D1.1 – Definition of framework, scenarios and requirements

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Table of Contents

1. INTRODUCTION 5

2. DEFINITION OF THE TEAMMATE CAR FRAMEWORK 5

2.1. THE DRIVING TASK 6
2.2. THE SYSTEM PERSPECTIVE ON THE DRIVING TASK 7
2.3. HUMAN-AUTOMATION COOPERATION 8
2.4. LEVELS OF COOPERATION 11
2.5. A PRELIMINARY ARCHITECTURE 12
2.6. TEAMMATE CAR RESEARCH QUESTIONS 14

3. SCENARIOS AND USE CASE DEVELOPMENT 15

3.1 SCENARIOS DESCRIPTION 16
3.1.1 Scenario "Peter" 16
3.1.2 Scenario "Martha" 17
3.1.3 Scenario "Eva" 18
3.2 USE-CASE DESCRIPTION 19
3.2.1 Peter Use cases 19
3.2.2 Martha Use cases 20
3.2.3 Eva Use cases 21

4. DEFINITION OF REQUIREMENTS 22

4.1.1 Enabler 1 – Sensor and communication platform 25
4.1.2 Enabler 2: Probabilistic Driver Modelling and Learning 28
In order to reach the expected outcomes for the understanding, assessment and anticipation of the driver, the following requirements have been identified, in order to develop solutions for flexible, gradual and smooth distribution of tasks between driver and automation to better handle critical driving situations. 29
4.1.3 Enabler 3: Probabilistic Vehicle and Situation Modelling 30
4.2 AUTOMATE OBJECTIVE 1 AND OBJECTIVE 3 31
4.2.1 Enabler 4: Adaptive Driving Maneuver Planning, Execution, and Learning 32
4.3 AUTOMATE OBJECTIVE 4 35
4.4 AUTOMATE OBJECTIVE 5 37
4.5 AUTOMATE OBJECTIVE 6 39

6. CONCLUSIONS 42

REFERENCES 43

ANNEX A 44

1. Introduction

Automation in passenger cars is constantly increasing. Many automated functions have been developed for enhancing safety and efficiency of driving in the past. In order to continue this trend current roadmaps of OEMs and suppliers predict automated vehicles on highways by 2020. Fully and highly automated driving comprising also rural roads and inner-city situations will follow within the next decades. Nevertheless, humans will remain part of the system for a long time due to several reasons. At least in the next 10 years automation cannot cope with highly complex traffic situations, e.g. dense urban traffic. In this context, the top-level objective of AUTOMATE is to develop, evaluate and demonstrate the "TeamMate Car" concept as a major enabler of highly automated vehicles. This concept consists of viewing driver and automation as members of one team that understand and support each other in pursuing cooperatively the goal of driving safely, efficiently and comfortably from A to B.

The first steps to achieve this "top-level" objective is to define the operative scenarios (target-scenarios, TSs), the use cases (UCs), and the requirements (REQs) as well as a general TeamMate Car frame-work as a starting point for the technology development in WP2–WP5.
In details, this document is structured in the following sections. This chapter (Ch. 1) provides an overview, while chapter 2 is focused on a first description of the general framework for the TeamMate Car, starting from what is available in literature and from previous similar projects. Chapter 3 describes the set of relevant scenarios and related use cases, which the development will be focused on. Then, chapter 4 defines a draft set of requirements and associated KPIs for the TeamMate Car.
This is an initial version for the TSs, UCs and REQs; a refinement is foreseen in the cycle 2 of the AUTOMATE project.

The complete list of top-level requirements is available as an annex, which is constituted by a separated EXCEL file.

2. Definition of the TeamMate Car framework

In this section, the TeamMate car concept is drafted, in order to be further developed into a general TeamMate Car framework, starting from this description. Based on the vision of designing vehicle automation that can act as an effective team player for the human driver, the framework aims at providing a general understanding on how driver and automation shall interact with each other in the TeamMate car and which kind of traffic and interaction situations will be tackled in general. The final goal is to establish the needed interaction and communication with other vehicles for the traffic perspective. The idea is to provide a starting point for the work on the TeamMate Car driving strategies (WP3), HMI (WP4) and system architecture (WP5).

2.1. The driving task

The driving task is a complex interplay of different subtasks that have to be executed in a coordinated way to ensure safe, efficient and comfortable driving. According to several frameworks the driving task can be viewed as a hierarchy of three levels, each level addressing different tasks (e.g., Michon, 1985; Donges, 1982; McRuer, Allen, Weir, & Klein, 1977). According to Michon (1985) one can distinguish between the control level, the maneuvering level and the strategical level of driving. At the strategical level the general planning of the trip, including besides others the determination of the goal, the route, an evaluation of costs, benefits and risks of involved in the trip, take place. At the maneuvering or tactical level the drivers make tactical decisions, such as whether to overtake or not, to accept a given gap, to make a turn. These decisions are based and derived from the general goals and plans from the strategical level but also take into account the current situational characteristics and requirements of the driving situation. The outcome of these decisions can on the other hand also influence the goals and plans developed at the strategical level. The control level consists of operational processes directly related to the control of the vehicle by manipulating the control inputs for stable driving. The parameters for these control processes are derived from the tactical decisions made at the tactical level and these tactical decisions are, of course, influenced by the outcome of the control processes at the control level. For example, recognizing that the acceleration of the vehicle is smaller than expected (e.g., due to a wet road) will probably lead to the decision to stop an already started overtaking maneuver in the view of oncoming traffic. Consequently, to fully understand the complexities of the driving task one has not just to take into account the different levels of the driving task but also the control of information flow between the different levels and how control of behavior at the different levels is integrated. The latter point, the integration of control, is clearly beyond the concept of Michon (1985) that assumes that at any given point in time control of behavior is located at one level of the hierarchy. This assumption does not take into account the fact that drivers (and machines) in most cases pursue multiple goals at the same time. For example, a driver may at the same time keep the lateral position of the vehicle, keep the speed below the current speed limit, perform an overtaking maneuver and consider whether the desired arrival time can be met.

2.2. The system perspective on the driving task

Based on its perceptual capabilities (including algorithms for data fusion, situation interpretation, etc.) the TeamMate Car will collect information from its surrounding and will construct an environment and situation model on its own. Based on this representation of the environment and the situation the TeamMate Car is able to generate and evaluate possible action plans in the background parallel to the driver's actions, decisions and planning. It will make decisions and execute these decisions. That is, the TeamMate Car can and will take over control of some driving subtasks or the complete driving task in certain situations. Therefore, driver and vehicle have to be viewed as a joint system rather than two separate systems (Hollnagel, Nåbo, & Lau, 2003) and this joint system has to perform all relevant driving tasks to achieve a safe and efficient driving.

It has to be made sure that at any given moment in time all relevant subtasks are carried out by the joint system. Consequently, the distribution of subtasks between the human driver and the TeamMate Car must not possess any gaps leaving some subtasks unattended. On the other hand some overlaps in task distribution are unavoidable and in some cases absolute necessary. For example the vehicle will always collect information from the environment and construct and update its environment and situation model based on the collected data, independent of the fact whether the human driver also attends to the driving situation or is occupied with a driving irrelevant task, such as reading emails. This is the only way to efficiently create a shared situation representation as the basis for communication between the human driver and the TeamMate Car.

The distribution of tasks within the joint driver-vehicle system needs to be dynamic due to several reasons. First, the joint driver-vehicle system is faced with a dynamic situation meaning that the situation changes without any action from the driver or automation due to other factors. These dynamics of the traffic situation lead to changes in demands on the joint driver-vehicle system and the system has to adapt to these changes. If these changes in demands lead to an unacceptable load for one of the agents of the system or surpass the limits of one of the agents, a redistribution of tasks has to be carried out so that the joint system stays within a safe state.

For example, as the automation will for a long time not be able to handle all possible traffic situations, because of sensory limitations and limitations in situation comprehension and prediction the human agent is needed to support the automation in very complex situations in appropriate ways. AutoMate will certainly contribute to improve these capabilities and to decrease the number of situations intractable for the automation, but nevertheless some will remain. These remaining situations are especially

those where hidden or unexpected situational factors lead to changes and situations that are unforeseen by any automation developer and designer. Currently, we know of no better system than the human to deal with such new and unexpected situations.
Secondly, as long as the human agent in the system is not just a passenger, but has the possibility to actively take a hand in the driving task, the human agent might prefer to take over the control of some or all driving subtasks even though the automation is able to handle the driving situation completely. Additionally, the human agent might even be asked by the automation to become involved in driving in order to optimize the human's workload level.

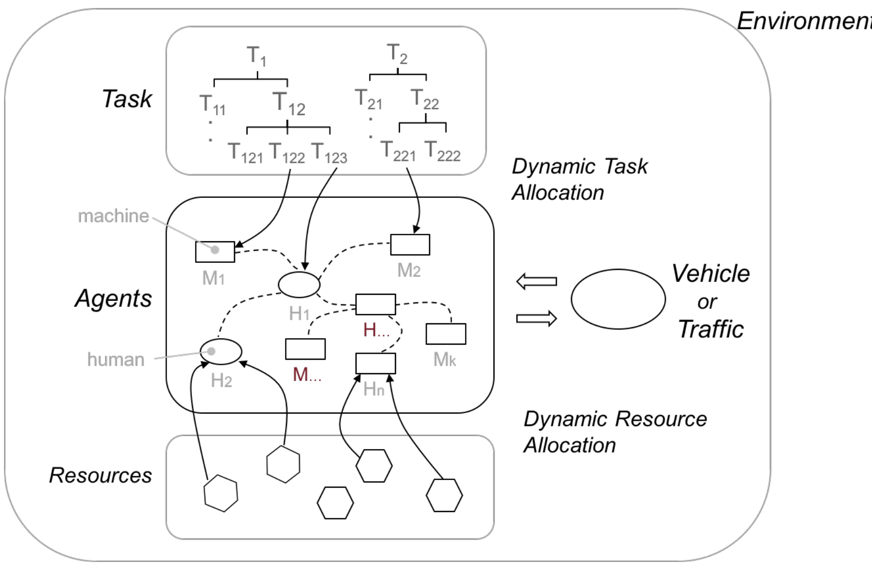

Figure 1: task distribution in a joint-vehicle system

2.3. Human-automation cooperation

In order to achieve this flexibility in task distribution, based on the current demands of the situation, on the capabilities and on the states of the human driver, as well as on the automation and its components, in the joint driver-vehicle a close coordination between driver and automation is necessary. In our view this goal can only be reached if the automation is made into an effective team player (Christoffersen & Woods, 2002). In this case, the human driver and the automation cooperate to keep the joint driver-vehicle system in a safe and efficient state.

Before discussing the requirements of how to turn driver-vehicle interaction into driver-vehicle cooperation, we will first define our understanding of cooperation. Here we follow the definition of Hoc (2000). According to Hoc (2000, p. 839) "two agents are in a cooperative situation if they meet two minimal conditions:

- Each strives towards goals and can interfere with the others on goals, resources, procedures, etc. Interference can take several forms, for example precondition (an agent' s action being a precondition for another agent's action), mutual control (contributing to correct the others' mistakes), redundancy (replacing another agent for diverse reasons), etc. If there is no interference, coordination is prebuilt and is not questioned during task execution; thus, the agents' activities are independent
- And each tries to manage interference to facilitate the individual activities and/or the common task when it exists (e.g. cooperation on resource utilization does not imply a common task)".

How can such a cooperation between human and automation be achieved? What are the requirements for turning automation into an effective team player? According to Klein, Woods, Bradshaw, Hoffman, & Feltovich (2004) there are four basic requirements that have to be met:

- The cooperating partners need to enter an agreement that they want to work together. Klein et al. (2004) call this the *Basic Compact.*
- The partners' actions need to be mutually predictable.
- The partners need to be mutually directable.
- A shared situation representation has to be maintained.

At the beginning of each cooperation, the partners have to enter a basic agreement (often this happens tacitly), the Basic Compact. This agreement encompasses the will to facilitate the coordination between partner's activities, to collaborate for shared goals and to prevent breakdowns of coordination (Klein et al., 2004). Furthermore, it includes the expectation that partners will invest in activities that ensure the Compact's integrity, for example by repairing incorrect mutual knowledge, beliefs or assumptions, when recognized; in addition, they counteract factors that are able to compromise the Compact's integrity (Klein, et al., 2004). It is important that this Basic Compact has to be renewed or reinforced continuously, for example by subtle signals that indicate that one is continuing the cooperation. If a partner intends to leave the Compact this has to be made very clear to the other partners to avoid severe breakdowns of coordination (Klein et al., 2004).

Mutual predictability of the cooperating partner's activities is key for successful coordination (Klein et al., 2004). This mutual predictability is in most cases based on previous experience of cooperation within the team (Hoc, Young, & Blosseville 2009). Experience leads to the development and refinement of mental models both about the cooperation partner as well as about the interaction with the partner (Hoc et al., 2009). In cases where partners need to cooperate without the possibility of extensive previous experience with each other clear, explicit and predesigned procedures can be used to allow mutual predictability (Klein et al., 2004). Mutual predictability is of special importance and needs special consideration in the light of adaptive agents that change their behavior to adapt to the behavior and styles of the other partner(s). Clear and comprehensible communication of these adaptation processes is necessary to enable the cooperating partners to acquire an appropriate mental model and to avoid any surprises in the interaction with the adaptive agent.

Another important requirement for successful cooperation is that the partners need to be mutual "directable". "*Directability*" refers to the partners' capability "for deliberately assessing and modifying other parties' actions in a joint activity as conditions and priorities change" (Klein et al., 2004, p. 92). This requirement is very closely related to the issue of control and to the question who is in charge of how problems are solved (Christoffersen & Woods, 2002). In cases where the human agents are responsible for the outcomes they have to be given ultimate control of how problems are solved (Billings, 1996). Consequently, the automation has to be designed as a resource that supports the human agents in their problem solving activities (Christoffersen & Woods, 2002). This being a challenge for automation design in itself the situation becomes even more complex when the responsibility for the outcomes can be with the automation in some situations, as for example in the case of highly automated driving. Whereas the cooperation between human agents and automation can run smoothly in routine situations the appearance of unanticipated problems represents the major challenge. By definition in such cases the decisions to be made and the actions to be performed are outside the scope of the automation's capabilities. In addition, the central question is whether the joint human-machine system is able to adapt to this situation to solve the problem?

In many cases this question is answered by giving the complete control back to the human operator and many current studies investigate how to design such take-over-requests in the automotive domain (e.g., Gold, Damböck, Lorenz, & Bengler, 2013; Gold & Bengler, 2014). However, this answer means that the human gets only back into control at the cost of losing a lot of useful and still available functionality of the automation and being exposed to high cognitive load (Christoffersen & Woods, 2002). What is really needed in these cases is not a kind of all-or-none automation but the possibility to apply a much more fine-grained task distribution within the joint human-automation system based on the current situational demands and capacities of human and automation. This allows the human operator to focus on the problem which the automation is not able to solve and to leave those tasks to the automation it still is capable to manage.

Finally, successful cooperation and coordination requires the establishment of a "shared situation representation (e.g., Baumann & Krems, 2009; Klein et al., 2004; Hoc, 2000; Christoffersen & Woods, 2002). This shared situation representation consists of two basic components: a shared representation of the current situation and representations of the cooperating agents' goals, activities, plans, and their state (Christoffersen & Woods, 2002). This shared situation representation facilitates coordination and cooperation as it allows the agents to understand the other agents' actions, to anticipate their behavior and to adapt one's own activities and plans appropriately. It reduces the communication effort between agents greatly (Christoffersen & Woods, 2002). This means for the TeamMate Car that needs to be able to communicate its situation representation and goals and plans to the human driver in a way that does not overload the driver. Moreover, there has to be mechanisms that allow the driver to communicate goals and plans and relevant aspects of the situation to the TeamMate Car.

2.4. Levels of Cooperation

As aforementioned in the previous paragraphs, the question for successful human-machine interaction design is: "how to turn automated systems into effective team players"?

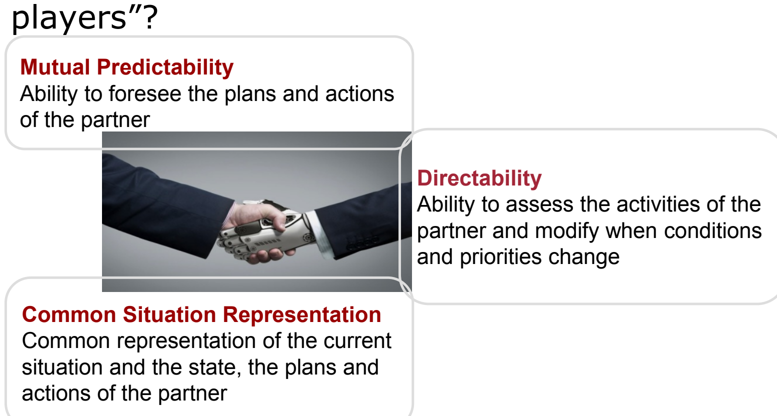

Figure 2: requirements of successful Human-Machine-cooperation

Figure 2 relates the Michon (1985) model of driving and Hoc's et al. (2009) model of cooperation. Hoc et al. (2009) distinguish three levels of cooperation based on the level of the driving task where the interaction between driver and automation takes place. At the lowest level there is "cooperation in action" (Hoc et al., 2009, p. 138) where the cooperation is directly related to the control actions necessary for longitudinal and lateral control. The second level is "cooperation in planning" (Hoc et al., 2009, p. 138). Cooperation at this level mainly addresses activities and goals at the manoeuver level of the driving task. For successful cooperation at this level, the maintenance of a shared situation representation is highly important as human driver and automation have to agree on and make decisions about the upcoming manoeuvers what requires an adequate and correct representation of the environment and the cooperating partners' goals and plans. The third so-called "meta-level" (Hoc et al., 2009, p. 138) involves maintaining long-term models of the partners, based on the experience and training.

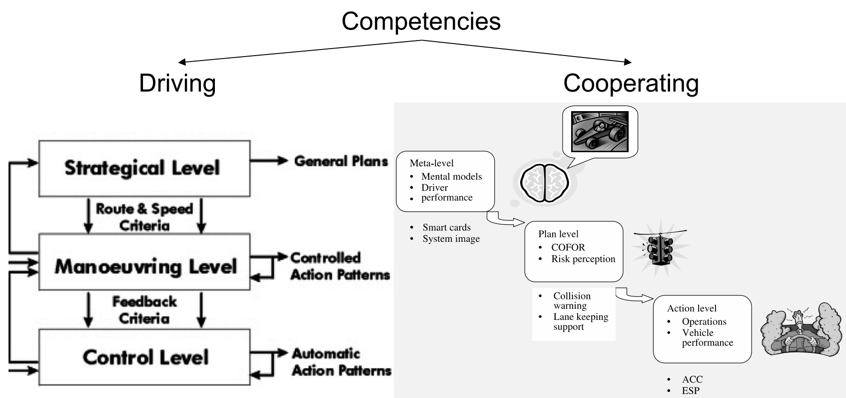

Figure 3: TeamMate car competencies (Left: Michon, 1985, p. 489; Right: Hoc et al., 2009, p. 138).

2.5. A preliminary architecture

Based on the aforementioned description, the concept of driver-automation teams is illustrated as following:

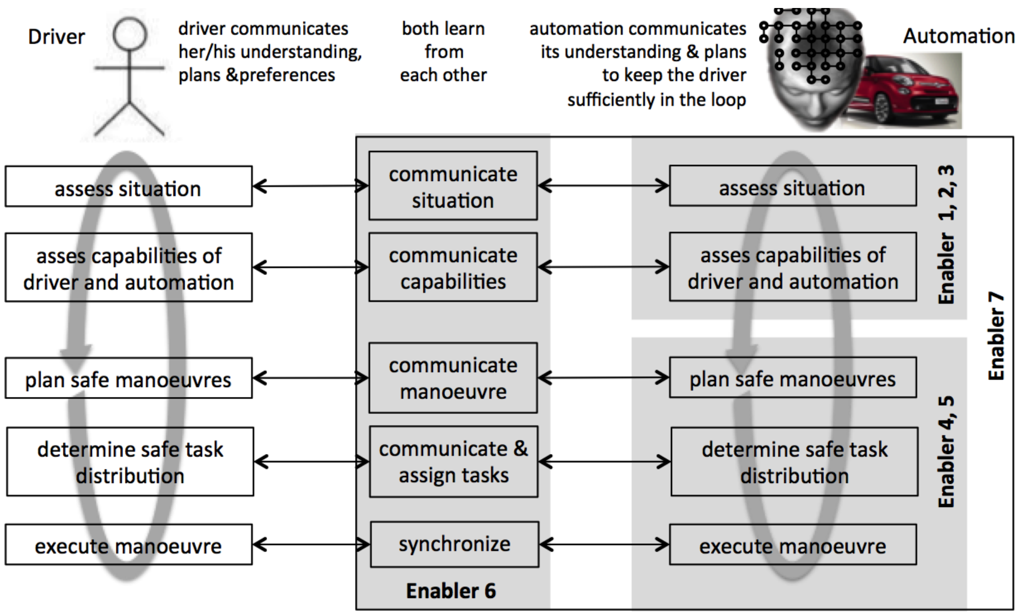

Figure 4: interaction between Automate system, driving functions and human driver within the TeamMate car.

Figure 4: interaction between Automate system, driving functions and human driver within the TeamMate car.
shows the main building blocks of the TeamMate Car architecture: TeamMate system, automated driving functions (like automated overtaking) and the vehicle. The TeamMate System manages the automated functions according to the needs of the situation and the driver, taking also into account the system constraints. It performs a cycle involving several steps:

1. track & assess the situational states, capabilities, limitations and information demand of both driver and automation (left part of the figure);
2. plan safe maneuvers considering all these factors;
3. distribute the shared maneuver execution to driver and automation, including handing-over tasks to the driver or accepting/rejecting tasks assigned by the driver to the automation;
4. "explain" maneuvers, situation & task distribution to the driver;
5. execute maneuvers in a human-like way, which feels natural and comfortable for the driver as well as for drivers in other cars;
6. learn from the driver how to drive human-like, by observing the driver and adopting her/his manual behavior if it assessed to be safe;
7. ask for information and even for decisions.

All communication takes driver's situational awareness into account to prevent annoying the driver, consequently the HMI provides only information that is not yet known.
We propose now a technical view of the TeamMate system architecture (as already mentioned in the "Technical Annex" of the project):

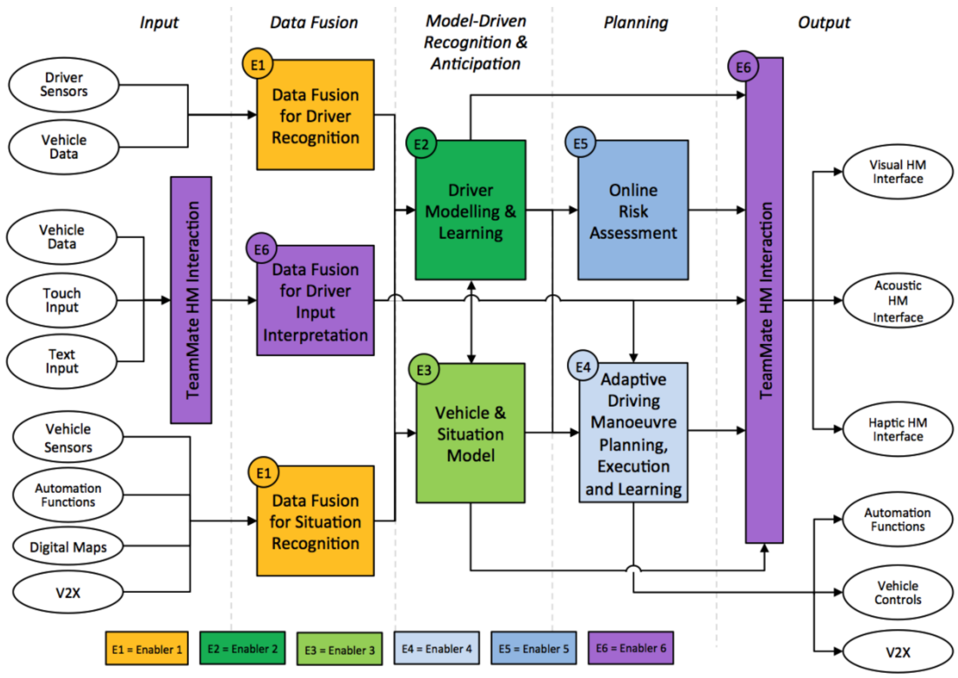

Figure 5: sketch of the intended TeamMate system architecture.

This system architecture will be used during the whole project to build the TeamMate car demonstrators (despite the fact they are real-vehicles or driving simulators) and it can be re-used after the project completion to implement highly automated systems with sophisticated human-machine cooperation capabilities.
Input is received from sensors (considering several aspects and sources, e.g. internal camera for gestures and eye movements, from maps, from the environment and so on). There are software components for each Enabler linked with each other according to a three main functional steps: data fusion, model-driven assessment, as well as anticipation and planning. Output is delivered to the driver (visual, acoustic, haptic), the automation subsystems, the vehicle, and possibly to other vehicles via V2X.

2.6. TeamMate car research questions

1. At what levels of driving is cooperation feasible and which is the best level?
2. How fine-grained can tasks be shared?
3. How will driverless cars adapt their driving for contextual factors like human drivers do? For example, How is the automated car configured with contextual factors like time pressure of the passengers, or other vehicles that don't behave cooperatively?
4. How would a driverless car make a right turn (for example) when thousands of people are trying to cross the same street? This is something (few) humans can do!
5. How should driverless cars (when such a modality is running) communicate they are driverless and communicate to others outside of the car?
   How does a driverless car handle the breaking of the law when it's needed? E.g.: violate speed limits when everybody does, cross continuous lane for fallen trees or to make it safer for pedestrians and bicyclists, etc.

3. Scenarios and use case development

In this section, the first version of the scenarios and use cases relevant for the TeamMate Car concept are defined and described (cycle 1). These scenarios and use cases focus especially on situations where:

- drivers need the support from an automated teammate to achieve safe, efficient and comfortable driving (e.g. Martha's scenario);
- the automated teammate reaches its system limits and needs the driver's support (e.g. Peter's scenario);
- where accordingly control of the driving task or its subtasks has to be shifted between driver and automation (e.g. Eva's scenario);
- where the automated teammate learns from the driver (e.g. Eva's scenario).

The first version of the scenarios has been discussed with subject matter experts from the science, industry and with potential users to ensure that the project can address the most relevant scenarios, since the early phases of development. The identified scenarios are translated into use cases that guide system development in the regard that these situations will have to be tackled.

3.1 Scenarios description

Three scenarios have been described: Scenario "Peter" (lead by ULM); scenario "Martha" (lead by VEDECOM) and scenario "Eva" (lead by CRF/Re:LAB).

3.1.1 Scenario "Peter"

The Peter scenario mainly answers to the first objective of the project which is to "develop solutions for flexible, gradual and smooth distribution of tasks between driver and automation to better handle critical driving situations".
The main idea of the Peter scenario is to keep the automation level as high as possible and to concentrate on cooperation at the maneuver level of driving.
In the proposal, an example with Peter and his AutoMate car was given:
"*After a long working day I was facing a two-hour drive back home. My car showed me that there were currently no disturbances on the road ahead and I could hand over control to my TeamMate Car. I was happy to relax and started reading my book. I felt comfortable, because I knew that my car would take care. After a while it gently informed me about a slowly driving tractor on the road about three kilometers ahead which it could not handle. Well, it asked me how to deal with it, either it will slowly drive behind the tractor, or I indicate when to overtake or I overtake manually. Well, I decided to do the indication. I carefully observed the traffic and when it was ok, I initiated the overtaking. Everything went smooth and safe. […] What a great car!*"
The following table describes the scenario in more detail.

Scenario Peter	**Driver out of the loop, maneuver becomes necessary**	**Rural Road**
A driver is reading in full automation when a large vehicle makes an evasive maneuver necessary.		
Sequence of events		
Initial state: Peter has handed over the control to the TeamMate. During the fully automated drive, the TeamMate constantly monitors the route for risks and situations, in which input or a take-over becomes necessary. Peter starts reading and thus is fully out of the loop. Scenario Evolvement: The TeamMate receives information by V2V about a slowly driving tractor three kilometers ahead, which it cannot overtake safely on its own (due to the fact that the automation of the car is not enough performant and effective yet). Via the Teammate HMI the system starts an escalating strategy to bring Peter back in the loop. The TeamMate offers him		

different options how to deal with the occurring situation: (A) to slowly drive behind tractor, (B) to tell when to initiate an overtaking maneuver, (C) to overtake manually. Scenario Resolution: Peter selects option B. Thus, the TeamMate approaches the tractor and opens a dialog. Peter carefully checks the traffic and selects the right situation for the maneuver and communicates this to the TeamMate. After double-checking with its sensors the system starts, or not, the overtaking maneuver while constantly controlling safety margins. The TeamMate keeps on communicating with V2V and V2X in order to check for any changing conditions. When the system detects oncoming traffic or a tight curve, it will inform the driver and stop the overtaking maneuver. After the maneuver has been successfully finished, the TeamMate indicates the availability of unobserved autonomous driving again.

3.1.2 Scenario "Martha"

Main directive for Martha scenario is to follow the second objective of the project which is to "develop solutions to monitor, understand, assess and anticipate the driver, the vehicle and the traffic situation".
In the proposal, the following example was given: *"I definitely love my car! I was driving home from a brunch with my best friend. It was sunny; I felt really good and enjoyed driving my car by myself on the motorway. Suddenly I received a text message from my boss about our meeting the next day. Well, I instantly grabbed my smartphone, scrolled through the message and started to type. I immediately felt soft impulses in the steering wheel and the pedals. My car started to guide me. Well, it noticed that I was distracted. It knows that I prefer being in full control, but, when it offered to switch to fully automated mode, I accepted. It was right, safety first. Then, I was able to finish my text message."*

Scenario Martha	Take-over of automation after driver distraction	Motorway
While driving manually, a driver suddenly receives a distracting message and the system takes over.		
Sequence of events		
Initial state: Martha enjoys driving in manual mode in nice weather. The Team Mate assists her with information gathered by its sensors and communication channels (V2V, V2X, traffic information). Above this, the TeamMate steadily monitors the driver's physical and psychological condition (e.g. situational awareness, workload, emotional and affective state) in regard to evaluate her ability to drive.		

Scenario Evolvement: Martha drives safely on a calm motorway section as she gets an important text message. She grabs her phone and starts reading. The TeamMate identifies her distraction by eye-tracking and her driving parameters. Based on the driver's preferences, the system knows she will be annoyed by an immediate full take-over. Therefore the system communicates in a multi-modal way that a distraction has been noticed and that the TeamMate could take over control.

Scenario Resolution: Martha realizes her own distraction and agrees with the take-over request (if she refuses, nothing more will happens). If the system takes over full control of the vehicle then Martha is able to continue replying to the text message safely. The TeamMate keeps watching her distribution of attention and after it detects that she has finished texting, the TeamMate asks, if she wishes to take over again. In this process, the system continuously checks for her ability to take over the single functions of the vehicle.

3.1.3 Scenario "Eva"

The Eva scenario answers more specifically to the third objective of the project which is to "develop solutions allowing the TeamMate Car to plan and execute driving maneuvers in a human expert-like way".

Eva on myAutoMateCar.com: "*My car and I, we are a true team! Where I used to live when I was a child, the traffic lights where recently replaced by a two-lane roundabout at a busy crossroads. It is a complex one with five exits and two lanes. In was driving there with my TeamMate Car in full control. It informed me that we would approach the roundabout. It asked me to be attentive and be ready for support the TeamMate Car when entering the roundabout, due to its complexity. It showed me a plan how it attends to handle the situation: staying in the outer lane, blocking other traffic from entering the roundabout. I decided that using the inside lane is more efficient and safe. I took over lateral control, leaving the longitudinal control to my TeamMate and guided my car onto the inner lane, because it was free and another vehicle planned to enter the roundabout. Before approaching the desired exit I changed back to the free outer lane. I drove out of the roundabout and gave the lateral control back to my car. I stayed for some weeks in my childhood hometown and thus drove through that round about several times. My car learned my way of dealing with the situation and after a while it was able to drive the roundabout on its own, also using the inner lane*".

User Scenario 3: Eva	Learning to efficiently manage a roundabout	City Traffic
By driving through a complex roundabout several times, the system learns from the driver how to deal with it efficiently, in a “human-like” mode.		
Sequence of events		
Initial state: Eva’s TeamMate is approaching a busy two-lane roundabout with five exits. As a complex roundabout, like this is encountered for the first time, the probability of need for support by the driver is high enough to request Eva’s attention. When handing over control to the driver, the TeamMate has the capability to learn by observing the solutions of the driver and from other TeamMate cars. Scenario Evolvement: Before entering the roundabout, the TeamMate starts an escalating HMI strategy to bring Eva back into the loop. The TeamMate has already generated a plan and presents the planned trajectory to Eva. It plans to stay in the outer lane, which is less efficient and safe than using the inside lane when possible. Scenario Resolution: Eva decides, or not, to help the TeamMate. The system will learn how to efficiently deal with the roundabout. If Eva takes over control, she carefully guides the vehicle into the inner lane. After the roundabout she hands back control to the system. The TeamMate recorded the driving behavior together with all information about the environment and traffic situation to improve its capabilities. After several similar situations and interventions by the driver the TeamMate is able to handle the roundabout in an efficient and safe way. Additionally, the TeamMate can communicate with other cars via V2v in order to solve this complex traffic situation safely and efficient in the future (both providing information and also learning how to handle this roundabout from other TeamMate Cars).		

3.2 Use-case description

The next use cases may change with the evolution of the project. We agreed that 3 or 4 use cases as are a the minimum number of use-cases for each scenario. For the beginning, but each scenario leader has chosen to attend with define 6 use cases, which are described in the following sections.

3.2.1 Peter Use cases

Six use cases were derived from the Peter scenario (for more details, see the related annex).

1. Use case 1: First use case is the simplest instantiation of the Peter scenario. The autonomous vehicle is waiting for the indication to

overtake from the driver. Then it executes the manoeuver. There is no traffic, no particular situation and weather conditions are good.

2. Use case 2: For the second use case, the indication from the driver to overtake is in contradiction with the traffic situation. When the driver initiates overtaking, system drives to left lane and sees that it is not safe so it drives back into initial lane and informs the driver[2].
3. Use case 3: In this scenario we have bad weather conditions. Due to a wet and slippery road, the system prompts the driver to be very attentive. Then the overtaking manoeuver starts.
4. Use case 4: Here the scenario is similar to the use case 2. Because the street is curved, the system thinks the driver is not able to perform a safe overtaking manoeuver due to the bad sight. When the driver instructs the system to overtake, it refuses and explains it to the driver.
5. Use case 5: In this use case, the system helps the driver to make a decision. Due to a massive tractor, the driver hesitates and thinks the road is too narrow to overtake. The system will give him feedback that it is not. Then the overtaking is initiated by the driver and conducted by the system.
6. Use case 6: For this last use case, the tractor stands on road because of an accident, but it is not allowed to overtake by the regulation. The driver has to overtake manually and the system must learn from this particular situation.

3.2.2 Martha Use cases

Six use cases were derived from the Martha scenario. Unless specified, there is no traffic, no specific situation and weather conditions are good (for more details, see the related annex).

1. Use case 1: First use case is the simplest instantiation of the Martha scenario. The autonomous vehicle proposes to the driver to drive autonomously and the driver accepts. When the driver finished her SMS, the system proposes to give her the control back.
2. Use case 2: In this scenario, the driver first refuses to give the hand to the system after it asked him. But because the car arrives on a dangerous area (RoadWork) the system explains the situation and asks the driver again.
3. Use case 3: After refusing, the driver shows a dangerous behavior (drive close to the lane, abnormal speed). The system asks the driver again and she refuses.

[2] There is always a dialogue between the driver and his TeamMate about the maneuver.

4. Use case 4: This use case is only different to the use case 3 by the final decision of the driver. After refusing the first proposition, the driver has a dangerous behavior (drive close to the lane, abnormal speed) so the system asks her again and the driver accepts.
5. Use case 5: In this use case, the driver accepts to give the hand to the system but due to the end of the Autonomous driving area (SAE lvl 4), the driver must takes back the control. The driver is inattentive and has to come back in the loop, but she accepts.
6. Use case 6: The last use case is quite similar to use case 5. Due to the end of the Autonomous driving area (SAE lvl 4), the driver must takes back the hand but he refuses. Then the system engages a Minimum Risk Maneuver while the TeamMate still informs the driver of this particular situation.

3.2.3 Eva Use cases

Six use cases were derived from Eva scenario. Each of them is during the day with good weather conditions (for more details, see the related annex).

1. Use case 1: With the first use case, the system does not need any help from the driver (for example, this can happen when the system has learned how to deal with the roundabout). The TeamMate just informs the driver about the maneuver and goes through the roundabout.
2. Use case 2: For the second use case, the system is not able to deal with the situation. The TeamMate will require Eva's intervention by an escalating HMI strategy. Process of self-learning is possible, depending on the sensorial system available for the TeamMate car.
3. Use case 3: In this use case, the system is able to deal with the situation but not alone; especially when a pedestrian seems to want to cross the street. Because the driver is reading (not attentive) and while the car is approaching the roundabout, the system asks for supervision. Here, it is possible to have an assisted control of the vehicle and the system can also learn the human behavior.
4. *Use case 4:* Here, the system is approaching the roundabout but there are road constructions, so that the TeamMate car is not anymore able to deal with and therefore it asks for the driver intervention.
5. *Use case 5:* The use case is nearly the same as use case 2, but here, in addition, Eva is also distracted. The system is not able to deal with the roundabout that is changed due to road work. The TeamMate will require Eva's intervention by an escalating HMI strategy to bring her back into the loop (she is distracted). Since the system is aware that Eva is (partially) impaired, it can ask also for further confirmation.
6. Use case 6: For the last use case, the driver is in control while the car approaches the roundabout. But the driver receives an incoming call

and answers it. Detecting this, the TeamMate system offers the driver to let him drive because it can deal with the situation.

All in all, in these sections a list of the most relevant use-cases for each scenario has been proposed. During the project development, it will be selected the ones that will be implemented in the demonstrators.

4. Definition of Requirements

In this section, the requirements for the TeamMate car are described. This is based on the scenarios and use cases, as illustrated in the previous paragraphs. The requirements address the system functionality required for the TeamMate car to handle the identified scenarios and use cases, as well as the required cooperation capabilities of the TeamMate car to behave as the driver's efficient and supportive team-mate.

The approach applied in Cycle 1 of the project takes into consideration the project objectives which have been clearly defined in the project Grant Agreement.

For each project objective, a related Enabler has been identified and a specific WP or Task assigned.

The partners involved in the development of each enabler, as well as the demonstrator owners have been asked to specify what is the Challenge, the State of the Art, how AutoMate is expected to go beyond the SoA, as well as the expected outcomes, as shown in the figure below.

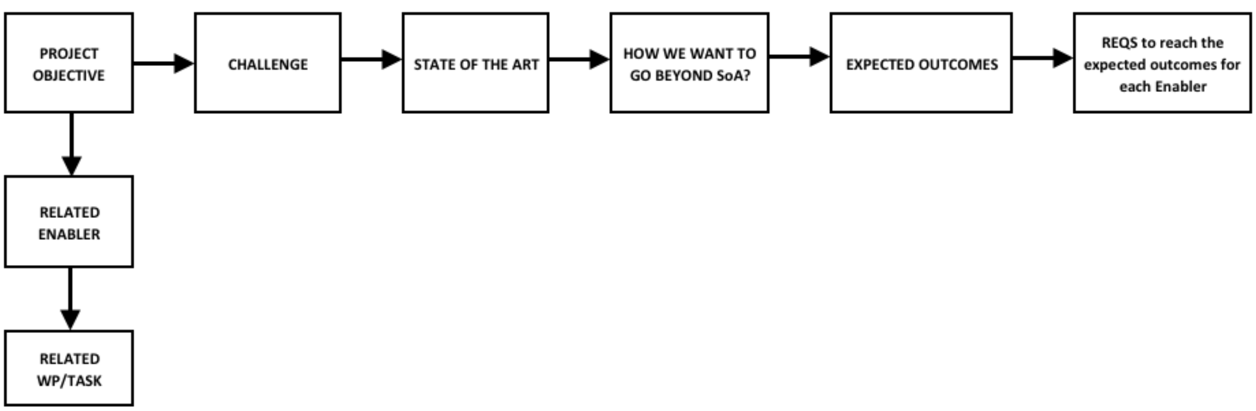

Figure 6 Requirements definition approach

For each expected outcome, specific requirements have been identified.

A matching between the identified requirements and the 3 demonstrators (i.e. ULM, VED, CRF/REL), according to scenarios and use-cases, has been performed and it is detailed in Appendix 1 for each Enabler.

Partners made a SMART-analysis regarding the defined requirements which was integrated in the Excel tables as well.
SMART is an acronym, giving criteria to guide the setting of goals, for example in project management.
The meaning of these five criteria is explained in the following table:

Criteria	Meaning
Specific	A requirement must say exactly what is required
Measurable	It is possible, once the system has been implemented, to verify that the requirement has been met
Attainable	It is possible physically for the system to exhibit that requirement under the given conditions
Realizable	It is possible to achieve a requirement given what is known about the constraints under which the system and the project must be developed
Traceable	Requirements Traceability is the ability to trace (forwards and backwards) a requirement from its conception through its specification to its subsequent design, implementation and test

Table 1: the five SMART-criteria

All in all, the requirements presented hereafter are more high-level requirements; during the project, within the development of the high-level requirements, they will be specified in more details.

The requirements are then translated into objective *Key Performance Indicators* (KPIs) that will be used for the assessment and evaluation whether the whole system performance and the performance of its components, i.e. the Enablers, is in accordance with the defined requirements.
The KPIs will be the basis for the definition of the evaluation plans and the actual evaluations done in the different WPs.

In the following, requirements will be presented according to the aforementioned approach, in relation to the achievement of AutoMate objectives they are linked to.

4.1 AutoMate Project Objective 2

AutoMate project objective 2, i.e. "Develop solutions to monitor, understand, assess and anticipate the driver, the vehicle and the traffic situation", is related to the activities carried out in WP2 and it underlies:

- Two main **type of activities**: (1) monitoring as well as (2) understanding, assessing, and anticipating;
- Two different **targets:** (1) the driver and (2) the vehicle and the traffic situation.

For this reason, the Objective 2 is strictly related to Enabler 1, 2 and 3, as shown in the picture below.

Enabler 1 is strictly interconnected to Enabler 2 and Enabler 3 since the data collected from sensors, both on the driver status and the vehicle and traffic situation, are then deployed into Enabler 2, i.e. *Probabilistic Driver Modelling and Learning*, and Enabler 3, i.e. *Probabilistic Vehicle and Situation Modelling*.

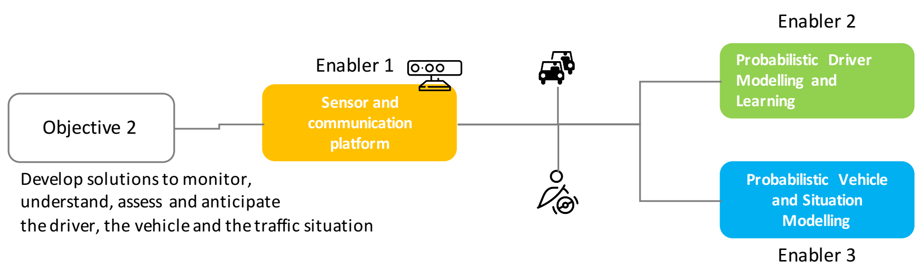

Figure 7: Objective 2 and related Enablers (1, 2, 3)

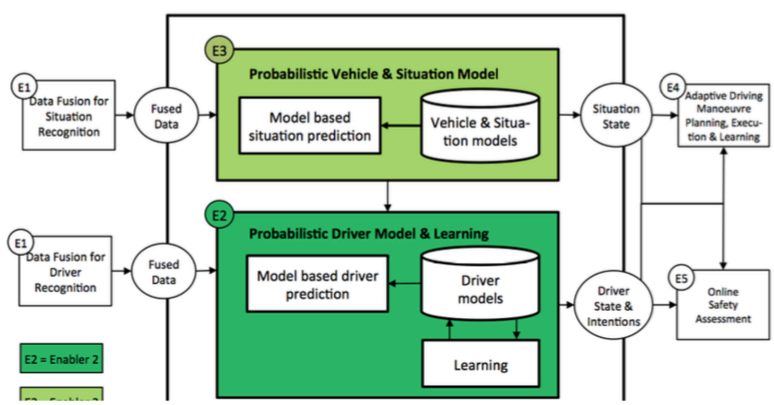

Figure 8: Objective 2 and related Enablers (1, 2, 3)

4.1.1 Enabler 1 – Sensor and communication platform

The **Sensor and communication platform (Enabler 1)** deals with the development of solutions, on the one hand, to monitor the vehicle, the traffic situation and on the other hand the driver.
The intended architecture for Enabler 1 is shown in the picture below:

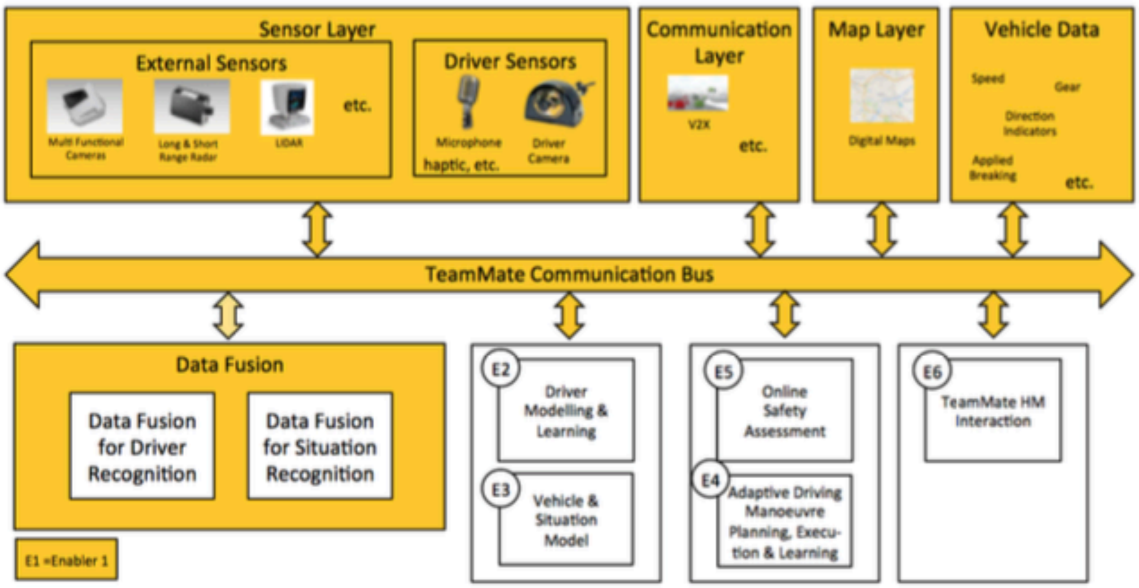

Figure 9 Enabler 1 - architecture sketch

The Challenge, State of the Art/Baseline, as well as the SoA for both the driver and the vehicle and traffic situations, the plan to go beyond the SoA and the expected outcomes are described in the following table.

Project Objective 2	Develop solution to **monitor (1) the driver, as well as (2) the vehicle, and the traffic situation.**
Related Task/WP	*T2.2 "Design and implement AUTOMATE sensor and communication platform"*
Leading partner	*CAF*
Challenge	The challenge is to identify data and associated data sources that allow to infer information about the driver, the traffic situation and other vehicles at the highest level of reliability.

State of the Art (SoA)/ Baseline	*Concerning (1) the driver monitoring:* The current State of the Art in the field of driver monitoring is a combination of driver direct and indirect monitoring. *Concerning (2) the vehicle and situation monitoring:* The current State of the Art in the field of environment monitoring is traditional on-board ADAS sensors (e.g. camera, radar, lidar, laser), which have limitations due to unfavorable topography, such as curves or hills, or to the impact of light and weather conditions.		
How AutoMate plan to go beyond SoA	*Concerning (1) the driver monitoring:* **Sub-objective 1:** AutoMate aims at investigating more deeply driver activities including the use of on-board systems like radio and navigation system.	**Expected Outcomes**	**Expected Outcome 1:** Novel vision-based activity sensors will be studied to measure upper limb activity and further movements of the driver.
	Concerning (2) the vehicle and situation monitoring: **Sub-objective 2:** AutoMate aims to expand the measurement range and, thus, the time horizon for subsequent predictions (performed in Enabler 3).		**Expected Outcome 2:** Integration of data coming from V2X and V2V communication with on-board ADAS data
	Concerning (2) the vehicle and situation monitoring: **Sub-objective 3:** AutoMate aims to further benefit from V2V communication by extending the Cooperative Awareness Messaging (CAM) protocol from the AutoNet2030 project		**Expected Outcome 3:** Enable exchange of information about driver-automation teams (e.g. behavior, state, intention) between different TeamMate Cars

Table 2: Vehicle and traffic situation monitoring

In order to reach the expected outcomes the following requirements have been identified.
For **Driver monitoring:**

Expected outcome	REQ NAME	REQ Description
Novel vision based activity sensors will be studied to measure upper limb activity and further movements of the driver.	DM: distraction classification in good conditions	Driver monitoring system shall classify the driver state (i.e. distracted vs. not distracted) in an accurate way in good weather conditions
	DM: distraction classification in harsh conditions	Driver monitoring system shall classify the driver state (i.e. distracted vs. not distracted) in a accurate way in harsh conditions (e.g. bad weather)
	DM: eye gaze areas	Driver monitoring system shall identify where the driver is looking at
	DM: eye gaze duration	Driver monitoring system shall identify for how long the driver is looking at a specific area

	DM: looking road ahead	Driver monitoring system shall provide a looking road ahead when face is not detected
	Hands-on-detection steering wheel	The system must provide a Hands-on-detection on the steering wheel
	States of the gas and brake pedal	The system must provide the state of the gas and brake pedal
	State of indicator lever	The system must provide the state of indicator lever
	Activation-button for the automation system	The system must provide a activation-button for the automation system
	Vehicle velocity	The system must provide the vehicle velocity
	Possibility to warn driver about hands-off the steering wheel	The system must provide the possibility to warn driver about hands-off (regarding steering wheel)
	CAN BUS Data	Data will be integrated with data from on-board communication buses

Table 3: Driver monitoring REQs

For **vehicle and traffic situation** monitoring:

Expected outcomes	***REQ NAME***	**REQ Description**
Integration of data coming from V2X and V2V communication with on-board ADAS data	*V2X COMMUNICATION*	The sensor and communication platform shall implement communication with the surrounding vehicles and roadside units.
	V2X CAPABLE PARTNERS	The sensor and communication platform shall implement V2X communication with capable vehicles and roadside units.
	RELEVANT V2X INFORMATION	The sensor and communication platform shall implement V2X communication with partner with relevant information regarding the current situation (eg. slow vehicle is blocking the line).
	DIGITAL MAPS	The sensor and communication platform must provide precise digital maps of the environment, including lane information (number of lanes, curvature, lane widths, etc.) and speed limits, as well as other traffic signs
	SURROUNDING TRAFFIC	The sensor and communication platform must provide precise information concerning surrounding vehicles (position, velocity, etc.) within a vicinity of approx. 200 meters in front and behind the TeamMate car.
	VEHICLE STATE	The sensor and communication platform must provide precise information concerning the current state (velocity, actuator states, etc.) of the TeamMate car

Expected outcomes	*REQ NAME*	REQ Description
	LOCALIZATION	The sensor and communication platform must provide precise information concerning the current location and pose of the TeamMate car.
	Sensor-, object- and fusion-data (Ego-Vehicle)	The system must provide ego-vehicle sensor-, object- and fusion-data including a high accurate digital map
	Sensor-, object- and fusion-data (V2X)	The system must provide V2X sensor-, object- and fusion-data
	Driver- and automation-state (Ego-Vehicle)	The system must provide ego-vehicle driver- and automation-state
	Driver- and automation-state (V2X)	The system must provide V2X driver- and automation-state
	Time synchronization	The provided sensor-, object- and fusion-data must be synchronized according to a global time
	Sensors calibration	The sensors intrinsic and extrinsic parameters must be provided
	Global coordinate system	The provided sensor-, object- and fusion-data must be in a global coordinate system
Enable exchange of information about driver-automation teams (e.g. behavior, state, intention) between different TeamMate Cars	*DATA FOR CAM*	Assembling Cooperative Awareness Message requires data from vehicle and traffic situation model (current speed, driving mode, distance to nearby vehicles, path prediction etc.)

Table 4: Vehicle and traffic situation monitoring REQs

4.1.2 Enabler 2: Probabilistic Driver Modelling and Learning

The Enabler 2, i.e. Probabilistic Driver Modelling and Learning, concerns the *understanding*, *assessment,* and *anticipation* of the driver.
The Challenge, State of the Art/Baseline, as well as the plan to go beyond the SoA and the expected outcomes are described in the following table.

Project Objective 2	Develop solutions to **understand, assess and anticipate the driver**.
Related Task/WP	*T2.3 "Build and integrate driver models"*
Leading partner	*OFF*

Challenge	The challenge is to develop models that predict the driver status, behavior and intentions in a way that allows to validly assess if the driver is able to perform the tasks that are or will be assigned to her/him.		
State of the Art (SoA)/ Baseline	By now, no mature attempts have been made for incorporating the intra- and interdependencies between the many different aspects of driver states, typologies, and/or control behavior into a profound human driver model.		
How AutoMate plan to go beyond SoA	AutoMate aims at developing a probabilistic structure for modelling driver states, typologies, and control behaviour in an integrated way.	**Expected Outcomes**	**Expected Outcome 1:** Unifying modelling approach based on probabilistic (graphical) models
			Expected Outcome 2: Integrated driver models
			Expected Outcome 3: Online learning algorithms that allow incorporating new observed data during runtime to continuously recalibrate the driver model in order to adapt the TeamMate Car to the characteristics of individual drivers and to new situations

Table 5: Probabilistic Driver Modelling and Learning

In order to reach the expected outcomes for the understanding, assessment and anticipation of the driver**, the following requirements have been identified**, in order to develop solutions for flexible, gradual and smooth distribution of tasks between driver and automation to better handle critical driving situations.

:

Expected outcome	**REQ NAME**	**REQ Description**
Unifying modelling approach based on probabilistic (graphical) models	DRIVER_MODEL	Each model must realize one or more aspects of human state recognition, intention recognition, and human behavior assessment and prediction.
	KNOWLEDGE OF THE DRIVER STATE (attention, sleep, fatigue)	The system must provide knowledge of the driver state (attention, sleep, fatigue)
Integrated driver models	PROBABILISTIC_FORMALISM	Each model must follow a probabilistic formalism that allows the integration in a unified probabilistic architecture
Online learning algorithms that allow incorporating new	TEAMMATE_INTERFACE	Each model must provide a unified interface to be integrated in the TeamMate architecture

observed data during runtime to continuously recalibrate the driver model in order to adapt the TeamMate Car to the characteristics of individual drivers and to new situations	ONLINE_LEARNING	Each model that represents aspects of the human driver with strong intervariability must provide means to recalibrate its parameters based on data obtained during runtime

Table 6: Probabilistic Driver Modelling and Learning REQs

4.1.3 Enabler 3: Probabilistic Vehicle and Situation Modelling

Enabler 3, i.e. Probabilistic Vehicle and Situation Modelling, concerns the *development of solutions to understand, assess and anticipate the vehicle and the traffic situation.*

Project Objective 2	Develop solutions **to understand, assess and anticipate the vehicle and the traffic situation**.		
Related Task/WP	*T2.4 "Build and integrate vehicle and situation models"*		
Leading partner	*DLR*		
Challenge	The challenge is to infer and model the vehicle and traffic situation in a way that is consistent with the human mental traffic representation.		
State of the Art (SoA)/ Baseline	State of the Art approaches treat surrounding objects as independent entities and only infer information about individual objects.		
How AutoMate plan to go beyond SoA	Develop a human-like traffic understanding	**Expected Outcomes**	**Expected Outcome 1:** Integrated vehicle and driver state
			Expected Outcome 2: Situation modelling

Table 7: Probabilistic Vehicle and Situation Modelling

In order to reach the expected outcomes for the **understanding, assessment and anticipation of the vehicle and the traffic situation**, the following requirements have been identified:

Expected outcome	**REQ NAME**	**REQ Description**
Integrated vehicle and driver state	Integration of sensor- and fusion-data (Ego-Vehicle)	The traffic model must integrate ego-vehicle sensor- and fusion-data
	Integration of sensor- and fusion-data (V2X)	The traffic model must integrate V2X sensor- and fusion-data

	Integration of driver- and automation-state (Ego-Vehicle)	The traffic model must integrate ego-vehicle driver- and automation-state
	Integration of driver- and automation-state (V2X)	The traffic model must integrate V2X driver- and automation-state
Situation modelling	Representation of the spatial relations and physical states	The traffic model must combine data-, object- and sensor-fusion with probabilistic modelling techniques to represent the spatial relations and physical states of the vehicle and all objects in the environment
	Estimation of the spatial relations and physical states	The traffic model must combine data-, object- and sensor-fusion with probabilistic modelling techniques to estimate the spatial relations and physical states of the vehicle and all objects in the environment
	MULTI-OBJECT TRACKING	The traffic model must track multiple objects while taking into account state- and object-uncertainties
	Situation prediction	The traffic model must predict and represent possible evolutions of the traffic situation in respect to potential interventions of both the driver and the automation

Table 8: Probabilistic Vehicle and Situation Modelling REQs

4.2 AutoMate Objective 1 and Objective 3

AutoMate project Objective 1 concerns the *development of solutions for flexible, gradual and smooth distribution of tasks between driver and automation to better handle critical driving situations,* and it is related to the activities carried out in WP3 with relation to Enabler 4, i.e. Adaptive Driving Maneuver Planning, Execution, and Learning, as shown in the picture below. The same Enabler is also addressing Objective 3 of the project, i.e. *"Develop solutions allowing the TeamMate Car to plan and execute driving maneuvers in a human expert-like way.",* as shown in the picture below, especially involving partners in task T3.4 and T3.5.

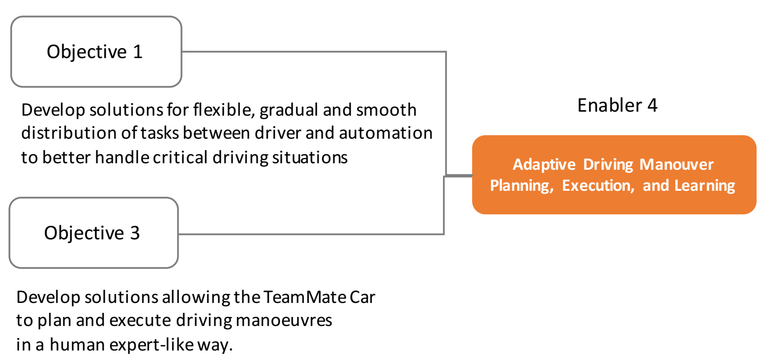

Figure 10: Objective 1&3 and Enabler 4

The intended architecture for Enabler 4 and 5 is the following:

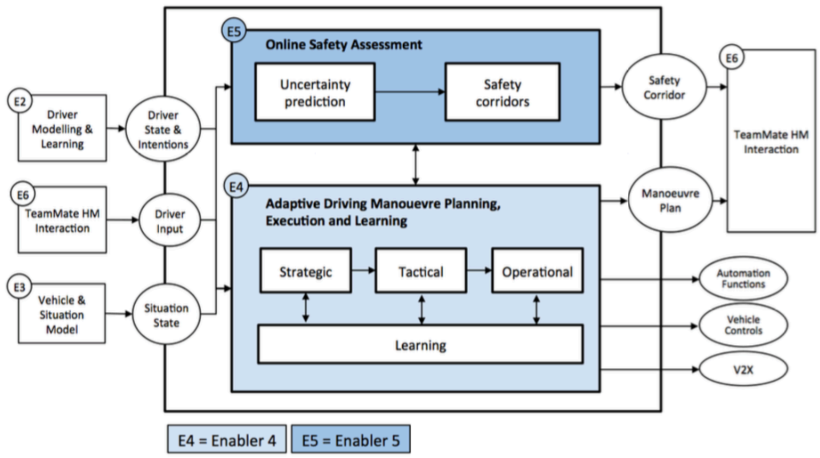

Figure 11 Enabler 4&5 architecture sketch

4.2.1 Enabler 4: Adaptive Driving Maneuver Planning, Execution, and Learning

The Challenge, State of the Art/Baseline, as well as the plan to go beyond the SoA and the expected outcomes for the achievement of **Objective 1** are described in the following table.

Project Objective 1	Develop solutions for **flexible, gradual and smooth distribution of tasks** between driver and automation to handle critical driving situations better.
Related Task/WP	*WP3*
Leading partner	*DLR*
Challenge	An adaption to a preferred driving style of drivers gets more and more important. The system must be suitable to serve and blend the aspects of driver's intention and situation aspects to a safe and appropriate driving and interaction strategy that is comprehensible and acceptable for the driver.
State of the Art (SoA)/ Baseline	First approaches to learning human and adapting automated driving styles were done in the 1990s, e.g. by Schreiner [28] and Kopf [13]. Most approaches use machine learning techniques in various fashions (e.g. [30]).

How AutoMate plan to go beyond SoA	*We will reuse such automation functions and will upgrade them with new driver adaptive functionality.*	**Expected Outcome**	The planning algorithms can incorporate and involve the driver in the driving task to generate a dynamically type of responsibility assignment. This enables the system to handle diverse inclusions of the driver's inputs.

Table 9: Adaptive Driving Maneuver Planning, Execution, and Learning

In order to reach the expected outcome on planning and task distribution, the following requirements have been identified:

Expected outcome	REQ NAME	REQ Description
The planning algorithms incorporate and involve the driver in the driving task to generate a dynamically type of responsibility assignment	TRAJECTORY	The planning algorithms shall identify and provide the optimal trajectory
	OPTIMAL TRAJECTORY BASED ON INTERACTION WITH HUMANS	Selection of optimal trajectory may be selected by using a Reinforcement Learning approach, for the interaction with the driver.
	Driver Task allocation	The system must allocate tasks to driver according to the traffic situation, the driver and the automation state.
	Automation Task allocation	The system must allocate task to Automation according to the traffic situation, the driver and the automation state

Table 10: Adaptive Driving Maneuver Planning, Execution, and Learning REQs

The Challenge, State of the Art/Baseline, as well as the plan to go beyond the SoA and the expected outcomes for the achievement of **Objective 3** are described in the following table.

Project Objective 3	Develop solutions allowing the TeamMate Car **to plan and execute driving maneuvers in a human expert-like way.**
Related Task/WP	*T3.4 - T3.5*
Leading partner	*HMT - ULM*
Challenge	The system has to avoid collisions with static, as well as dynamic obstacles. When executing the trajectory, a comfortable driving style is desired. The algorithm should although utilize as many available information about the environment, as possible. Additionally, it should be able to provide a flexible control sharing between the driver and the automation.

State of the Art (SoA)/ Baseline	Since trajectory planning is not only required for autonomous driving cars, but as well for other fields in robotics, many planning algorithms have already been developed. A large number of persistent algorithms can be distinguished into sampling- based and continuous approaches. Sampling-based algorithms create at first a plenty of possible trajectories and try to find the best alternative which is also feasible. (As an example, see the RRT approach [1] or the state-lattices-method [2]) Continuous algorithms calculate a trajectory from a continuous plenty of possible solutions. (For example see the potential fields approach [3] or the planning method used in [4] which arranges a optimal control problem. In both approaches, driver preferences can be respected by defining some kind of "quality-" or "cost-functions". Feasibility can be reached by respecting "constraint functions").		
How AutoMate plan to go beyond SoA	*The first step will be to find a skeletal structure of a planning algorithm, eventually based on a approach mentioned in the SoA section.* *The algorithm will be extended for the corresponding project objectives.* *Therefor it is necessary, that the found algorithm structure is as generic as possible.* *To get beyond the SoA, well researching must be performed.* *For example a measure can be defined to decide if a trajectory is consistent with driver preferences.* *Machine learning algorithms could be used to learn the preferred behavior from the driver.*	**Expected Outcome**	The TeamMate car is able to learn from the driving style of the human driver in a wide range of situations. The trajectories are safe and perform a comfortable driving style.

Table 11: Adaptive Driving Maneuver Planning, Execution, and Learning

In order to reach the expected outcome on learning the driver style of the human driver and execute trajectories in a human-like driving style, the following requirements have been identified:

Expected outcome	REQ NAME	REQ Description
The TeamMate car is able to learn from the driving style of the human driver in a wide range of situations. The trajectories are safe and perform a comfortable driving style.	DRIVING STYLE	The TeamMate Car should identify the most suitable driving style according to the driver profile
	Environment model	Predefined data must serve as input for a planning algorithm.
	Risk assessment	The measure for the risk of the current situation (for example based on a "time to collision"-metric)
	Situation prediction	The plan for a specific duration of time, the behavior of other traffic participants must be predicted.

	Specify driving maneuvers	The basic driving maneuvers have to be identified. A decision has to be made about which maneuver should be performed by the automation
	Learn driver-like maneuver performance	Learn to perform maneuvers similar to the driver by adapting performance parameters to the actual driver behavior.
	Learn driver's preferred decisions	The model should be able to learn the driver's preferred decisions in specific situations, e.g., either overtaking or following a slightly slower lead car
	Interface to driver model	Needs interface to driver model, e.g. to be able to modify parameters of driver model.
	Learn only safe behavior	The model should only learn safe driving behavior or decisions
	Interface to risk assessment	Needs interface to risk assessment, e.g. to know if gathered learn data contains unsafe behavior
	Driving behavior observation	The model/algorithm must be able to observe the driving behavior
	Able to integrate in Demonstrator	Should run on the demonstrator hardware or, if it runs on its own HW, it should be possible to connect it to the Demonstrator

Table 12: Adaptive Driving Maneuver Planning, Execution, and Learning REQs

4.3 AutoMate Objective 4

AutoMate project Objective 4 concerns the *development of solutions to assess and guarantee safety of all manual and automatically generated maneuvers at any time.*
It is related to the activities carried out in T3.3 with relation to **Enabler 5: Online Risk Assessment,** as shown in the picture below.

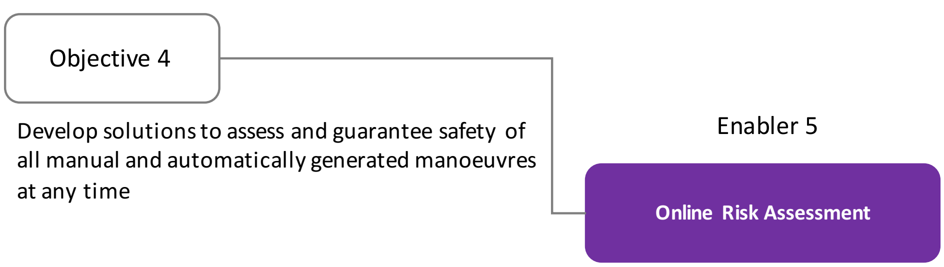

Figure 12: Objective 4 and Enabler 5

The Challenge, State of the Art/Baseline, as well as the plan to go beyond the SoA and the expected outcomes for the achievement of **Objective 4** are described in the following table.

<table>
<tr><td>Project Objective 4</td><td colspan="3">Develop solutions to assess and guarantee safety of all manual and automatically generated manoeuvres at any time.</td></tr>
<tr><td>Related Task/WP</td><td colspan="3">T3.3</td></tr>
<tr><td>Leading partner</td><td colspan="3">OFF</td></tr>
<tr><td>Challenge</td><td colspan="3">The challenge is to assess a huge number of possible evolutions of the traffic scene in real time.</td></tr>
<tr><td>State of the Art (SoA)/ Baseline</td><td colspan="3">Current approaches to risk assessment can roughly be classified into probabilistic and not-deterministic approaches. Both approaches then aim at checking whether any given trajectory is feasible or will likely lead to a collision. However, these approaches only consider the safety of individual actions and only address the fully automated case.</td></tr>
<tr><td rowspan="2">How AutoMate plan to go beyond SoA</td><td rowspan="2">Consider dynamic task distributions between driver and automation in AUTOMATE.</td><td rowspan="2">Expected Outcome</td><td>Construct situation dependent corridors of safe actions.</td></tr>
<tr><td>Assess the safety of a trajectory</td></tr>
</table>

Table 13: Online Risk assessment

In order to reach the expected outcomes on on-line risk assessment, the following requirements have been identified:

<table>
<tr><th>Expected outcome</th><th>REQ NAME</th><th>REQ Description</th></tr>
<tr><td rowspan="3">Construct situation dependent corridors of safe actions.</td><td>PROVIDE SAFETY CORRIDOR</td><td>The online risk assessment must be able to calculate a context-dependent safety corridor based on a set of pre-defined metrics.</td></tr>
<tr><td>CONTRACT ALGORITHM</td><td>The online risk assessment must be able to return a safety corridor within a predefined duration</td></tr>
<tr><td>TEAMMATE INTERFACE</td><td>Each module implementing online risk assessment must conform an interface to be integratable in the TeamMate architecture</td></tr>
<tr><td>Assess the safety of a trajectory</td><td>ASSESS TRAJECTORY SAFETY</td><td>The online risk assessment must be able to assess the safety of a planned trajectory based on a set of pre-defined metrics</td></tr>
</table>

Table 14: Online Risk assessment REQs

4.4 AutoMate Objective 5

AutoMate project Objective 5 concerns the *development of solutions for optimized human-machine interaction.*
It is related to the activities carried out in WP4 with relation to **Enabler 6: TeamMate HMI,** as shown in the picture below.

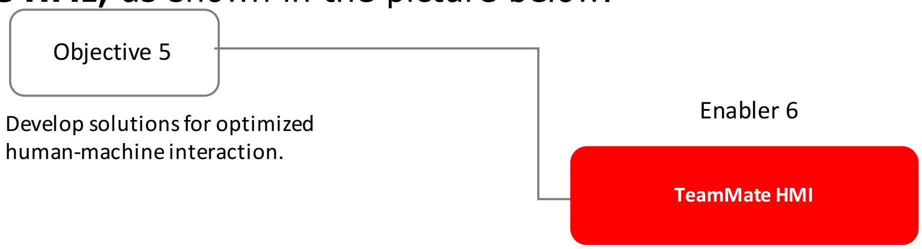

Figure 13 Objective 5 and Enabler 6

The intended architecture for Enabler 6 is the following:

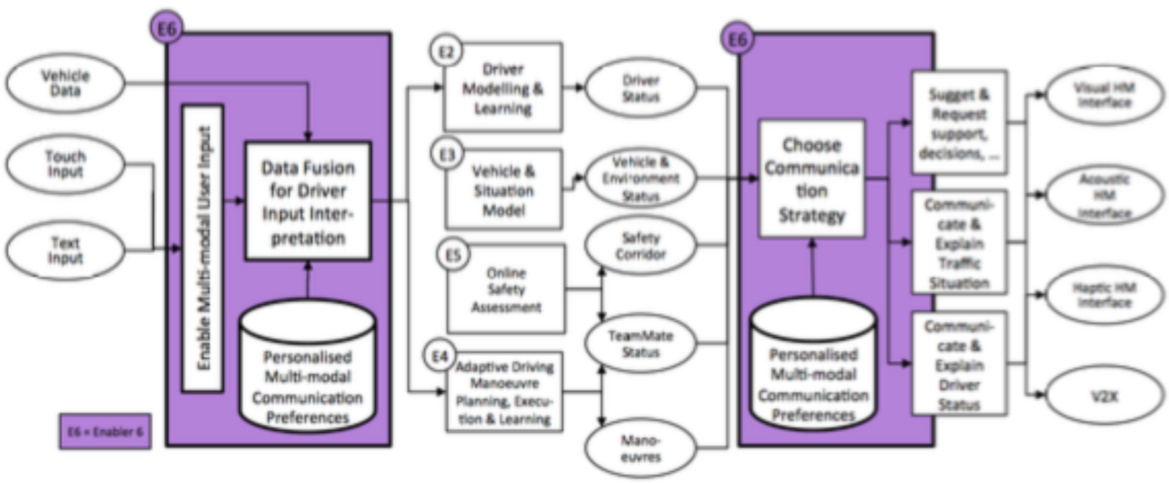

Figure 14 TeamMate HMI architecture sketch

Project Objective 5	Develop solutions for optimized human-machine interaction.
Related Task/WP	*WP4*
Leading partner	*BIT, REL, ULM*
Challenge	The main challenge is to keep the driver sufficiently in the loop or to get her/him back in the loop according to her/his current and anticipated state and driving tasks.
State of the Art (SoA)/ Baseline	There has not been any research yet on actually finding the most comprehensive way to convey the rationale for autonomous actions to drivers. First studies exist on applying the Ecological Interface Design (EID) approach for communicating automation behavior. However, this has only been achieved for isolated automation functions.

How AutoMate plan to go beyond SoA	*HMI should explicitly explain automated driving actions, thus improving driver's understanding and the overall performance of automated driving.*	**Expected Outcomes**	Navigation-Centred Driving Cluster (NCDC)
			Adaptive HMI
			Multimodal HMI
			External communication to other road users

Table 15: TeamMate HMI

In order to reach the expected outcomes on HMI, the following requirements have been identified:

Expected outcomes	REQ NAME	REQ Description
Navigation-Centred Driving Cluster (NCDC)	GUI Integration of information	Integrate all relevant information on the traffic, driver, and automation by showing safe driving corridors and constraints on these corridors using graphical means.
	Automation ON/OFF	NCDC should display when the automated driving mode is switched on or off
	Mode confusion prevention	HMI should prevent mode confusion by clarifying driver's and system's responsibility
	Lateral and longitudinal control	NCDC should display the information on lateral vehicle control and the longitudinal vehicle control
	Non-attended traffic	NCDC should display important non-attended traffic information (e.g. in form a "bunch of telltales" that magnifies the warning telltales that the driver should focus on).
	Map representations	NCDC should display different map representations (short term as well as long term) to show intuitively imminent risks as well as distant hot spots where the vehicle may request the support of the driver.
Adaptive HMI	Uncommon rules adaptation	HMI should learn and adapt to uncommon rules (e.g. Use-Case PETER, it´s not allowed to overtake)
	Actions/Maneuver	The HMI should offer different actions on a maneuver level to the driver

	Maneuver advise	The mentioned actions should be adequately shown/offered to the driver
Multimodal HMI	Communication channel selection	The HMI should select the right channel of communication at the right moment depending on the driver and traffic situation
	Intervention understanding	For the driver it should always be visible how to intervene
	Number and typology of communication channels	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)
	Warning	Alert drivers of possible dangers by using stimuli of different modalities
	Situation awareness	The performance of the human-automation system should be evaluated by measuring driver situation awareness for each mission
	Attention allocation efficiency	The performance of the human-automation system should be evaluated by measuring attention allocation efficiency
	Physical comfort / fatigue	The performance of the human-automation system should be evaluated by measuring driver physical comfort and fatigue for each mission
	Acceptance	The performance of the human-automation system should be evaluated in terms of human/automation collaboration by measuring trust in the system
	Trust	The performance of the human-automation system should be evaluated in terms of human/automation collaboration by measuring trust in the system
External communication to other road users	External communication	Communication to external users (i.e. other cars, pedestrians, …) should be always visible concerning who is driving, either automated system or human driver

Table **16: TeamMate HMI REQs**

4.5 AutoMate Objective 6

AutoMate project Objective 6 concerns the *development of demonstrators to test the safety, efficiency and effectiveness of the TeamMate technologies in real life conditions and consider security, legal and societal issues* and it is strictly related to Enabler 7 (TeamMate System Architecture).

By Month 4 of the project, the expected outcomes have been identified, while requirements on the Architecture will be clearly defined in the following phase of the project according to the features of Enabler 1-6 and to the scenarios and use-cases of each demonstrator.
The architecture will be implemented in three driving simulators provided by ULM, REL, and VED to demonstrate in particular the driver-vehicle team interaction (vehicle perspective) in highly complex and safety critical traffic situations and to demonstrate the cooperation between various TeamMate Cars as well as other road-users (traffic perspective).

<table>
<tr><td>Project Objective 6</td><td colspan="3">Develop demonstrators to test the safety, efficiency and effectiveness of the TeamMate technologies in real life conditions and consider security, legal and societal issues</td></tr>
<tr><td>Related Task/WP</td><td colspan="3">T5.4</td></tr>
<tr><td>Leading partner</td><td colspan="3">VED</td></tr>
<tr><td>Challenge</td><td colspan="3">None of the few commercially available systems can be considered as really automating some driving tasks, with the exception of the emergency braking support.
Additionally, due to their restricted HMIs, they provide neither the transparency, nor the directability to act as a teammate of the driver.</td></tr>
<tr><td>State of the Art (SoA)/ Baseline</td><td colspan="3">These systems are accompanied by dedicated HMIs providing simple messages and warnings
(such as simple tones, flashing visual signals, or vibrations on the steering wheel).
However, such systems encounter several technical limitations, which restrict their operation to controlled environments or well-structured spaces.
Current unsatisfactory market penetration of Advanced Driver Assistance Systems in Europe is evident.</td></tr>
<tr><td rowspan="3">How AutoMate plan to go beyond SoA</td><td rowspan="3">Not the automation alone should be the object of design but the driver automation team.</td><td rowspan="3">Expected Outcomes</td><td>TEAMMATE DEMOS WORKING AND READY FOR TESTS</td></tr>
<tr><td>TEAMMATE DEMOS TESTED (by a technical point of view)</td></tr>
<tr><td>TEAMMATE DEMOS READY FOR FINAL DEMONSTRATION</td></tr>
</table>

In order to reach the expected outcomes on TeamMate Architecture, the following requirements have been identified:

Expected outcomes	**REQ NAME**	**REQ Description**
TEAMMATE DEMOS WORKING AND READY FOR TESTS	*Accurate ego-localization*	At each moment the vehicle must have an accurate global localization or at least a lane shift information in the lane
	Accurate lane-detection	At each moment the vehicle must have all the information about the surrounding lanes
	Accurate ego-lane estimation	An accurate estimation of the ego-lane in the case of highway
	Accurate obstacles detection and localization in lanes	At each time the we must have an accurate obstacle detection and affectation to the lanes . Region of interests are needed in this case.
	Tracking of the lanes and obstacles	in case of lane markers absence or localization absence the Automation must continue for a certain period
	Computation of safe corridors	According to the information below, the computation of all possible corridors is done
	Computation of safe manoeuvers	The adequate manoeuvers are deduced from the point below by choosing the best corridor according to a defined objective/cost function.
	Understandable HMI	An HMI that informs permanently the driver of the current , possible actions and surrounding situations,
	Behavior adaptation and learning	according to the choices of the driver, the teammate is able to learn the driving choices and driving style and reproduce it safely in case of autonomous driving.

6. Conclusions

The present document reflects the structure of WP1 in the project. Therefore, first, we have illustrated the main concept of TeamMate car, which is the key-concept and the focus of AUTOMATE.
Then, we have defined the target-scenarios and the use-cases we deal with. They “fix” what the system has to do and which are the cases we are able to cover (or, we aims at covering).
After that, as a crucial part, we have presented the definition of requirements for the cycle 1. They cover different types of system implementation, but – at the same time – they cannot be regarded as definitive, since we are still at the beginning of the project. That is why, they constitute our starting point that could be modified during cycles 2 and 3.
Finally, we provided the complete list of scenarios, use-cases and requirements in annexes (and with the original EXCEL tables).

References

[1] Steven M. Lavalle; (1998) “Rapidly-Exploring Random Trees: A New Tool for Path Planning”

[2] Mikhail Pivtoraiko; Alonzo Kelly; (2005) “Efficient Constrained Path Planning Via Search In State Lattices”

[3] Choset, H.M.; Principles of Robot Motion (2005): “Theory, Algorithms, and Implementation”

[4] J. Ziegler, P. Bender, T. Dang and C. Stiller; (2014) "Trajectory planning for Bertha — A local, continuous method,"

Annex A

The complete list of top-level requirements is available as an annex, which is constituted by a separated EXCEL file.

Fields	Meaning
OBJ. N.	ID number indicating the (project) objective.
AutoMate Objective	Description of the considered project objective.
ENABLERS	Which are the enablers allowing the achievement of the objective.
WP	Reference Work-Packages where the enablers are developed.
Partner	Main responsible of the enabler.
Challenges	Which are the technical and scientific challenges that the project wants to solve.
SoA	The current state of the art.
How to go beyond SoA?	Which are the innovations – with respect to the current state of the art – provided by AutoMate solutions.
Expected outcomes	The outputs / results expected by the project.
REQ NAME	Name of the requirement.
REQ Description	Its description.
Metric (if available) [e.g. x>10]	If possible, or when possible, a parameter (with numerical value) to make the requirement measureable.
REQ created by	Indicating the author by: Name, Surname and Company
Linked to DEMO 1 (ULM)	If the requirement is associated to the demonstrator 1, leaded by University of ULM partner.
Linked to DEMO 2 (VED)	If the requirement is associated to the demonstrator 2, leaded by VEDECOM partner.
Linked to DEMO 3 (CRF/REL)	If the requirement is associated to the demonstrator 3, leaded by CRF and RE-LAB partners.
Degree of REQ	It can be: Fulfilled, Partially Fulfilled, Not Fulfilled

fulfillment	
Implemented?	If it is so, in which demonstrator? Indicate [Demonstrator X]

Legends:

- WP = Work-Package
- SoA: State of the Art
- REQs = Requirements
- DEMO = Demonstrator

In this Annex, we provide a quick explanation of the main fields presented in the EXCEL file (see table above).