; in addition, special emphasis was given to the Wizard of Oz (WoOz) approach, seen as a useful method to test in advance, with different users, the HMI acceptance, modifying the design if HMI isn't properly accepted. Below are listed the main HMI validation needs, mainly focused on mid-term:
- Ambient light vs functional light
- HMI tests and workload
- HMI test with parallel tasks
- HMI and distraction effects.

Figure 4.12 reports the post-its on the billboard according to needs and time (related to the TRL). Suggestions are mainly referred to TRL 5-6; no suggestion were given for validation at TRL 7-8 and TRL 3-4.

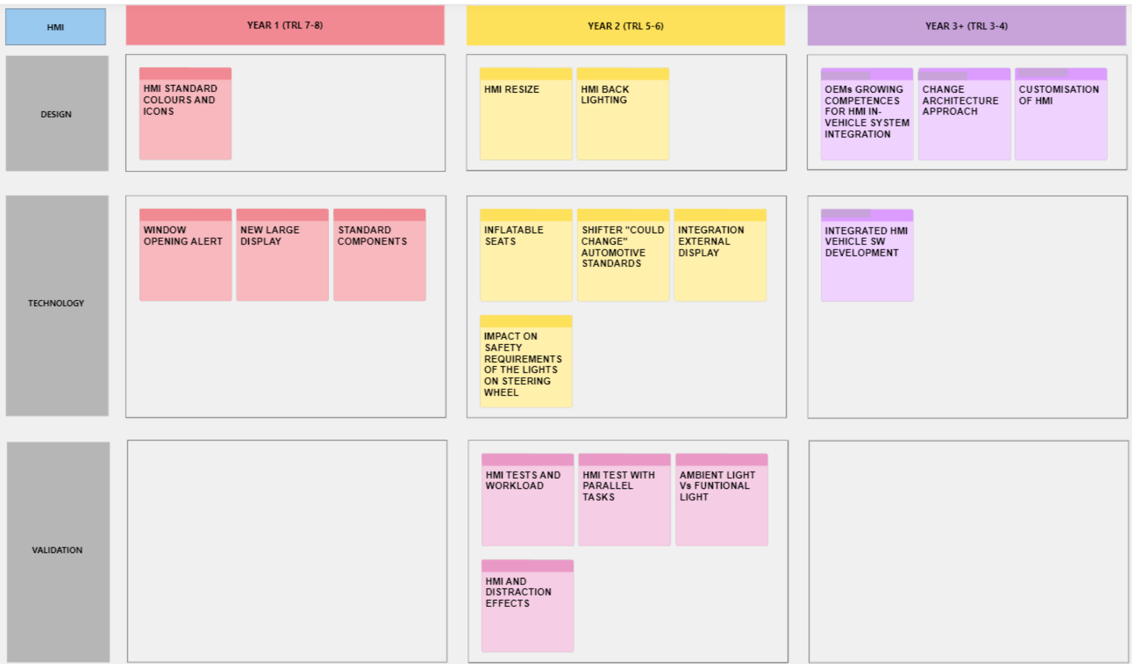


Figure 4.12 Participants' suggestions from the first HMI table.

Human fitness/unfitness table

The discussion at the Human fitness/unfitness table was focused on the different technologies to detect the state of the driver, and on the validation approach that requires to overcame privacy and ethical aspects related to the users.

In terms of design needs several suggestions were received, mainly based on the specialisation of driver state algorithms, according to the future regulations. Discussions also covered the suggestion to introduce, similarly to the HMI, a holistic approach, based on data fusion of different technologies, to properly estimate the human fitness/unfitness. Below are listed the main design needs in short-, medium- and long-terms:

- Algorithm for driver monitoring linked to vehicle data
- Drowsiness prediction
- Algorithms for driver monitoring specialized with physiology data
- Algorithms for comfort assessment
- Sleepiness and fatigue detection algorithms based on either physiological data, context data, face camera data, vehicle data, or a combination of these.

Similarly, were discussed the technology needs in terms of technologies available for the detection of different driver states, even is not developed in MEDIATOR:

- Electronic consumer (smartwatches) for sleep cycles detection (Heartbeat, heart rate variability, activity recognition)
- Drowsiness detection: Camera and driving performance (GSR 2.0)
- Stress detection
- Physiology sensors
- Comfort detection
- Motion sickness detection
- Mind wandering detection
- Driver emotion detection
- Alcohol/drug detection.

Finally, the group discussed on the validation needs. The discussion was based on the necessity to have standard validation methods, also involving medical experts during the testing phase; in addition, to overcame privacy and ethical issues, was discussed the necessity to have large available dataset to calibrate properly the algorithms, also using synthetic data.

Figure 4.13 reports the post-its on the billboard according to needs and time (related to the TRL). Suggestions are mainly referred to TRL 3-4 and TRL 5-6. Design and validation needs were merged.

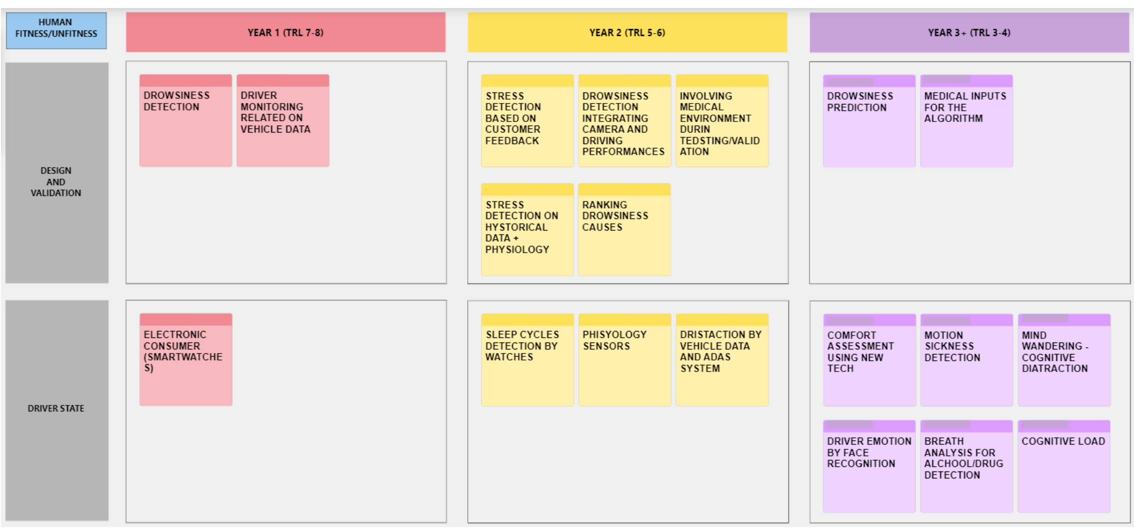


Figure 4.13 Participants' suggestions from the Human fitness/unfitness table.

Automation fitness/unfitness table

The discussion at the Automation fitness/unfitness table was mainly focused on the main issues related to the design and validation of automation algorithms. Research is ongoing and in the next years are expected more progresses.

In terms of design needs discussion focused on:

- privacy by design
- calibration with the vehicle diagnostic data (i.e., out petrol, dead battery, etc)
- integration in electrical &electronics in-vehicle's architecture.

About the validation needs the group discussed on the following topics:

- Misuse and disuse of automation by human operators
- Training of test drivers with driving simulator
- Test automation in realistic traffic conditions (pedestrian, cyclist, etc).

Figure 4.14 reports the post-its on the billboard according to needs and time (related to the TRL). Suggestions are mainly referred to TRL 5-6; no suggestions were given for TRL 7-8.

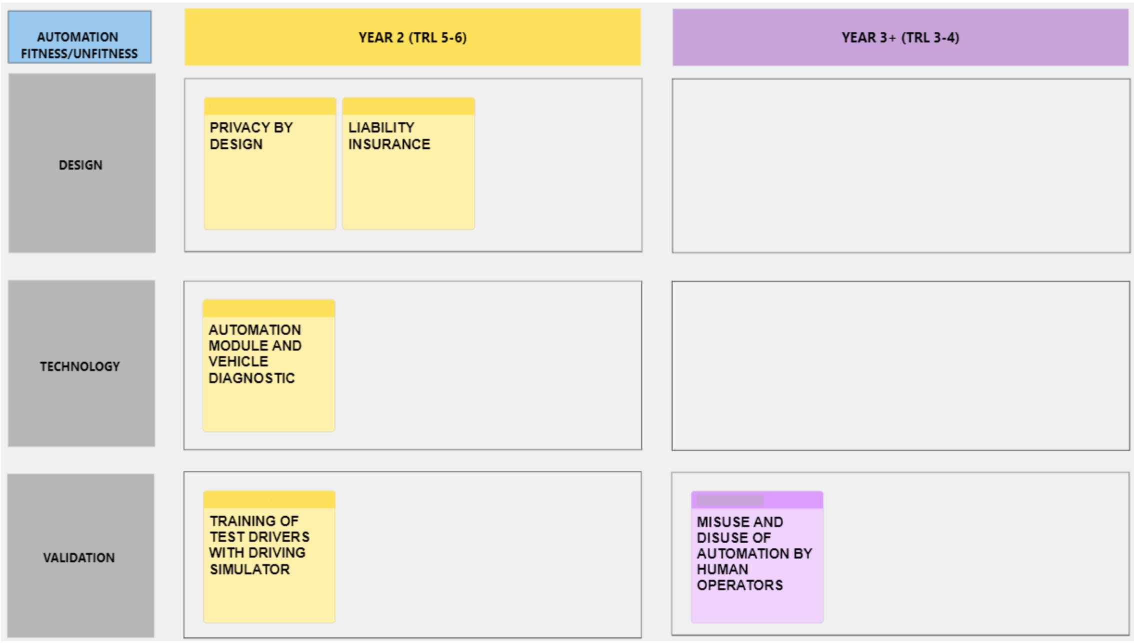


Figure 4.14 Participants' suggestions from the Automation fitness/unfitness table.

4.3. Other MEDIATOR Workshops

4.3.1. The MEDIATOR Workshop on 31st January 2023

The MEDIATOR stakeholder Workshop organized at SWOV aimed to share the MEDIATOR project with external parties who may benefit from its findings, and who may help shape deliverables to maximize impact. SWOV presented project concepts, findings and approach to formulate guidelines on Driver Monitoring Systems (DMS) and HMI. A small group of Dutch policy stakeholders was invited to facilitate in-depth discussions on the interests of each party.

4.3.1.1. Workshop structure

The workshop consisted of three parts:

1. a general discussion about the main concepts of the Mediator system,
2. a discussion on the guidelines for safe HMI design and
3. a discussion on the guidelines for DMS.

The following questions were raised during the workshop:

- How do the results and insights relate to your needs/interests?
- How can we tailor the final results more towards your needs and interest?
- What are for you the most important (knowledge) questions?
    - For the mid-long term (2 – 10 years)
    - For the short term (today – 2 years).

4.3.1.2. Results

The stakeholders valued MEDIATOR's contribution and broad approach. MEDIATOR concepts and results could be valuable input to further support the regulation process.

Some main questions or key statements were raised during the workshop, such as:

- There was a discussion on the operationalization of the concept of driver fitness. It was raised that one of the reasons why advanced drowsiness detection warning is still not finished is that while computer vision systems work well, classification algorithms do not. Policy makers may not be sufficiently aware that people rely on and trust these systems, while they are unreliable.
- Experimental DMS tend to be much better than systems used in industry.
- Regarding HMI, it is debatable what features should be regulated, and what features should be left free for OEM to communicate brand identity.
- Implementation of policy should be a parallel and iterative process: some regulations should be put in place based on current knowledge and should be refined when more scientific knowledge becomes available.
- Much HMI research and development is done by industry. It would be very valuable if industry would share that research for type approval.
- We have to ensure that the interaction between users and automation is going to be part of type approval process.
- The focus seems to shift to very specific approvals for certain systems (e.g., ALKS), also more general guidelines are desirable.
- It is/ remains important to convince policy makers and industry for the need to consider human factors in the development of vehicle automation systems
- There should be a push for an integrated Human Factor approach addressing the complete HMI in an integrated, holistic way such as adopted in the Mediator system
- There should be a push for harmonization of system design, a common approach for all (semi-) automated vehicles (transition of control should be similar)
- With respect to the understandability of vehicle automation levels and communication through the HMI: Less automation levels, such as the MEDIATOR approach, is better than more levels.

4.3.2. The MEDIATOR Workshop on 14th March 2023

The MEDIATOR workshop mainly organized at Chemnitz University of Technology (TUC, see Figure 4.15) aimed at discussing the overall concept of MEDIATOR, the overall HMI concept of MEDIATOR and the design space (i.e., branding options for different vehicle manufacturers), as well as the implementation of the MEDIATOR HMI in the TUC driving simulator study. For this purpose, experts from both scientific and industrial communities with different expertise (e.g., HMI design, human factors etc.) were invited. In total, 11 experts (seven from the industry) took part accompanied by 8 partners for the MEDIATOR consortium (the “Mediators”).

Figure 4.15 Presentation of the overall concept of MEDIATOR at the MEDIATOR Workshop.

4.3.2.1. General MEDIATOR Concept

The first part of the workshop focussed on discussing the general MEDIATOR concept, hence, the idea that a system is mediating between the human driver and the automated system by assessing the limitations (i.e., fitness/unfitness) and strengths of both. After a short presentation of the MEDIATOR concept, the 11 experts discussed the concept in three smaller groups supported and guided by the Mediators. The main points of discussion and questions posed by the participants are listed below.

- Definition of automation states, i.e., how are the automation states defined in the MEDIATOR concept?
- Prediction of automation and driver (un-)fitness, i.e., how does the MEDIATOR system predict these states?
- “Useful” duration of automated driving, i.e., what is a “useful” duration of automated driving, since too short intervals would result in too many takeovers.
- Automation as source of driver unfitness, i.e., could the automation itself be a source of driver unfitness (i.e., skill decay)?
- Unfit driver and automation usage, i.e., should an unfit driver (e.g., inebriated) be allowed to actually use automation or not?
- Acceptance of MEDIATOR, i.e., would older drivers accept a system like MEDIATOR?
- Cultural differences, e.g., German drivers want to have a stable system without issues whereas in other cultures it might be OK if the system is not 100% perfect

- Trust in new technologies, i.e., users need to trust in the Mediator system and it depends on the capabilities of the system and how well it detects different situations (i.e., lane markings) etc.
- Standards need to be set for a concept like MEDIATOR, including laws.
- Standards set for the MEDIATOR system might conflict with brand "standards" and identities, e.g.:
  - conflicting colour schemes
  - conflict between giving away *power* while handing over vehicle control to the automated system and the brand values/identities (i.e., joy of driving)
- Clear communication, i.e., the system needs to communicate clearly
- Complexity, i.e., the MEDIATOR system needs to take into account the drivers' capabilities/fitness, the environment inside the car and the environment outside the car.

4.3.2.2. Overall MEDIATOR HMI concept and design spaces

The second part of the workshop focussed on the overall HMI concept of MEDIATOR and potential design spaces, especially regarding the option for branding by different vehicle manufactures. Hence, how could the MEDIATOR system be adapted within the design space of the different brands. After a short presentation, the three groups of experts discussed the HMI concept and the main points of discussion and questions posed by the participants are listed below:

- Conflicts between MEDIATOR guidelines/standards and brand "standards"/identities, how can we combine both? E.g.:
  - Conflict might arise between "regular" ambient light concepts that are currently individually adaptable and the colour schemes chosen for the ambient light of the MEDIATOR HMI concept
- Standardization is necessary from a psychological point of view, i.e., standardization supports understanding, e.g.:
  - Warnings should have standardized colours
- Legislation/guidelines regarding fixed specifications of the MEDIATOR HMI concept and free choices/broad range of options for different brands, e.g.:
  - Feedback must be provided by all brands, but *how, where, when* should be a free choice of each brand;
  - Time budget as potential design element for branding i.e., time vs. meters as option to display automation states
  - The gear shifter as potential design element for branding
- Customizability i.e., drivers should be able to customize the presented information (e.g., switch off certain information after certain time) to a certain point and there should be more options to display the different aspects of the HMI.
- Usage of several modalities in parallel i.e., ambient light, acoustic warnings, symbols etc.
- Transitions of states/colours, i.e., the transitions between the states and colours are more important than the chosen colours itself and need to be clearly understandable
- Cultural differences need to be taken into account.
- Additional use cases/scenarios need to be taken into account and tested. Also in combination with other already existing ADAS systems in the vehicle.

4.3.2.3. MEDIATOR HMI implementation in the TUC driving simulator study

The last part focused on the implementation of the MEDIATOR HMI in the TUC driving simulator study. For that matter, a short presentation of the study and its results were given and a demonstrator was set up to show how the HMI as implemented in the driving simulator as realistic as possible, and how it functioned during the different drives in the study (see Figure 4.16).

Figure 4.16 Demonstrator of the HMI as implemented in the driving simulator.

The main points of discussion by the participants are listed below:

- Difference between handing over control *during* a traffic jam vs. *before* a traffic jam, i.e., some of the experts mentioned that they would not want to give up vehicle control before a traffic jam, since the approach of the traffic jam might be too unpredictable to be handled by the automated system but would hand over control during the traffic jam.
- Problems of the wording i.e., difference between "automated driving is available" (as implemented in the study) vs. "automated driving is useful/helpful, you should use it"
  - Focus on comfort use cases, e.g., the drivers do not have to use automated driving, it is just a proposal.
- User profiles, i.e., individual adaptability regarding receiving proposal from the Mediator systems and how many/in which use cases.

5. Exploitation roadmaps

This chapter describes the MEDIATOR exploitation roadmaps related to road transport. The exploitation roadmaps on road transport are based on the foreseen exploitable results of MEDIATOR system that have relevance to road transport communities, also with reference to a potential market for the MEDIATOR system.

The methodological approach used to develop exploitable roadmaps has been based on the project's development and validation activities, and feedback from the MEDIATOR Advisory Board and MEDIATOR stakeholder workshops.

Four MEDIATOR roadmaps were developed related to human fitness/unfitness, automation fitness/unfitness, HMI and central mediation component.

All MEDIATOR results are described hereafter in a common structure based on:

- Design needs in terms of further development
- 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.

5.1. MEDIATOR roadmaps

The main objective of the MEDIATOR roadmaps is to provide a stakeholder view on the long-term development of systems like Mediator in Europe.

Methodological approach used to develop exploitable roadmap, has been based on project's development and validation activities, stakeholders' feedbacks collected during MEDIATOR workshops and ERTRAC roadmaps (ERTRAC, 2022).

The next decades confront society with the need for fundamental changes in mobility. A substantial amount of transport on roads will remain and requires new and innovative approaches. Among these, for example, the scenario database from which test cases will be extracted will need to be updated continuously in order to reflect Operational Design Domains (ODDs) that will still be expanding in some parts of the road network, that requires a real-time digital twin of the physical and digital infrastructure. Other changes in the transport system will also be considered in corresponding scenarios and test cases, such as a growing number of highly automated vehicles or the emergence of new means of transport, and some relevant trends and disruptions that are still hard to anticipate today. Moreover, it will remain essential to develop the approaches and tooling for the testing and verification of Artificial Intelligence (AI) applications. This tooling for verification can include also scenarios and synthetic datasets. Besides this, the recently emerging concepts of trustworthy AI and reliable AI are seen as key for boosting user acceptance of the technology, as well as for advancing the essential societal benefits like safety, emissions, inclusivity and access to mobility. At the same time, these concepts are needed to build on the ethics fundamentals of AI in road mobility.
Summarizing mobility in the near future will embrace the following challenges: Societal changes, infrastructure digitalization and validation strategies, technological evolution of vehicle and components, and large use of Artificial Intelligence techniques.

With this in mind, MEDIATOR results (human fitness/unfitness, automation fitness/unfitness, central mediation component and HMI) have been broadly discussed during the MEDIATOR workshops, to answer to the following questions:
- What characterises this result specifically?
- Why is this result seen as a focus of development?
- What is expected to be achieved for society?
- What are the typical issues to validate this result?
- Which aspects of infrastructure, vehicles technology and validation challenges are relevant for this result?
- Which standardisation areas are key for speeding up the industrialisation?
- Which regulation gaps are still to be covered?

All MEDIATOR results will be described following 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 TRL level and short-, medium- and long-terms.

5.1.1. Human fitness/unfitness

Impaired driver states and degraded performance are detected via different sensors monitoring drivers' behaviour and physiological activity. Based on these measures, drivers' ongoing and predicted state is estimated and compared against information about the automation level/status and the driving context. The component for assessment/prediction of human fitness is specifically comprised of the following software:
- Distraction assessment (TRL 6). Software that extracts gaze direction and Not-Driving Related Task (NDRT) engagement from video streams.
- Sleepiness and fatigue assessment (TRL 5). Software that extracts deep features resembling gaze direction, eyelid aperture, blink frequency, pupil size and facial expressions based on face videos and context information based on forward-facing videos is developed. Physiological fatigue indicators are extracted. Sleepiness and fatigue detection algorithms based on either physiological data, context data, face camera data, vehicle data, have been developed. Bio-mathematical models that make use of the real-time fatigue estimate are developed.
- Driver comfort assessment (TRL 2). 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.

Following, MEDIATOR results for human fitness/unfitness are listed and illustrated relating to TRL level and short-, medium- and long-terms.

Design needs

To keep drivers-in-the-loop it is required to consider and design all aspects that could influence their behaviour (i.e., drowsiness, distraction). Some MEDIATOR results are compliant with current regulations and industrial needs (TRL 7-8). Other MEDIATOR results require specialisation in design and algorithms (TRL 5-6) or new research (TRL 3-4). For this reason, Artificial Intelligence techniques could allow a better calibration of the human fitness component.

The main future needs are listed below. In Figure 5.1 the needs are listed according to short-, medium- and long- term functional requirements:

- Holistic approach to Driver State
- Data fusion Driver State sensors (Radar/sensors/medical etc.), ADAS data, vehicle data
- Drowsiness detection: camera + driving performance Global Safety Regulation (GSR) 2.0
- Evolution of drowsiness detection, integrating camera and driving performances (>L2)
- Distracted and drowsy driving models using physiological data
- Drowsiness prediction.

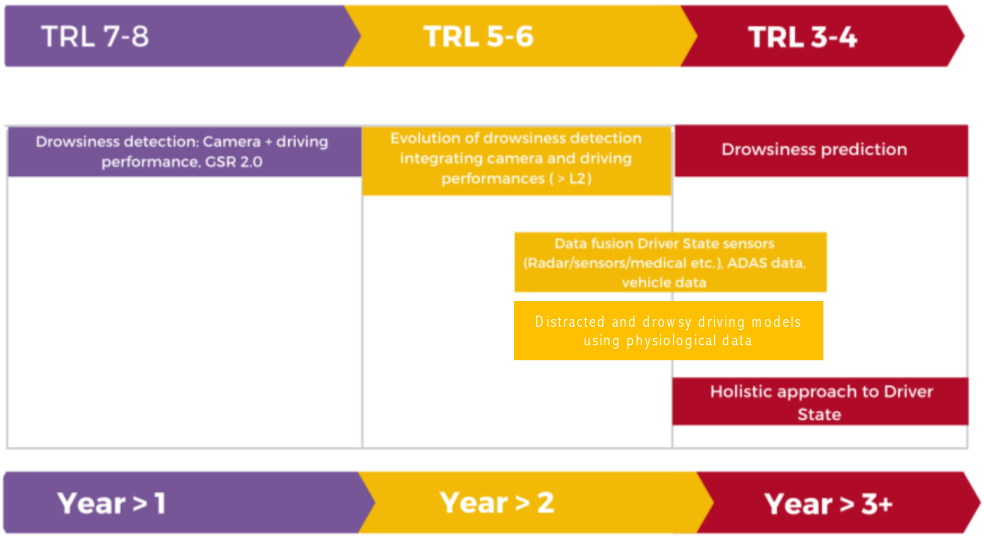


Figure 5.1 Human fitness/unfitness future needs roadmap: Design needs.

Technological needs

To consider the driver with a holistic approach it is necessary to define (TRL 3-4) and specialise (TRL 5-6) technologies to monitor the following driver parameters:

- Physiological data detection
- Emotion detection
- Health data detection by electronic consumers
- Alcohol/drug detection
- Stress detection
- Sleep cycles detection by wearables (Heartbeat, heart rate variability, activity recognition)
- Visual distraction detection
- Mind Wandering – Cognitive distraction detection
- Motion sickness detection
- Comfort detection.

The main future short-, medium- and long-term needs, are reported in Figure 5.2:

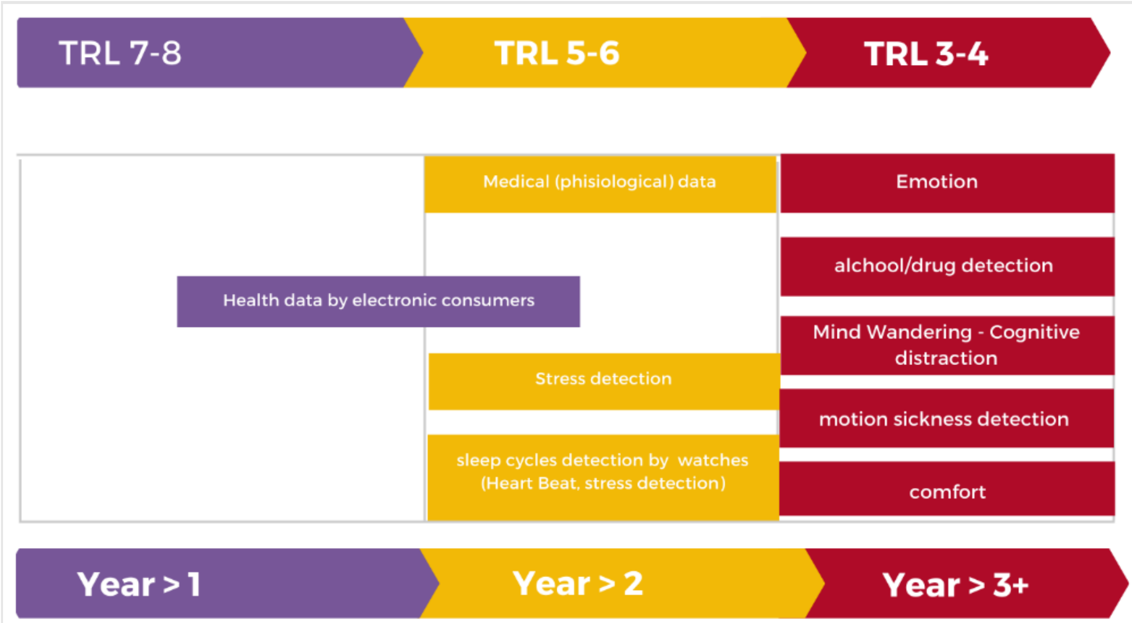


Figure 5.2 Human fitness/unfitness future needs roadmap: Technological needs.

Validation needs

Validation activities, especially on-road, require a direct involvement of the driver with consequent ethical implicants.

The main future needs are listed below. Figure 5.3 reports short-, medium- and long-term needs:

- Synthetic data vs real data
- WoOZ approach for studying driver state and reaction time
- Trials/training to improve Driver State Dataset (DB).

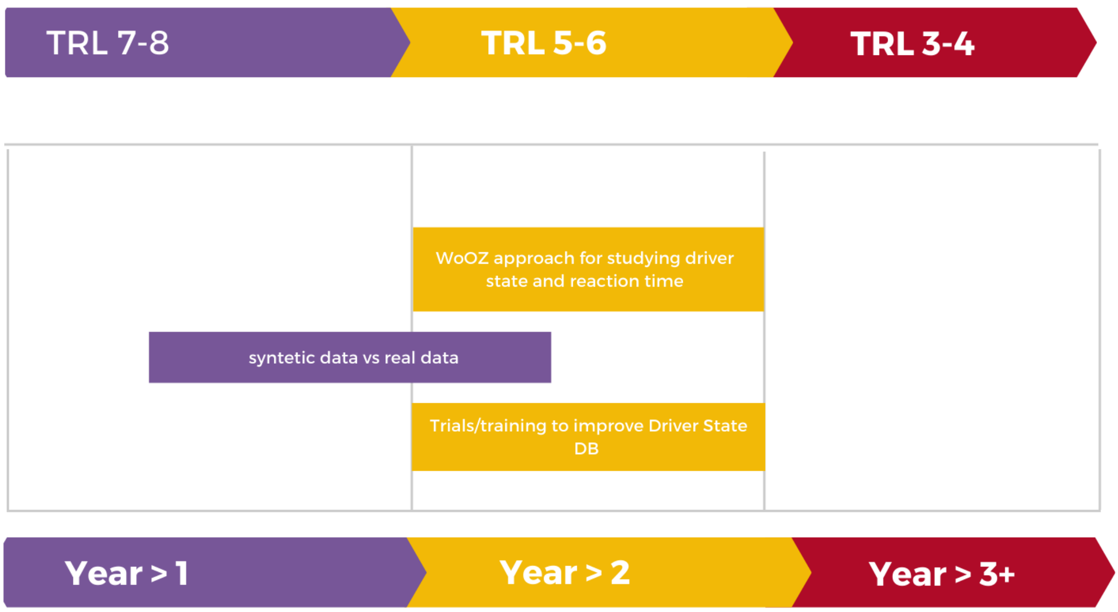


Figure 5.3 Human fitness/unfitness future needs roadmap: Validation needs.

5.1.2. Automation fitness/unfitness

To determine automation fitness/unfitness, 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 path (like highway exit, roundabout, construction zones, etc.). This information allows to estimate whether the current automated system/mode is fit for the present and upcoming driving context and whether driver attention and/or intervention is required.

Following, MEDIATOR results for automation fitness/unfitness are listed and illustrated relating to TRL level and short, medium and long terms.

Design needs

Automation fitness/unfitness was calibrated only referred to MEDIATOR use cases, not for all issues to address to ensure that technology like Mediator is safe and functions as expected technically and by the user when in real use (i.e., recovery actions in case of system fault, responsibility, etc.).

To overcome this lack, the main future needs are listed below, and in reported in Figure 5.4 according to short-, medium- and long-terms:

- Updated design with international standards
- Recovery Actions in case of Fault of software modules in vehicle
- Specialise confidence level of perception platform for automation fitness strategy
- Automation module and vehicle diagnostic
- Electric and Electronics architectures compliant with automotive standards
- Automotive cybersecurity.

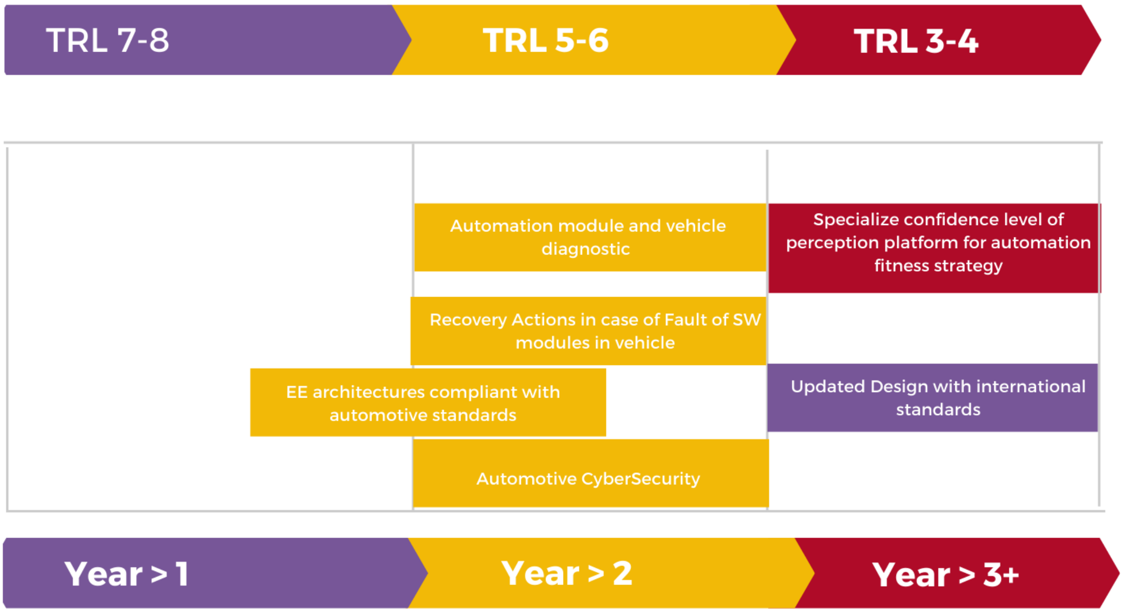


Figure 5.4 Automation fitness/unfitness future needs roadmap: Design needs.

Validation needs

Verification and validation for automation fitness/unfitness systems will be based on realistic and relevant test cases in different road contexts, follow commonly accepted methodologies and make use of validated tools, including driving simulator. In addition, some challenges will remain due to the dynamic nature of the constantly evolving transport system, and more connected infrastructure and vehicles (V2X).

The main future needs are listed below, and reported in Figure 5.5 according to short-, medium- and long-terms:

- Driving simulator to measure the effect of human driving behaviour on vehicle dynamics for vehicle automation
- Validation with realistic traffic environment
- Highway, Inter-urban and Urban Validation
- V2X applied to automation.

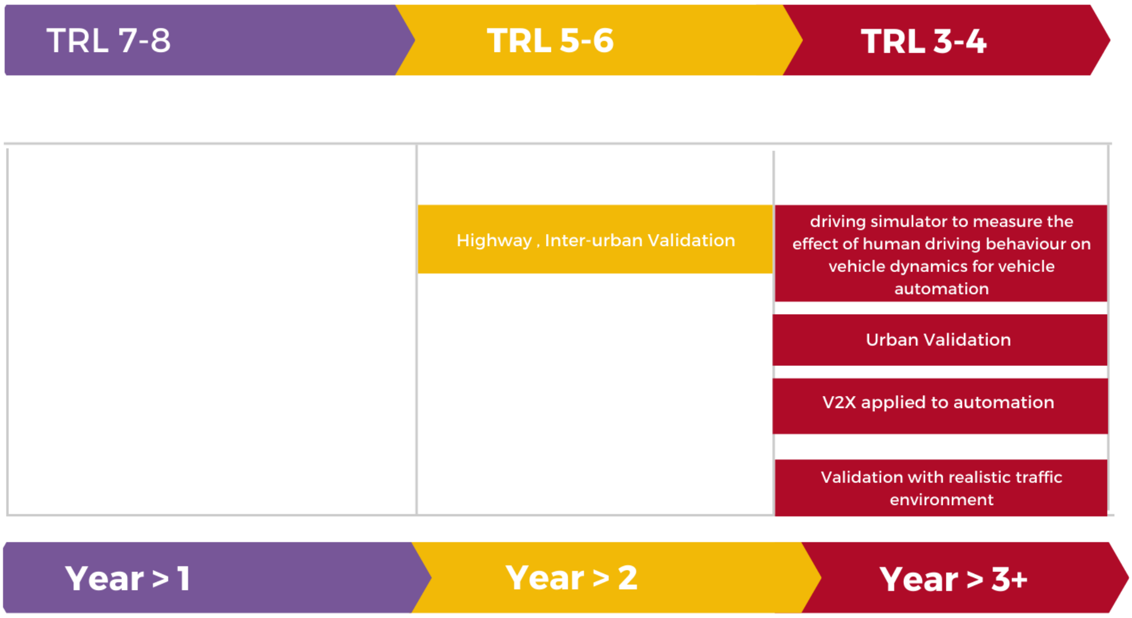


Figure 5.5 Automation fitness/unfitness future needs roadmap: Validation needs.

5.1.3. 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. The central mediation 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.

Following, MEDIATOR results for central mediation component are listed and illustrated relating to TRL level and short, medium and long terms.

Design needs

The central mediation component is the core of systems like Mediator, because it decides and supports the take-over from human to automatic driving tasks and vice versa. The component uses Artificial Intelligence technologies to merge the data related to automation or driver fitness, to decide the proper take-over strategy and to communicate through the proper HMI.

For a next in-vehicle application there are a lot of design needs, for the complete in-vehicle integration (respect of automotive standard, functional safety, in-vehicle architecture integration, recovery actions in terms of fault, etc.), to be solved in the next years.

The main future needs are listed below, and reported in Figure 5.6 according to short, medium and long terms:

- Hardware (HW) and Software (SW) components complaint to automotive standards (e.g., ISO 26262)
- Integration of Mediator system in different (existing or new) vehicle architecture
- Update and maintenance of Mediator Software
- Recovery actions in case of system fault
- Automotive cybersecurity
- Improve system design, effective training methods and safety policies (to cover misuse and disuse of automation by human operators)
- Mediator strategies take into account different driving styles.

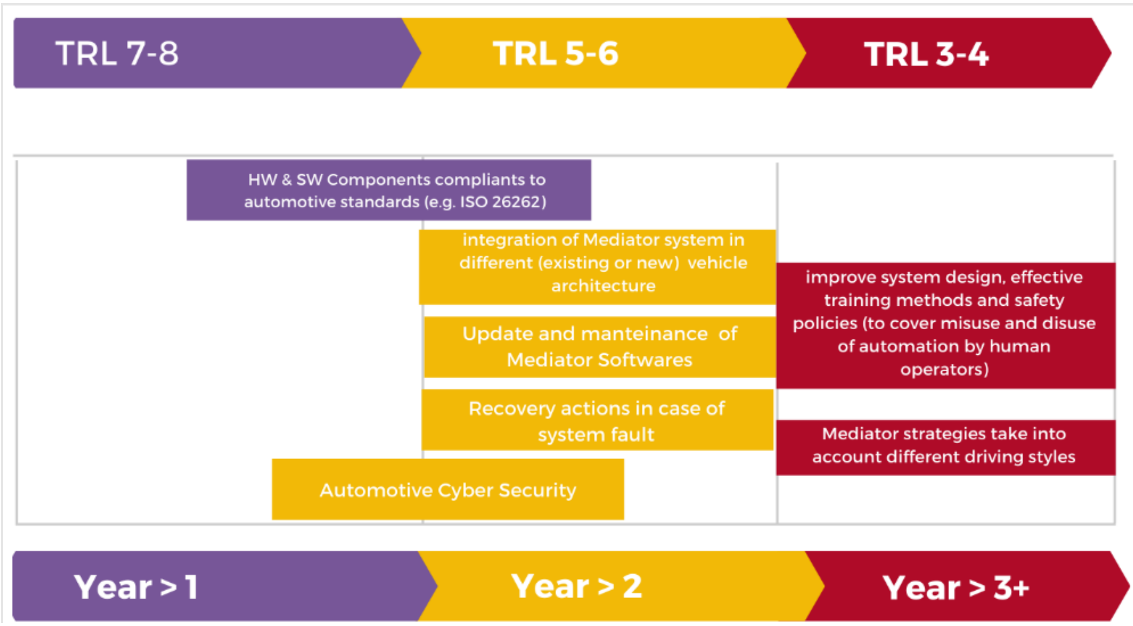


Figure 5.6 Central mediation component future needs roadmap: Design needs.

Validation needs

Verification and validation need for the central component are very similar to the needs for automation fitness and are related to test the component in different road contexts and with different traffic and users' categories. In addition, in short time it is fundamental to have trained drivers also with the driving simulator, skilled to interact with the car during the calibration and test of the component. Large scale tests in different countries are the main challenge to pursue at EU-level, ensuring the standard regulation in the different countries.

The main future needs are listed below, and reported in Figure 5.7 according to short, medium and long terms:

- Training of test drivers with driving simulator to promptly react in real on-road conditions
- Integrated technical tests of the different Mediator components
- Mediator system learnability
- Validation on real road with different user category
- Large scale validation in different countries

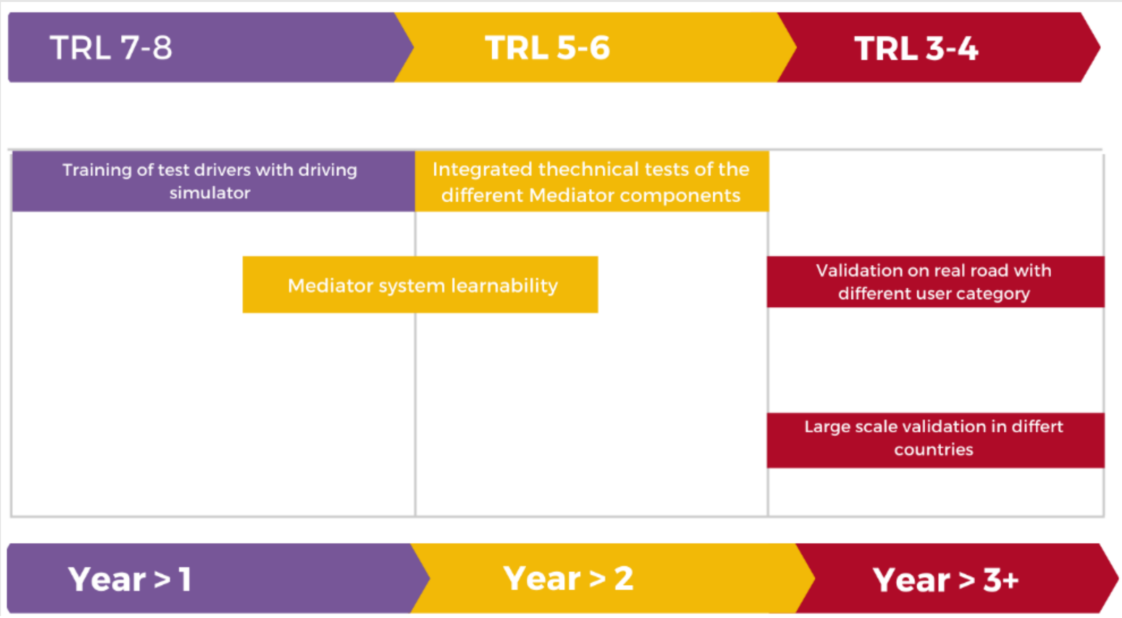


Figure 5.7 Central mediation component future needs roadmap: Validation needs.

5.1.4. HMI

The MEDIATOR HMI is addressing main challenges related to vehicle automation; the HMI, to mediate between the driver and the vehicle/system, is based on a holistic user centric design.
The HMI software receives inputs from the decision logic component regarding the automation current and near future fitness as well as actions to be implemented. 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 it is expected from them.
The MEDIATOR HMI uses several design principles to address main design challenges related to vehicle automation. The main design principles used for the MEDIATOR HMI design are: Holistic approach, designing for user acceptance, designing for industry acceptance, transfers of control, mode awareness (by transparency), keeping the driver in the loop.
The MEDIATOR HMI uses visual, audio, haptic, and vibrational interfaces, and it is based on 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.

Following, MEDIATOR results for HMI are listed and illustrated relating to TRL level and short, medium and long terms.

Design needs

Human interaction with the automated driving system inside the vehicle is mediated by the HMI. A safe interaction can be realized if the HMI provides an understanding of the capabilities and status of the technology (e.g., minimize mode errors), facilitates correct calibration of trust, stimulates an appropriate level of attention (e.g., when a takeover is imminent), provides comfort (e.g., reducing stress), and is usable in an intuitive way (e.g., by providing consistent feedback) (ERTRAC, 2022).

MEDIATOR HMI was tested in Italy and Sweden in terms of functionality in different driving conditions as well as in terms of users' acceptance/trust. Obviously, future challenges related to the evolution of the in-vehicle technologies and of the main components, the standardization of the solution in the different vehicle (to have a common language, e.g., in shared fleets) are some of the main needs to be solved in the next future. In addition, the holistic HMI requires that carmakers should improve their specific competencies, moving from specialistic (mechanical, electronics, etc.) engineering rules to system integrator engineering rules, to manage the integration between the different HMI components and between the HMI and the other MEDIATOR components, to set defined HMI strategies.

The main future needs are listed below, and reported in Figure 5.8 according to short, medium and long terms:

- Mediator HMI adapted to the standard for colours and icons
- HMI personal setting according to MEDIATOR states (Continuous mediation, Driver standby, Time-to-Sleep)
- HMI design approach user- centric
- HMI strategies based on drowsiness levels ranked.

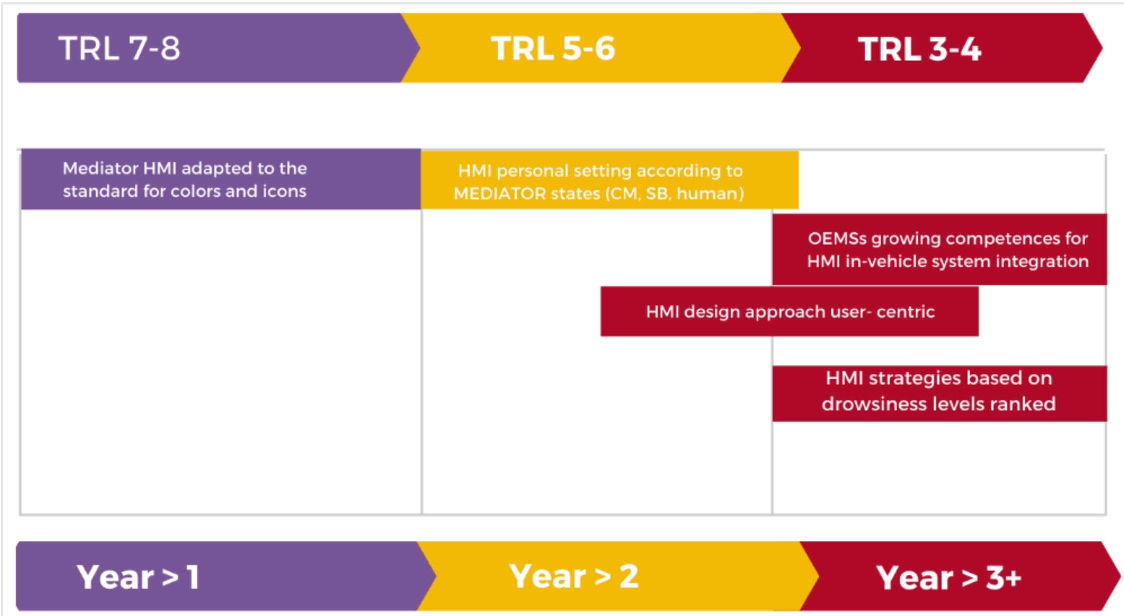


Figure 5.8 HMI future needs roadmap: Design needs

Technological needs

MEDIATOR HMI was based on commercial devices and was tested with the HF in-vehicle prototype, also with compromising solutions (e.g., two displays instead of one large display to maintain the vehicle homologation requirements and have on-road tests with volunteers). Technologies are running fast and at same time it is necessary to ensure the respect of automotive standards for the new in-vehicle-components.

The main future needs are listed below, and reported in Figure 5.9 according to short, medium and long terms:

- HMI on large new display
- Integration of commercial HMI components in vehicle architecture according to automotive standards
- Integration external display (smartphone, etc.)

- Upgrade HMI design to be compliant with new / updated vehicle components (L4 w/o steering wheel; shifter, etc.)
- Vibrational devices in seat
- HMI voice assistant recognition
- Guidelines for ambient lighting in automation
- Retractable steering wheel

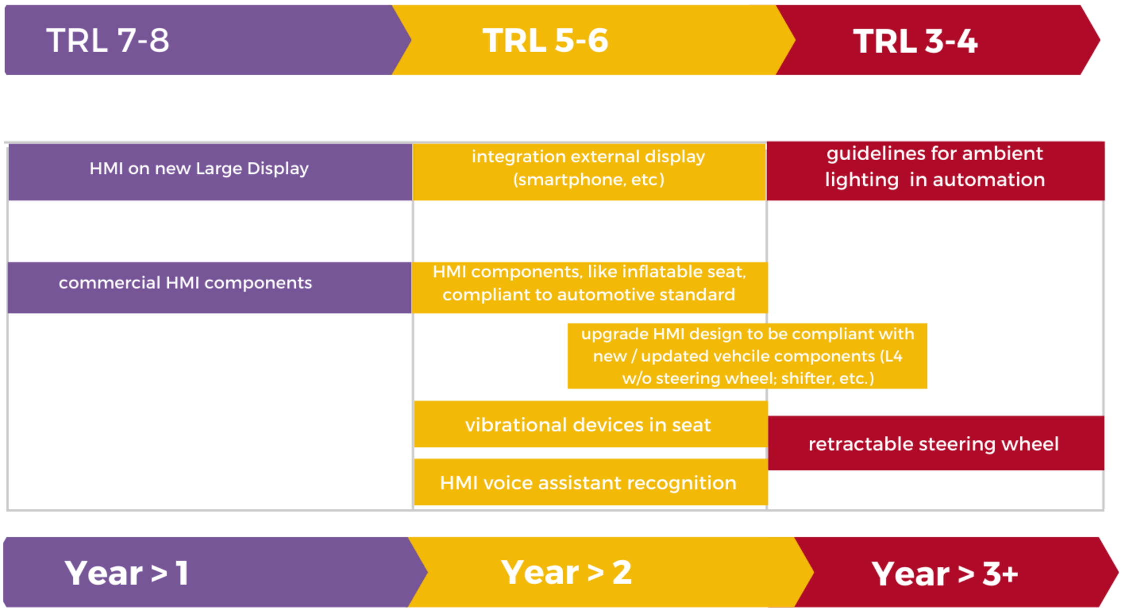


Figure 5.9 HMI future needs roadmap: Technological needs.

Validation needs

As reported before HMI was tested on road in Italy and Sweden; the on-road tests were conducted with 30 volunteers in Italy and 45 volunteers in Sweden on different use cases. Obviously, the HMI tests do not cover all possible test condition in terms of users, with different age, in terms of parallel tasks requested to driver, in terms of interaction with other in-vehicle devices (e.g., functional light). Finally, the WoOz approach has given a positive input to the HMI tests, allowing to have tests with volunteers not at the end of the vehicle development, but directly during the design and development phase, anticipating issues related to acceptability and trust, which could not be solved when the vehicle is almost ready to go on -market.

The main future needs are listed below, and in reported in Figure 5.10 according to short, medium and long terms:

- Trial test with different users and WoOZ approach
- HMI tests with parallel tasks
- HMI tests and driver workload
- Ambient light vs. functional light
- HMI and distraction effects

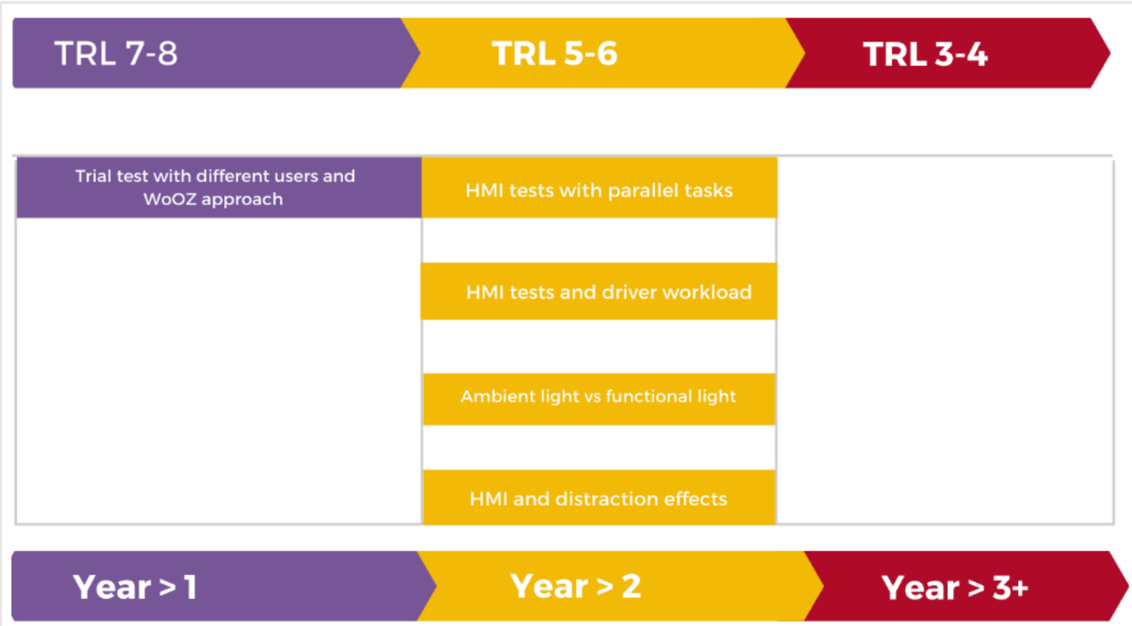


Figure 5.10 HMI future needs roadmap: Validation needs.

6. Conclusions

Autonomous driving is becoming one of the major business pillars for the automotive industry, and subsystems developed in the MEDIATOR project can play an important role in this field becoming new core components.
The technical realisation of automation in road transport has been progressing extensively in the last few years. MEDIATOR's results can contribute substantially to a safe transition in a broad range of levels of vehicle automation, contributing to the solution of a road transport issue.

The work in this deliverable is based around the identified exploitable results from MEDIATOR activities and revised based on the outcome of the identified use cases.

The main exploitable result from MEDIATOR is the Mediator system; algorithms and sensors, generated throughout the project are the MEDIATOR Key Exploitable Results (KERs).
Each of the MEDIATOR KERs have been grouped in the four Main Exploitable Results (MER), related to Mediator main components (Human fitness/unfitness, Automation fitness/unfitness, Human factors and HMI, Central mediation component). For each of these main exploitable result, different TRL, RRL and MRL scales were defined, according to the MEDIATOR activities, from the point of view of development and evaluation activities, regulatory aspects encountered in testing systems like Mediator and state of the implemented technologies.
For each main exploitable result, a market impact analysis has been performed by using an Integrated Assessment Model (IAM) for the assessment of both regulatory and market constraints, also taking into account systems and technologies actually available on the market or potential competitors. This framework represents the basis for developing strategies to target the appropriate level of research, to address the regulatory process governing the technology moving into the market and to engage the desired market adoption factors, required to achieve a good level of exploitation.

To make sure that MEDIATOR solutions were feasible for market implementation, in addition to the industrial partners within the consortium, stakeholders from the automotive industries were involved in different ways:

- from the beginning with the Industrial Advisory Board
- at the end of the project with three MEDIATOR Workshops in Netherlands, Italy and Germany, to: (1) involve all possible interested stakeholders (academia, tier supplier, engineering companies, etc.); (2) collect their feedbacks about MEDIATOR outcomes (automation, human factor, HMI and Central mediation component) also with their direct involvement in discussion (Word Café approach).

project's development and validation activities, as well as feedback from the MEDIATOR Advisory Board and MEDIATOR stakeholder workshops allowed to develop exploitation roadmap for road transport communities.
Four MEDIATOR roadmaps were developed related to MEDIATOR main components: human fitness/unfitness, automation fitness/unfitness, HMI and central mediation component. All MEDIATOR results are described hereafter in a common structure based on: design needs in terms of further development; 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.

MEDIATOR results key findings have potentiality to be mainly implemented in mid-term. Further developments of technical solutions, adaptations to automotive field and validation were also seen as relevant.

Since the novelty of the concept developed in MEDIATOR project, the outcome results can be of high potential for exploitation in HMI solutions for autonomous driving.

The work suffers from some limitations. For example, the text in the deliverable is based on the results achieved at three 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.

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