D4.5 – Metrics and plan for V&V of the TeamMate HMI software in the 3rd cycle

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1 Executive Summary

This document describes the requirements and the test plan for the enablers related to the HMI. These requirements were extracted from D1.5 where they have been updated after the 2nd cycle in order to provide the ground work for the development in the 3rd cycle.

As well as in this document deliverable D4.3 was updated with additional requirements to assure an optimal improvement of the TeamMate HMI.

This deliverable takes the results from the V&V of the 1st and the 2nd cycle, to describe the plans and experiments for verification and validation of the HMI components for both the car demonstrators in the 3rd cycle and continuous testing in driving the simulators.

2 Introduction

After the 1st and the 2nd cycle, many requirements have been reviewed and redefined in order to assure the goals that were established at the beginning of the project. In order to build trust between the driver and the vehicle, the HMI plays a very important role as a communication channel between them. Information displayed on the HMI should be perceived naturally, to 1) facilitate understandability, 2) reduce interaction time and 3) ensure cooperation between vehicle and driver.

As another safety component in the TeamMate HMI, an Augmented Reality system was implemented and developed as a natural way to perceive the information mixed with the context (i.e. traffic, infrastructure, etc.) to create a global awareness. This mixed reality ensures a more accurate perception of the information, because generated information from the display directly interacts with the environment. As an extension of the information displayed in the cluster and the central panel, the AR-HMI helps the driver to understand the situation and evaluate the scenario in the most accurate way.

In the 3rd cycle, the final enablers for WP4 have been merged in three main groups: E6.1 as interaction modality, E6.2 as Cluster + Central Display + Audio + Haptics and Ambient Lights and E6.3 as Augmented Reality.

As the final cycle of the project, the importance of verifying and validating the enablers is crucial in order to ensure safety and correct functionality.

3 Approach for verification, validation and metrics definition

The approach for verification has already been described in D4.3, whereas in this deliverable the approach is adapted to the 3rd cycle referring to the requirements described in D1.5.

As a short review from the previous deliverable, the definition of the metrics and the plan for 3rd cycle experiments are specified as follows:

1. Take the general requirements from D1.5 as a starting point.
2. Redefine the requirements and/or add new requirements for V&V.
3. Define specific metrics for the redefined/extended requirements.
4. Define concrete experiments to verify or validate the requirements for the specific enabler.

The enablers developed in WP4 were already described in previous deliverables (e.g. in D4.4). The four Enablers E6.2 Cluster + Audio, E6.3 Central Display, E6.4 Ambient lights and E6.6 HUD have now been merged into a single enabler, referred to as E6.2 (Multimodal HMI).

This choice has been made to clarify the role of these components. All of them are designed in a harmonic and interrelated way, where each of the original enabler interacts with the others according to the overall HMI strategy defined in D4.2 and D4.4.

Moreover, the amendment served also to distinguish between the concrete hardware and software components that are developed by different partners: with this new identification numbering, E6.1 by ULM, E6.2 by REL and E6.3 by HMT.

4 Reference of requirements and metrics defined in D1.5

In Table 1-3, the requirements are reported related to Enabler 6.1, Enabler 6.2, and Enabler 6.3 based on D1.5. Three columns have been added compared to the requirements table in D1.5, in order to describe in detail how each requirement will be validated:

- **How to measure the metric?** – in this column, a short description of the methodology/tool used to validate the requirement is reported.
- **Brief description of the experiment (if needed)** – in this column a description of the part of experiment performed to validate the requirement is briefly described. For "verification" requirements, the wording "Not needed" is used, if only a simple check is needed to satisfy the requirement.
- **Experiment ID** –ID of the corresponding experiment described in Chapter 6.

4.1 Definition of requirements for Enabler 6.1

Enabler 6.1 is Interaction modality.

Name: HMI interaction modality
Enabler Type: HMI
Owner: ULM

Table 1: Requirements for E6.1 from D1.5

ID	Verification / validation	Req. Owner	Description	Metric	How to measure the metric?	Brief description of the experiment (if needed)	Experiment ID (+ partner)
R_EN6_ INT1.1	Verification	ULM	The interaction strategy should be usable according to ISO 9241-11	Check: Y/N	Check if the design of the interaction is in accordance to the ISO norm	Not needed (check only)	NA
R_EN6_INT1.2	Validation	ULM	The interaction modality must be usable	SUS > 80	SUS questionnaire	Was checked during 2nd cycle and will also be validated during 3rd cycle using the SUS after each interaction modality	E2 (ULM)
R_EN6_ INT1.3	Validation	ULM	The trust for the system cannot be affected	Check: Y/N	Trust scale	The system trust cannot drop significantly with the interaction modality	E2 (ULM)
R_EN6_ INT1.4	Verification	ULM	The most efficient channels of interaction should be used according to the situation	Check: Y/N	Reaction time	The interaction modality with the fastest reaction time is the most efficient	E2 (ULM)
R_EN6_ INT1.5	Verification	ULM	The HMI should offer different actions on a manoeuvre level to the driver	Check: Y/N	Already validated in the 2nd cycle		
R_EN6_ INT1.6	Verification	ULM	The system must provide a way of intervention by the driver in non-crucial situations.	Check: Y/N	Check if there is a way of intervention	Not needed (check only)	NA
R_EN6_ INT1.7	Validation	ULM	The interaction modality must be intuitive	Check: Y/N	During experiments the participants should not ask questions how to use the system	No confusion during the 2nd cycle. Will be also checked during 3rd cycle	NA
R_EN6_ INT1.8	Validation	ULM	The system must distinguish between intentional and unintentional intervention.	Check: Y/N	Threshold for steering wheel angle (e.g. 2 degrees) or braking pedal position	Not needed (implementation only)	Already implemented in Cycle 2

4.2 Definition of requirements for Enabler 6.2

Enabler 6.2 is Cluster + central display + audio + haptics + ambient lights = Multimodal HMI.

Name: Multimodal HMI
Enabler Type: HMI
Owner: REL

Table 2: Requirements for E6.2 from D1.5

ID	Verification / validation	Req. Owner	Description	Metric	How to measure the metric?	Brief description of the experiment (if needed)	Experiment ID (+ partner)
R_EN6_HMI 1.1	Verification	ULM	The ambient light must clarify the driving mode (e.g. the takeover requests)	Check: Y/N	Already validated in the 2nd cycle		
R_EN6_HMI 1.4	Verification	REL	The HMI must have different states for each automation mode	Check: Y/N	Check the consistency between the state machine and the states of the HMI	Not needed (check only)	NA
R_EN6_HMI 1.5	Verification	REL	The HMI must show the Take Over Request on the cluster and mirror it on the Central Stack Display and the HUD	Check: Y/N	REQ NOT USED –HUD will not be integrated in any demonstrators		
R_EN6_HMI 1.6	Verification	REL	The overall HMI concept must include a strategy to modify the ambient lights to improve the driver awareness on the automation state	Check: Y/N	Check if the ambient lights colour changes according to the state	Not needed (check only)	NA

R_EN6_HMI 1.7	Verification	REL	The HMI must have 3 visual displays: - an instrument cluster - a Central Stack Display - a Head Up Display	Check: Y/N	Check if the HMI has 3 displays	Not needed (check only)	NA
R_EN6_HMI 1.8	Verification	REL	In TeamMate mode the HMI must show the possibility to interact with it through vocal interaction	Check: Y/N	REQ NOT USED – vocal input will not be implemented		
R_EN6_HMI 1.9	Verification	REL	Navigation info and surrounding view must be visible on the instrument cluster both in automatic and manual mode	Check: Y/N	Check if navi info and surrounding view is visible	Not needed (check only)	NA
R_EN6_HMI 1.10	Verification	REL	In "Handover", the Instrument cluster must show the correct handover through a popup that informs the driver of the current transition	Check: Y/N	Check if the IC shows the transition	Not needed (check only)	NA
R_EN6_HMI 1.11	Verification	REL	Infotainment features must be mirrored on the instrument cluster only in Automatic Mode	Check: Y/N	Check that infotainment is NOT available in Manual Mode	Not needed (check only)	NA
R_EN6_HMI 1.12	Verification	REL	In TeamMate mode, the HMI must show the suggested manoeuvre through animated features	Check: Y/N	REQ NOT USED – we used animated features to EXPLAIN the REASON for the request of support, not to suggest manoeuvres		
R_EN6_HMI 1.13	Verification	REL	In Manual mode, the Central Stack Display must show redundant information on navigation and surrounding situation	Check: Y/N	Check if information is shown on Central Display	Not needed (check only)	NA
R_EN6_HMI 1.14	Verification	REL	In Automated mode, the Central Stack Display must allow to reach all the features of the NIT navigation menu	Check: Y/N	Check that in Automated Mode some functions can not be reached	Not needed (check only)	NA

R_EN6_HMI 1.15	Verification	REL	In Manual mode, in Manual to Automated transition mode and in emergency mode the Central Stack Display must allow to reach only some features of the navigation menu (e.g. it should not be possible to reach the "Messages", "Web" and "Settings" items)	Check: Y/N	REQ NOT USED – the states have been changed in the second cycle		
R_EN6_HMI 1.16	Verification	REL	In Automated to Manual transition mode (TOR activated) the Central Stack Display shouldn't allow to navigate the menu	Check: Y/N	REQ NOT USED – the states have been changed in the second cycle		
R_EN6_HMI 1.17	Verification	REL	In manual mode, the HUD must provide crucial information on navigation (e.g. current speed, navigation info, speed limit)	Check: Y/N	REQ NOT USED – no HUD will be integrated on demonstrators		
R_EN6_HMI 1.18	Verification	REL	A HUD must be provided for Manual mode and for Automatic to Manual transition mode	Check: Y/N	REQ NOT USED – no HUD will be integrated on demonstrators		
R_EN6_HMI 1.19	Verification	REL	The HMI must integrate all relevant information on traffic, driver and automation	Check: Y/N	Check if info on traffic, driver and automation are shown	Not needed (check only)	NA
R_EN6_HMI 1.21	Verification	REL	Central Stack Display must display when the automated driving mode is switched on/off	Check: Y/N	Check if automation state is shown	Not needed (check only)	NA
R_EN6_HMI 1.22	Verification	REL	The HMI must clarify driver's and system's responsibility in order to prevent mode confusion	Check: Y/N	Check if automation state is shown	Not needed (check only)	NA
R_EN6_HMI 1.23	Verification	REL	Central Stack Display must display the information on lateral vehicle control and the longitudinal vehicle control	Check: Y/N	Check if shared control is expressed	Not needed (check only)	NA
R_EN6_HMI 1.24	Verification	BIT	Central Stack Display must display different map representations (short term as well as long term) to intuitively show imminent risks	Check: Y/N	Already validated in the 2nd cycle		

R_EN6_HMI 1.26	Validation	ULM	The HMI must be understood by the driver when shows the different actions on a manoeuvre level	CR for level of understanding - >90% acceptable	Already validated in the 2nd cycle		
R_EN6_HMI 1.27	Verification	REL	The HMI should select the right channel of communication at the right moment depending on the driver and traffic situation	Check: Y/N	Already validated in the 2nd cycle		
R_EN6_HMI 1.28	Verification	REL	The HMI must always make the driver aware on how to intervene	Check: Y/N	Already validated in the 2nd cycle		
R_EN6_HMI 1.29	Verification	REL	More than one channel of communication should be provided to the driver other than visual UI, including acoustic feedbacks (i.e. speech recognition, microphones, cameras, haptic feedbacks, speakers)	Check: Y/N	Already validated in the 2nd cycle		
R_EN6_HMI 1.30	Verification	REL	Driver must be alerted of possible dangers by using stimuli of different modalities	Check: Y/N	Check if different stimuli are used	Not needed (check only)	NA
R_EN6_HMI 1.31	Validation	REL	The performance of human-automation interaction must be evaluated by measuring: - attention allocation efficiency - mission effectiveness - driver physical comfort and fatigue trust in the system - user acceptance	CR for mission effectiveness - >90% acceptable	Already validated in the 2nd cycle		
R_EN6_HMI 1.36	Validation	REL	The different HMI modes visualized in the driving cluster must be recognized by the driver.	CR for level of understanding Situation Awareness	Already validated in the 2nd cycle		

R_EN6_HMI 1.37	Validation	VED	The crucial ambient light modes must be understood by the driver (automated mode, emergency mode)	CR for level of understanding < 90% not acceptable >90% acceptable	Already validated in the 2nd cycle		
R_EN6_HMI 1.43	Validation	REL	The use of multimodal elements in the HMI must increase the level of situation awareness	SA (SAGAT) > 0	Measure the SA in different HMI configurations	Each scenario part provides a different HMI configuration and users have to answer questionnaires for each of them using SAGAT	E1 (REL)
R_EN6_HMI 1.44	Validation	REL	The HMI must make the driver able to predict the relation among the HMI states (e.g. stable and transition)	Correct rate: > 90%	Already validated in the 2nd cycle		
R_EN6_HMI 1.45	Validation	REL	The user should always be aware of the automation state	Correct rate: > 90%	Already validated in the 2nd cycle		
R_EN6_HMI 1.46	Validation	REL	When a limit occurs, the user should be aware of the agent that has a limit	Correct rate: > 90%	Already validated in the 2nd cycle		
R_EN6_HMI 1.47	Validation	REL	When support is needed, the user should be aware of the type of expected cooperation	Correct rate: > 90%	Already validated in the 2nd cycle		
R_EN6_HMI 1.48	Validation	REL	The user should be able to understand the message communicated by the system	Correct rate: > 90%	Already validated in the 2nd cycle		
R_EN6_HMI 1.49	Validation	REL	The user should be able to predict the HMI mode of the system after the support was given.	Correct rate: > 90%	Already validated in the 2nd cycle		
R_EN6_HMI 1.50	Validation	REL	The H2A support in perception should be less demanding than the H2A support in action	NASA TLX Demand of perception support < Demand of action support	Already validated in the 2nd cycle		

4.3 Definition of requirements for Enabler 6.3

Enabler 6.3 is Augmented Reality (HMT)

Name: Augmented Reality HMI
Enabler Type: HMI
Owner: HMT

Table 3: Requirements for E6.3 from D1.5

ID	Verification/ validation	Req. Owner	Description	Metric	How to measure the metric?	Brief description of the experiment (if needed)	Experiment ID
R_EN6_HMI 1.20	Verification	REL	The HMI must show safe driving corridors and constraints on these corridors using graphical means	Check: Y/N	Already validated in the 2nd cycle		
R_EN6_HMI 1.33	Validation	REL	In manual mode augmented reality (AR) elements should be reduced to minimum and not distract the driver.	CR for level of understanding >90%	The users will be asked to explain the meaning of the GUI	A video will be shown and the user will be asked, through an online questionnaire, the meaning of the AR-HMI	E3 (HMT)
R_EN6_HMI 1.34	Verification	REL	In automated mode, augmented reality elements can be used to enhance the situation awareness.	Check: Y/N	Already validated in the 2nd cycle		
R_EN6_HMI 1.35	Validation	REL	In automated mode, the manoeuvres performed by the vehicle must be comprehensible for the driver through graphical visualizations.	CR for level of understanding >90%	The users will be asked to explain the meaning of the GUI	A video will be shown and the user will be asked, through an online questionnaire, the meaning of the AR-HMI	E3 (HMT)

R_EN6_HMI 1.41	Validation	HMT	The HMI should communicate to the driver why the automation is acting in a certain manner in an understandable way.	Situation awareness	The users will be asked to explain the meaning of the manoeuvre	A video will be shown and the user will be asked, through an online questionnaire, the meaning of the AR-HMI	E3 (HMT)
R_EN6_HMI 1.42	Validation	HMT	The driver needs to understand the meaning of the overtaking corridor visualized through AR.	CR for level of understanding >90%	The users will be asked to explain the meaning of the GUI	A video will be shown and the user will be asked, through an online questionnaire, the meaning of the AR-HMI	E3 (HMT)
R_EN6_HMI 1.51	Validation	HMT	The HMI must show safe driving corridors and constraints on these corridors using graphical means	Check: Y/N	Check if information is shown in the AR-HMI	Not needed (check only)	NA
R_EN6_HMI 1.52	Validation	HMT	In manual mode, augmented reality (AR) elements should be reduced to a minimum to avoid distraction of the driver.	Check: Y/N	Check if information is reduced to a minimum in the AR-HMI	Not needed (check only)	NA
R_EN6_HMI 1.53	Validation	HMT	In automated mode, augmented reality elements can be used to enhance the situation awareness.	CR for level of understanding >90%	The users will be asked to explain the meaning of the AR-HMI	A video will be shown and the user will be asked, through an online questionnaire, the meaning of the AR-HMI	E3 (HMT)
R_EN6_HMI 1.54	Validation	HMT	In automated mode, the manoeuvres performed by the vehicle must be comprehensible for the driver through graphical visualizations.	CR for level of understanding >90%	The users will be asked to explain the meaning of the AR-HMI	A video will be shown and the user will be asked, through an online questionnaire, the meaning of the AR-HMI	E3 (HMT)
R_EN6_HMI 1.55	Validation	HMT	The HMI should communicate to the driver why the automation is acting in a certain manner in an understandable way.	CR for level of understanding >90%	The users will be asked if they understood the action of the automation.	A video will be shown and the user will be asked, through an online questionnaire, the meaning of the AR-HMI	E3 (HMT)
R_EN6_HMI 1.56	Validation	HMT	The driver needs to understand the meaning of the overtaking corridor visualized through AR.	CR for level of understanding >90%	The users will be asked to explain the meaning of the AR-HMI	A video will be shown and the user will be asked, through an online questionnaire, the meaning of the AR-HMI	E3 (HMT)

5 Definition of additional requirements and metrics

In the 3rd cycle, the design and development of the HMI will focus on the *Take Over Request*. For this reason, different interaction modalities, e.g. haptic feedback will be implemented and validated. This section describes the requirements and the respective metrics added for the 3rd cycle.

Table 4: Additional requirements for E6.2 – TeamMate Multimodal HMI

ID	Verification/ validation	Req. Owner	Description	Metric	How to measure the metric?	Brief description of the experiment (if needed)	Experiment ID (partner)
R_EN6_HMI 1.57	Validation	REL	Users should understand the meaning of the haptic feedback as proxy of an imminent TOR	Correct Rate > 90 %	The users will be asked to explain the meaning of the haptic feedback	During an initial training phase, vibration cues will be given to the users to suggest a partial (or total) transition of control. Questionnaire: participants will be asked whether they are able to associate the vibration cue with the TOR.	E1 (REL)
R_EN6_HMI 1.58	Validation	REL	Haptic feedback must reduce the time needed to take over the control (partial or total)	Reaction time with Haptic feedback < of 20% of reaction time without haptic feedback	The delta time between the reaction time with and without haptic feedback will be measured	Two experiments in the Eva scenario to compare the reaction times: the HMI developed in the 2nd cycle will be the baseline against which the HMI developed in the 3rd cycle will be validated	E1 (REL)

R_EN6_HMI 1.59	Validation	REL	The HMI should allow the driver to take over the control within a maximum amount of time of 8 seconds as described in the state of the art [1]	Time to take over < 8 seconds	The driver should be able to take over the control within 8 seconds	This measure will be recorded during the experiment conducted for requirements 1.57 / 1.58; The experiment will be performed in the Eva scenario (roundabout).	E1 (REL)
R_EN6_HMI 1.60	Validation	REL	The HMI should allow the driver to take over the control before reaching the roundabout (to avoid a stop that can negatively impact the traffic)	Number of positive transitions > 90%	When a take over request occurs, the driver should take back the control before a safe stop at the roundabout	This measure will be recorded during the experiment conducted for requirements 1.57 and 1.58; The experiment will be performed in the Eva scenario (roundabout)	E1 (REL)

For the AR-HMI, a new graphical element will be added to support the interaction between the driver and the TeamMate vehicle. By using the same concept of the safety corridor, a new colour pattern will be added to the corridor. In consequence, a new additional requirement has been added for E6.3.

Table 5: Additional requirements for E6.3 – AR HMI

ID	Verification/ validation	Req. Owner	Description	Metric	How to measure the metric?	Brief description of the experiment (if needed)	Experiment ID (partner)
R_EN6_HMI 1.61	Validation	HMT	In automated mode, augmented reality elements can be used to request support in decision.	Correct Rate > 90 %	The users will be asked to explain the meaning of the AR-HMI	A video will be shown and the user will be asked about the meaning of the AR-HMI using an online questionnaire.	E3 (HMT)

6 Objectives of the experiments

This section introduces the objectives of the experiments that will be carried out during the 3rd cycle.

6.1 Experiment 1

In the 1st cycle different interaction modalities (E6.1) were tested with regard to their impact on trust, usability and other KPIs. Modifications were made to these interaction modalities in the 2nd cycle. Afterwards, they have been validated again to check whether there have been improvements to the KPIs.

The gesture interaction was rated as an interaction modality in autonomous driving. Therefore, the third cycle concentrates on both, the touch interaction as a state of the art baseline and the "natural interaction", where channels that are already used in manual driving (steering wheel and gas pedal) are used to interact with the TeamMate car.
Further modifications will be applied to the interaction modality resulting from the comments of the participants in the 2nd cycle. With these improved ways of interaction the requirements will be validated in this user study. The objective of the 3rd cycle experiment is to investigate the performance of the interaction modality compared to the baseline interaction in different situations.

The baseline will be the touch interaction. Participants will have to initiate the manoeuvres by pressing a button on the central stack touch display. The natural interaction modality will be tested with both, the steering wheel and the gas pedal. Therefore, it can be tested, which interaction modality is the best regarding the defined KPIs (see D6.1) in the different situations.

6.2 Experiment 2

For E6.2, the 1st cycle was focused on the overall HMI strategy and conceptualization, while the 2nd cycle was mostly focused on *Support in Perception* and the development of the second prototype of the HMI software. During the 2nd cycle, the validation phase focused on the driver's ability to clearly distinguish between a support in perception and a support in action (as described in D4.4). However, due to the safety-critical nature of the support in action (i.e. the partial or total Take Over Request with a transition of control from the vehicle to the human driver), in the 3rd cycle, we will focus on the reaction time needed to resume the control.

Therefore, in this 3rd loop, haptic feedback via the driver's seat will be added to the existing feedback channels for the support in action: visual (through the Graphical User Interface) and audio (i.e. the messages given by the vehicle).

The addition of the haptic feedback has been designed and implemented to reinforce the request of transition when the driver is distracted. The use of multimodal interaction has been described for the 1st and 2nd cycle in D4.2 and D4.4 (chapters on Information Structure and HMI strategy, related to Task T4.2) and will be further described for the 3rd cycle in D4.6.

The objective of Experiment 2 is the validation of the requirements related to Enabler 6.2, and to assess the improvements of this enabler in the 3rd cycle with a specific focus on the *Support in Action*. In particular, the validation will focus on the ability of the driver to immediately recognize a request of *Support in Action* (shared control and take over request), and on the role of the haptic feedback and the overall multimodal communication. The measure that will be tested is the reaction time of the driver.

6.3 Experiment 3

The objective of this experiment is twofold: 1) to validate the AR-HMI enabler (E6.3) and the related requirements R_EN6_HMI 1.35; 1.41; 1.42 that didn't meet the CR of 90% in the 2nd cycle, and 2) to validate the improvements of E6.3 that were made based on the results of the previous experiments and the related requirements R_EN6_HMI 1.51 to 1.56; 1.61.

In this experiment, a new graphical element added for the 3rd cycle will be tested (R_EN6_HMI 1.51). As an extension of the safety corridor, a corridor shown in blue colour will be used to ensure the communication between the driver and the TeamMate vehicle. The blue corridor will be shown when the TeamMate needs support from the driver (H2A), e.g. in a learning stage of the TeamMate, when the vehicle needs the input from the driver to execute a manoeuvre. Another scenario would be when the vehicle suggests a different manoeuvre or a new alternative trajectory.

7 Description of the experiments

This chapter presents the experiments planned for the 3rd cycle of the project.

7.1 Experiment 1

The experiment to validate the requirements for E6.1 will be conducted in the ULM driving simulator. The PETER scenario will be tested with the modification that it will include highways in addition to the rural road to test another way of interacting with the car (gas pedal) as it is done in manual mode. Three scenarios with different regulatory needs will be tested in a within-design study with around 20 participants. Figure 1 shows the first concept of scenariosFigure 2.

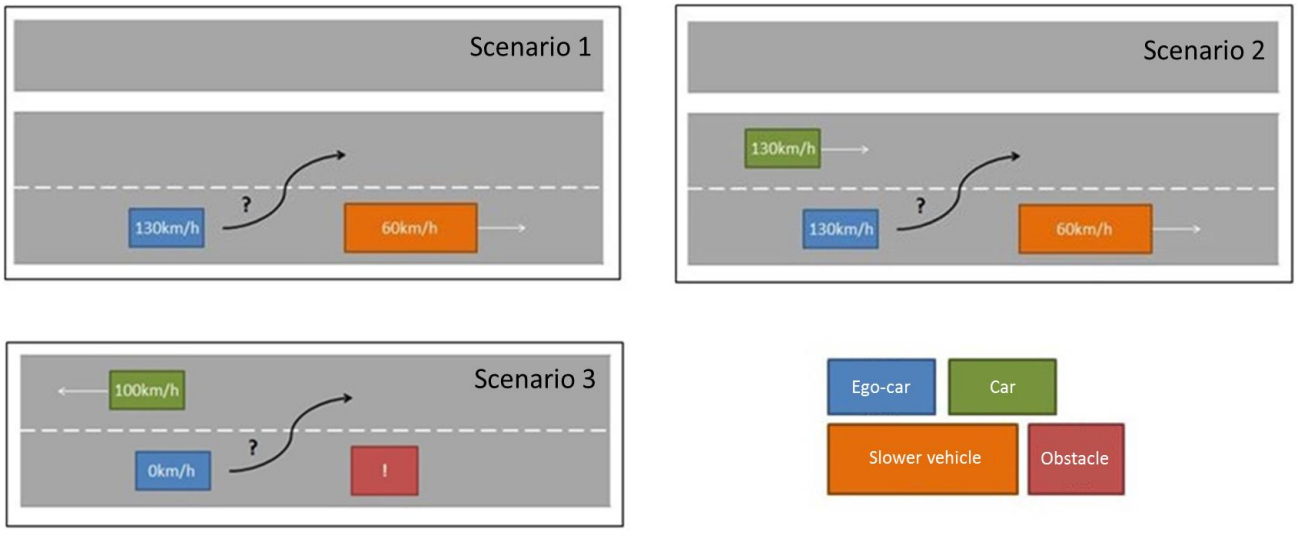

Figure 1: The three different scenarios of Experiment 1

At the beginning, the users will be asked to have a training session to practice with the driving simulator and especially the different interaction modalities, i.e. steering wheel and gas pedal.

Afterwards, each participant will start with a certain interaction style, the order of the interaction modalities will be counterbalanced across the participants.

The participants will drive through a course consisting of a repetition of three basic scenarios, seen in Figure 1. These three scenarios are:

- 2-lane (one-way) highway situation where the ego-car is approaching a slowly driving vehicle without other traffic participants.
- 2-lane (one-way) highway situation where the ego-car is approaching a slowly driving vehicle with a car approaching from behind.
- 2-lane (two-way) rural road where an obstacle forces the TeamMate car to decrease the speed to 0 km/h.

In each of these situations, the participant has to decide whether it is safe to overtake the slower vehicle or the obstacle. Different types of driving data will be collected as well as subjective measurements to test the requirements and the defined KPIs (see D6.1).

7.2 Experiment 2

The experiment to validate the requirements for E6.2 will take place in REL facilities, on the driving simulator. EVA scenario will be used in order to map the HMI behaviour on a concrete AutoMate use case, in particular the roundabout. The scenario is shown in Figure 2.

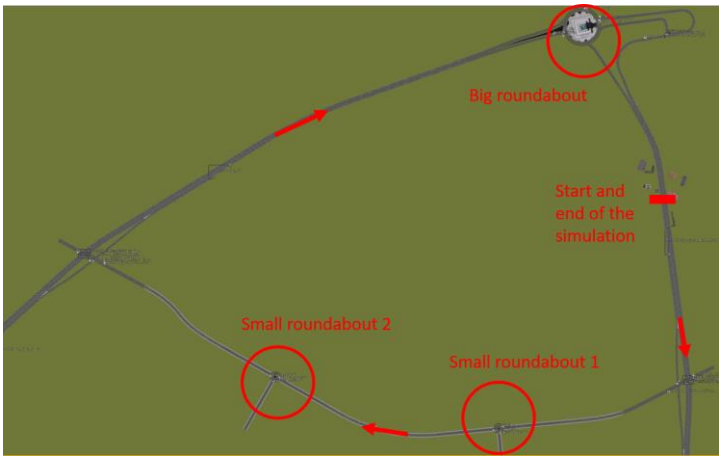

Figure 2: Driving simulator scenario for E6.2 "TeamMate Multimodal HMI" validation

At the beginning, the users will be asked to have a training session to practice with the driving simulator in the EVA scenario. In this phase, the requirement R_EN6_HMI1.57 will be validated. During this initial training phase, a vibration cue will be given to the users to suggest a partial or total transition of control. A question about the meaning of the vibration cue will be asked while driving to assess whether the driver is able to immediately associate this vibration cue with a request of support in action (partial or total TOR).

The scenario will start in Manual Mode; the users will be asked to drive up to the second roundabout. After the second roundabout, the users will receive a message/email on a phone placed on a device inside the simulator mock-up, and will be asked to answer a message. This secondary task will be used to distract the driver. Based on the implementation of Enabler 1.1 (Driver monitoring system) the TeamMate car is able to detect the distraction and it will offer a transition of control from Manual Mode to Automated Mode.
When approaching the third roundabout (i.e. the big one), the TeamMate car issues a *Support in Action request to the driver, which results in* a partial transition of control (i.e. the Shared Control).
The scenario will be performed twice, with and without haptic feedback, in order to quantify the added value given by the haptic interface.

The HMI developed in the 2nd cycle, i.e. without haptic feedback, will be the baseline against which the HMI developed in the 3rd cycle will be tested. The two scenarios will be randomized in order to avoid biases.

A sample of 8-10 users is expected to be used in this validation experiment; each user will perform the scenario in the two different conditions. More details on the experimental protocol will be given in D4.6.

7.3 Experiment 3

As an extension of the 2nd cycle experiment to test the Augmented Reality HMI, Experiment 3 has the objective to validate Enabler E6.3 according to the procedures described in the deliverables D4.3 and D4.4.

In addition, the functionality of the AR-HMI was extended and has to be validated, too. A blue corridor (see Figure 3) will be used to request support from the driver (Human-to-Automation). The automation will issue a request to the driver whether he/she agrees with the manoeuvre that is proposed by the HMI.

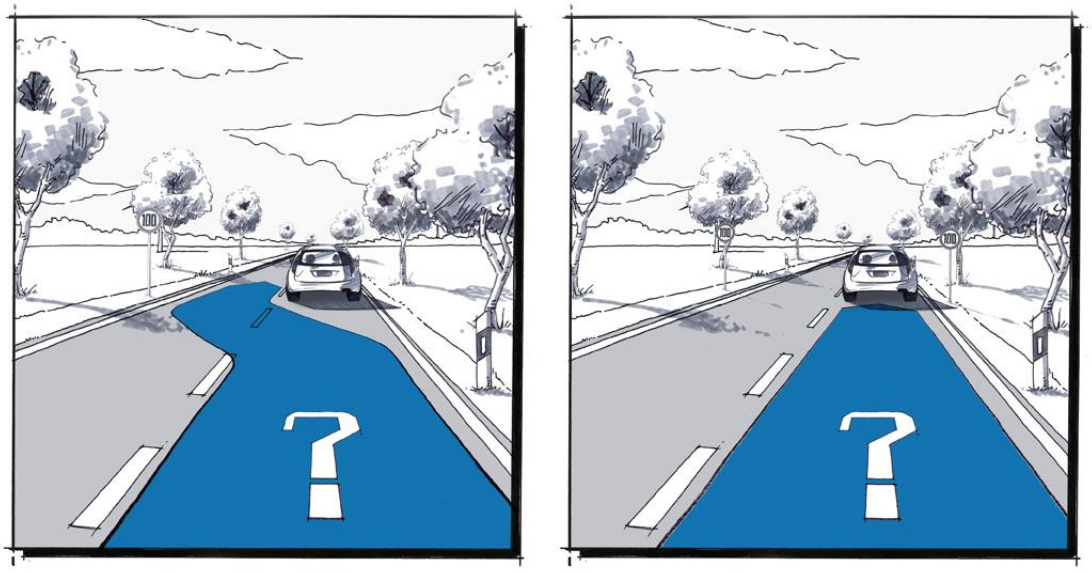

Figure 3: Request for support of the AR-HMI

The objective of the experiment is to assess whether participants are able to recognize and understand the meaning of the graphical visualizations of the AR-HMI in different scenarios.

The different scenarios were already described in D4.4 chapter 3.7.2 with addition of the new scenario, where the graphic for request in support will be displayed.

In these scenarios, the ego-car drives in automated mode and approaches a slower lead vehicle. The AR-HMI will display a request of the system, asking the driver which manoeuvre he would like to perform in the given situation. Figure 4 shows one of the possible scenarios.

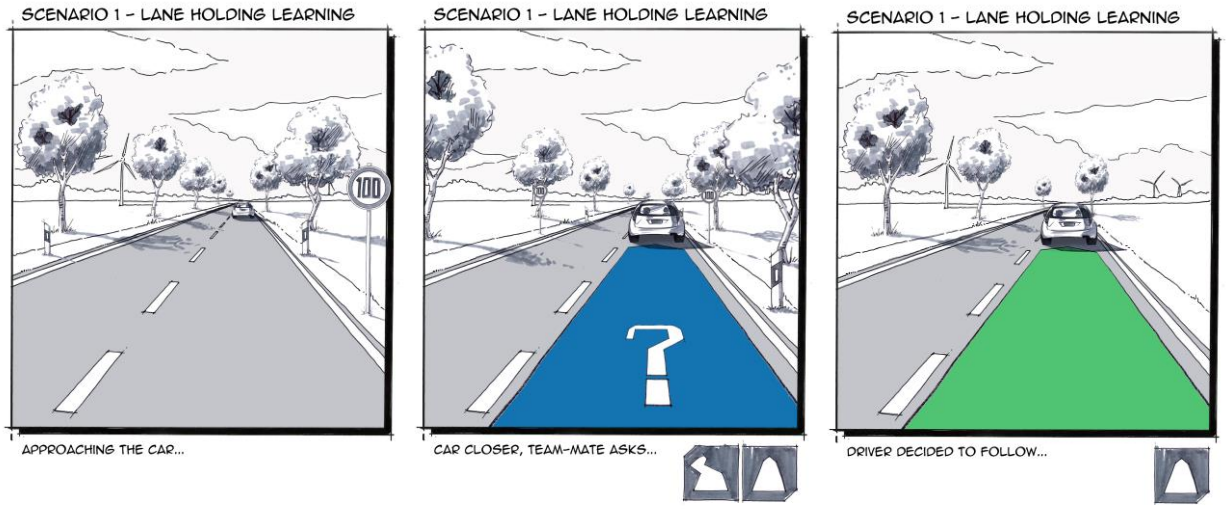

Figure 4: Lane holding scenario of the AR-HMI

The AR-HMI of the 2nd cycle will be the baseline against which the AR-HMI with the new graphical elements developed in the 3rd cycle will be tested.

8 Conclusion

This document presented the verification and validation plans of the TeamMate HMI. The corresponding requirements were included from D1.5 and extended by brief description of metrics and experiments. The reason of this is to overview what has been done during the previous cycles and what is planned for the 3rd cycle of the project. In addition to the existing requirements, new requirements were introduced to cover the new features that will be developed in this last cycle. Finally, the experiments were described in order to assess the new features' potential and acceptance by users. The experiments reflect the validation of requirements on the one hand and the usefulness of the enablers on the other hand. The results of the validation of the requirements will be reported in deliverable D4.6.

9 References

[1] Melcher, Vivien & Rauh, Stefan & Diederichs, F & Widlroither, Harald & Bauer, Wilhelm. (2015). *Take-Over Requests for Automated Driving*. Procedia Manufacturing. 3. 2867-2873. 10.1016/j.promfg.2015.07.788.