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Automotive Intelligence for Connected Shared Mobility

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1 Executive/Publishable summary

This document is intended to give an overview of smart connected shared mobility for urban area, collected from all partners participating in task T1.1 of AI4CSM WP1.

Task T1.1 results are fundamental to Supply Chain 1 (SC1), which targets to provide three demonstrators: **SCD 1.1: Lessons-learned based (critical scenario) update of ADAS/AD Controller**, **SCD 1.2: Robo-taxi** and **SCD 1.3: Virtual city routing**. The requirements collected in the task represent the foundation to develop these demonstrators. AI4CSM's technology enabler supply chains SC4 to SC7 and their related demonstrators target to integrate their results into the output enabler supply chains SC1 to SC3.

We use the following scheme to collect and compile T1.1 work products of the task members:

1. Partners concentrate on their individual work package tasks and contribute a chapter to D1.1 describing the work executed for T1.1.
2. The task leader provides a template for requirement definition. Partners use the template to collect their requirements and compile them into a separate document.
3. Inputs are reworked and consolidated. Further partners discuss cooperation and requirements alignment in regular meetings.
4. The task leader compiles an aggregation of the developed requirements into this document and documents the approach and achievements.

The following chapter of this deliverable D1.1 is describing the scope of the document and is giving an introduction and overview. The main chapter in which all partners describe their contribution in detail follows it. Finally, a conclusions chapter sets the work in context to related AI4CSM tasks and summarizes on the impact and contributions to the work packages and supply chains.

Annexed to this document are the detailed lists of developed requirements for the three demonstrators together with corresponding demonstrator descriptions.

2 Non publishable information

All the information below is publishable.

3 Introduction & Scope

3.1 Purpose and target group

The AI4CSM project will develop advanced electronic components and systems (ECS) and architectures for future mass-market ECAS (electric, connected, autonomous, shared) vehicles. This fuels the digital transformation in the automotive sector to support the mobility trends and accelerate the transition towards a sustainable ecosystem.

SC1 will demonstrate ECAS vehicles in future shared mobility situation. To enable this, SC1 will develop smart edge- and cloud-based building bricks for autonomous mobility interconnected with secure communication architectures and systems. SC1s **vision** to enable a safe, efficient, and green autonomous mobility in urban areas trough connected mobility represents the central element of the entire SC. In that sense,

- **safe** stands for safety enhancement via cooperative integration of cloud knowledge into edge perception and vehicle intelligence solutions
- **efficient** stands for maximize traffic throughput with minimum latency time together with minimizing active cars in urban environments
- and **green** stands for consideration of shared resources for minimizing energy consumption.

Based on this vision the **key challenge** represents the development of smart edge- and cloud-based building bricks for autonomous mobility interconnected with secure communication architectures and systems addressing the overall project objectives 1, 2 and 6. To realize the specified vision and tackle the key challenge SC1 focuses on the following objectives depicted in Figure 1.

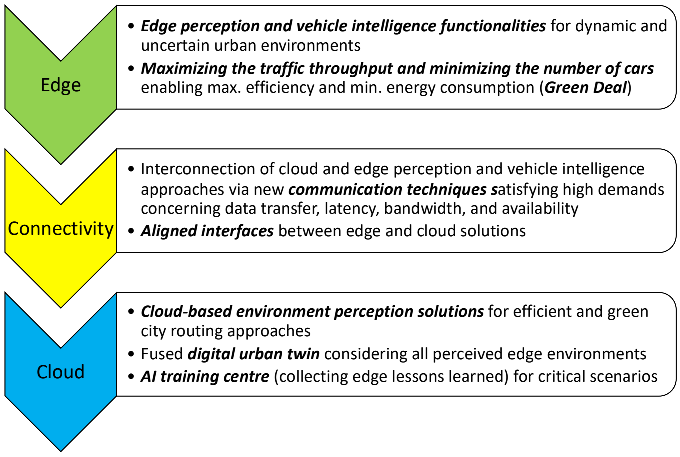

FIGURE 1: SC1 OBJECTIVES

All SC1 objectives can be categorized into edge-, connectivity- and cloud specific objectives. Results of task T1.1 activities form the foundation towards fulfilment of these objectives, finally leading to three demonstrators **SCD 1.1: Lessons-learned based (critical scenario) update of ADAS/AD Controller, SCD 1.2: Robo-taxi** and **SCD 1.3: Virtual city routing**. The requirements collected in the task are foundation to develop these demonstrators.

3.2 Contributions of partners

Individual partner summarized their contributions in following table and provided detailed contributions in the referenced chapters.

TABLE 1 OVERVIEW PARTNER CONTRIBUTIONS

Chapter	Partner	Contribution
1, 2, 3, 4.3, 5	VIF	Deliverable structure and draft outline, demonstrator SCD 1.2 description, requirements for demonstrator SCD 1.2, conclusion section
4.2	AVL	Demonstrator SCD1.1 description, requirements for demonstrator SCD1.1
4.4	OTH	Demonstrator SCD1.3 description, requirements for demonstrator SCD1.3
4.3	IFAG	ECS requirements for the communication platform, which is developed within SC5 and showcased in demonstrator SCD1.2
4.2	TUGRAZ	Demonstrator SCD1.1 description, requirements for demonstrator SCD1.1

4.3	TTTAUTO	Requirements for the communication platform, which is developed within SC5 and showcased in demonstrator SCD1.2
4.2	AIT	Demonstrator SCD1.1 description, requirements for demonstrator SCD1.1
4.3	VTGU	Requirements for a communication protocol for V2V and V2X communication in Robo-taxi usecases in SCD1.2
3, 4	TG	Visualization of SC1 key figures (Figure 2,3,4)

3.3 Relation to other activities in the project

SC1 represents one of the core output enabler supply chains and therefore acts as a first integration platform for the component demonstrators developed in the technology enabler SCs (SC4 to SC7) to be tested and validated in urban areas, see Figure 2.

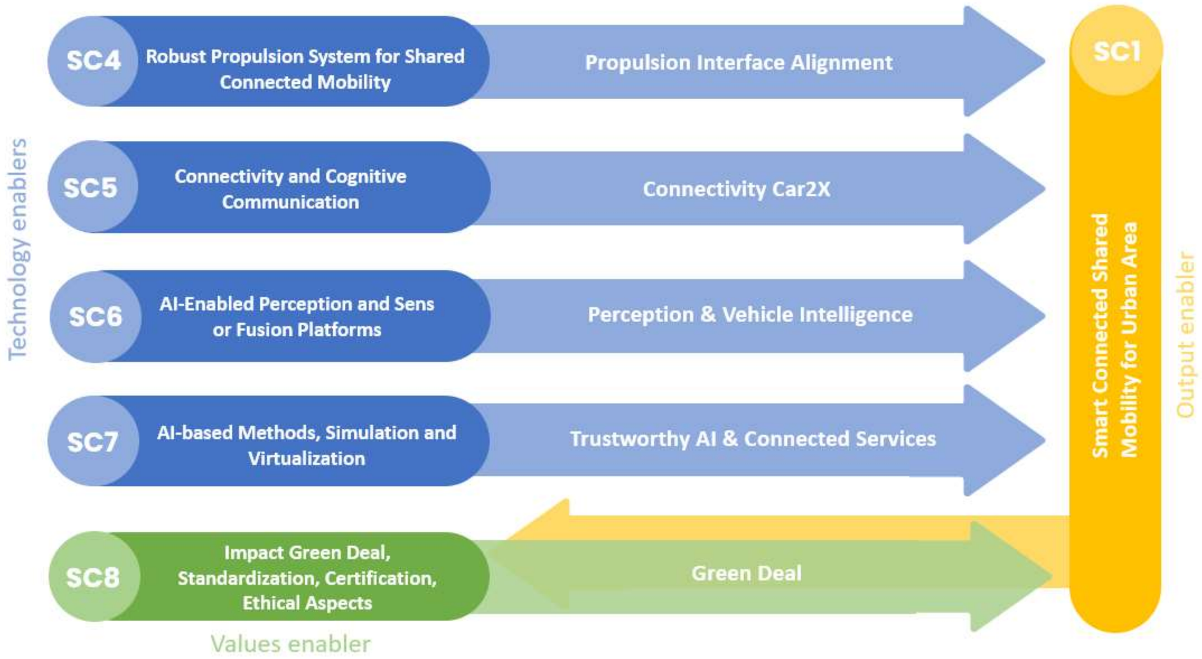

FIGURE 2: OVERVIEW SC1 INTERCONNECTIONS

Therefore, this supply chain will very closely collaborate with the following supply chains:

- Propulsion interface alignment with **SC4**
- Integration of connectivity solutions of **SC5** into the demonstrator SCD 1.2 for real-world approval
- Application of **SC6** related perception and vehicle intelligence approaches for urban use cases
- Synchronization of **SC7** cloud based digital twins for urban areas enabling trustworthy AI and efficient interconnection between the edge and the cloud.
- Bidirectional exchange and import of **SC8** related Green-Deal principles and potentials to maximize the impact of SC1 demonstrators.

3.3.1 Input from WPs, SCs and tasks

T1.1 is dedicated to the collection of the technical requirements for the development of the **smart edge- and cloud-based building bricks** for autonomous mobility interconnected with **secure communication** architectures and systems which encompasses three (3) demonstrators within SC1:

- **Demonstrator SCD 1.1: Lessons-learned based (critical scenario) update of ADAS/AD Controller (lead: AVL, partner: TUG, AIT)**
- **Demonstrator SCD 1.2: Robo-taxi (lead: VIF, partner: TTTA, IFAG)**
- **Demonstrator SCD 1.3: Virtual city routing (lead: OTH-AW, partner: TUG, VIF, AVL)**

To collect the technical requirements for the demonstrators, a top-down approach was followed; a list of high-level functional requirements was drafted for each demonstrator in collaboration with the leading partners. Special attention was put on the specific links to the technology enabler supply chains SC4 to SC7 as their developed systems and results will be integrated later into SC1 real-world demonstrators. In that manner, the targeted SC1 requirements will be shared and synchronized with the technology enabler supply chain requirements collection tasks 1.4 to 1.7.

3.3.2 Output from these results

The presented results comprise the output of T1.1 (Requirements and specifications for smart connected mobility) and will feed other WPs within AI4CSM that entail the implementation of the smart edge- and cloud-based building bricks together with their communication approaches in between, while they will serve as a means of verification to determine the level of achievement during the validation/demonstration phase. As such, these results will be linked to five (5) SCs and in four (4) WPs:

Supply chain links:

- Interface alignment with technology enabler supply chains:
  - SC4: Robust Propulsion System for Shared Connected Mobility
  - SC5: Connectivity and Cognitive Communication
  - SC6: AI-Enabled Perception and Sensor Fusion Platforms
  - SC7: AI-Based Methods, Simulation and Virtualization
- Integration of technology enabler (SC4 to SC7) supply chain results into SC1 demonstrators
- Synchronization of SC1 activities with Green Deal principles developed and evaluated in SC8

Work package links within SC1:

- According to the stated requirements within this deliverable **WP2** (T2.1 - System level design for Smart Connected Mobility) will develop simulation architectures capable to virtually verify the developed software solutions.
- **WP4** (T4.1 - Embedded HW/SW for Smart Connected Mobility) will focus on the development and implementation of the software building bricks in line with the requirements.
- The developed software solution of WP4 will be integrated into the specified demonstrators within SC1 in **WP5** (T5.1 - Integration of systems for Smart Connected Mobility).
- Finally, the output of deliverable D1.1 will be used in **WP6** (T6.1 - Validation and tests of Systems for Smart Connected Mobility) for testing and verification purpose to meet all stated

requirements in the SC1 demonstrators. The developed technologies, modules and systems will be validated against the requirements, specifications and KPIs defined in this deliverable.

Figure 3 depicts the relation of this deliverable with other WPs, SCs and tasks regarding inputs and outputs.

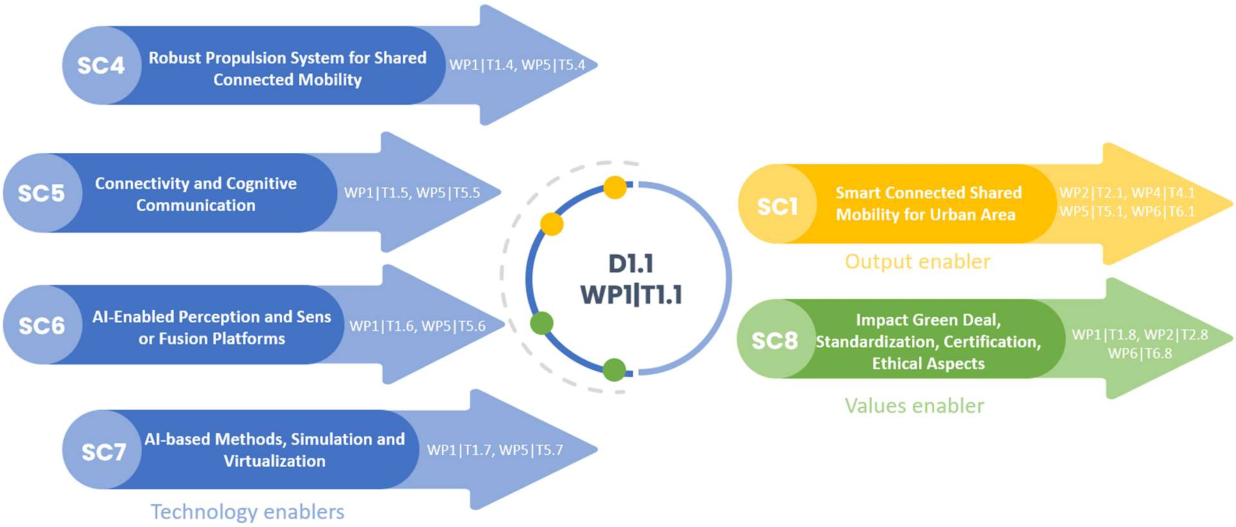

FIGURE 3: RELATION OF DELIVERABLE 1.1 WITH OTHER ACTIVITIES WITHIN AI4CSM.

4 Requirement collection process and methodology

The requirement collection process within SC1 follows a bottom-up approach, this means all demonstrators within SC1 are defined first to showcase the outcome addressing the SC vision and objectives accordingly. To showcase the targeted SC1 objectives all requirements are then referred to the individual demonstrators and corresponding use cases including use case specific KPIs which are used to measure the success. SC1 partners will validate the performance of the targeted ***edge- and cloud-based environment perception and vehicle intelligence functionalities interconnected with smart communication solutions*** (see Figure 4) in dedicated simulation frameworks and real-world demonstrator vehicles.

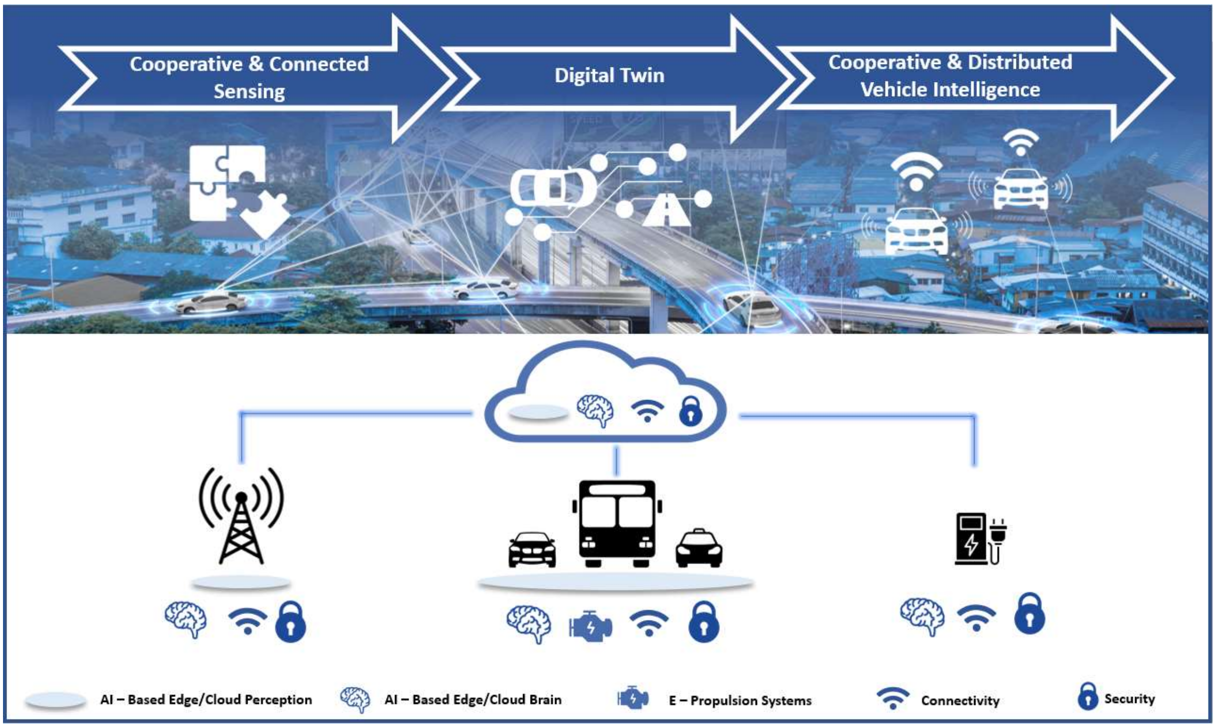

FIGURE 4: OVERVIEW SC1 CORE ACTIVITIES

The defined demonstrators will be verified in ***urban*** scenarios (e.g., robo-taxi customer fetch-up, virtual city routing, intersections, etc.). The performance of the individual use cases will be evaluated via specified KPIs addressing **safety**, **efficiency** together with special attention to the **Green-Deal** (SC8 acts as a value enabler).

4.1 Demonstrator specification

SC1 defines three main demonstrators to showcase the targeted SC1 objectives:

- **Demonstrator SCD 1.1: Lessons-learned based (critical scenario) update of ADAS/AD Controller (lead: AVL, partner: TUGRAZ, AIT)**

  SC1 partner will deliver an AI training center for safety-critical scenarios to further enhance the automated driving function under test. In that manner valuable situations for verification and validation of new driving functions will be detected and recorded, sent to a datacenter and in a post-processing step converted into a virtual driving scenario.

- **Demonstrator SCD 1.2: Robo-taxi (lead: VIF, partner: TTTAUTO, IFAG)**

  The robo-taxi demonstrator focuses on the verification and validation of edge environment perception and vehicle intelligence algorithms for customer fetch-up use cases in urban areas. In addition, bidirectional communication approaches to the cloud (developed in SC5) will be integrated and evaluated in complex urban areas.

- **Demonstrator SCD 1.3: Virtual city routing (lead: OTH-AW, partner: TUGRAZ, VIF, AVL)**

  The virtual city routing demonstrator showcases CO_2- and time-optimized routes for urban areas to decrease the shared mobility latency time by 20% together with a traffic throughput increase of 20%. SCD 1.3 has a strong link to SC8 considering geofencing and smart charging for future smart and green cities.

4.2 SCD1.1 - Lessons-learned based (critical scenario) update of ADAS/AD controller

Over the last years, impressive advancements were made in the field of ADAS/AD functions and controllers and with this, more and more of such functions get, and are already integrated within vehicles. However, since the number of scenarios that can occur during driving and which need to be handled correctly by the ADAS/AD controller are near infinite, there might still arise cases during driving where the controller might not able to handle the situation correctly and a human driver needs to interfere. Therefore, there is still the need to validate the correct behavior of such functions and controllers and explore the search space to find scenarios that might have not been tested yet and to validate the correct functionality in such situations to move towards more reliable, dependable, and trustworthy ADAS/AD.

Within the demonstrator SCD1.1, the partners AVL, TUG, and AIT will work on this problem and will demonstrate a lessons-learned based approach for updating and validating ADAS/AD controllers by monitoring deviations between an ADAS/AD function and the behavior of a human driver during driving. With this, valuable situations for the verification and validation of existing driving functions as well as newly developed driving functions are detected, recorded, and post-processed to be convertible into a virtual scenario. Within an AI training center those safety critical scenarios are then used to further enhance the ADAS/AD function under test by generating additional test cases to enhance the criticality of the collected scenarios in a simulation environment.

With our planned activities and the methods that will be developed within this demonstrator we address and contribute to the following project objectives:

- **O1** – Develop robust and reliable mobile platforms
- **O2** – Develop scalable embedded intelligence for edge and edge/cloud operation
- **O5** – Design functional integrated systems

In addition to that, our demonstrator supports the specific SC1 objectives **Edge**, **Connectivity**, and **Cloud,** shown in Figure 1, in the following way:

- **Edge:** monitoring of ADAS/AD function behavior and human driver behavior in real time during driving on the edge.
- **Connectivity:** communication techniques that satisfy the high demands of data transfer of recorded data to the AI training center.
- **Cloud:** AI training center for collecting critical scenarios and improving the reliability, dependability, and trustworthiness of ADAS/AD functions.

The following sections give an overview on the key building blocks of the demonstrator which will be developed, an exemplary scenario description, associated key performance indicators (KPI) and an overview of the demonstrator platform as well as the planned validation plan.

4.2.1 Key building blocks

4.2.1.1 Specification of AI4CSM building blocks

Figure 5 shows the proposed key building blocks of the demonstrator, depicting the different partner contributions and connections of the building blocks. The blocks show the different parts of our lessons-learned based approach for ADAS/AD controllers. As it can be seen, an iterative process is planned, starting with data collection within a demonstrator vehicle, followed by the virtualization of the collected data, scenario criticality enhancements, simulation in a virtual environment and diagnosis before the updated ADAS/AD controller is again deployed and tested.

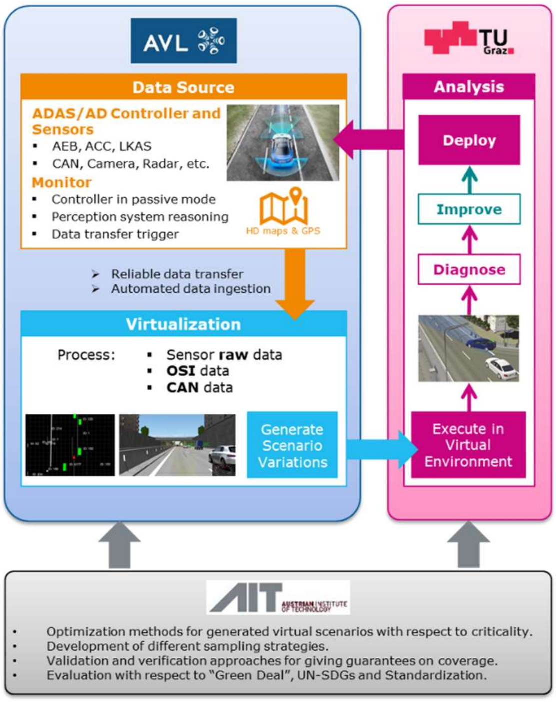

FIGURE 5: OVERVIEW OF THE KEY BUILDING BLOCKS AND PARTNER CONTRIBUTIONS WITHIN SCD1.1 DEMONSTRATOR.

AVL contributes within the SCD1.1 demonstrator with the topics concerning intelligent data collection and virtualization. This is accomplished via a passive testing methodology which monitors the behavior of an ADAS/AD function and compares it to the behavior of a human driver. In case of detected deviations the data collection process is initiated and in a post-processing step the data is prepared to be executable within a simulation environment. In addition to that, AVL contributes also to the generation of scenario variations of collected scenarios.

AIT contribution will tackle several crucial topics with respect to testing of ADAS/AD functions: testcase generation, and optimization methods which can be applied for obtaining a relevant test suite for critical parameters. To achieve this, we need to define a relevant sampling strategy which will allow us to extract only the relevant testcases, in a large space of potential testcases. Once the test suite is generated, we aim to provide coverage guarantees for the test suite users. Finally, we also provide insights and considerations w.r.t. the Green Deal and relevant standardization efforts.

TUG's contribution within the demonstrator concerns the analysis process of given critical scenarios. In this process, the planned initial step is to simulate the scenario in a virtual environment. Further on, in order to validate the scenario, a model-based reasoning approach is envisioned. By means of model-based diagnosis, the health state of every involved component will be checked, and possible adaptions of the given scenarios will be provided.

4.2.1.2 Role of previous developed building blocks

With respect to proposed building blocks of AVL in Figure 5, and in detail the block dealing with data collection, it should be noted that the basic hardware setup for collecting data within a demonstrator vehicle in real time and during driving was established within the NewControl project. However, since the indented functionality was a complete different within this projects (powertrain related data) it is necessary to integrate additional methods and sensors to use the setup in the context of ADAS/AD related data collection. In more detail, from the previous projects, just the basic hardware setup will be used and extended to fulfill the purpose of our proposed demonstrator.

For SCD1.1 AIT plans to integrate and extend the existing open-source tools for testcase generation, for the autonomous driving domain. We do not plan to reuse any of the building blocks from previous publicly-funded projects.

4.2.2 Validation concept

4.2.2.1 Scenario specification

Within our demonstrator we will focus on scenarios within an urban area or highway. During the operation of the demonstrator vehicle, an ADAS/AD function, e.g., AEB (autonomous emergency breaking), ACC (adaptive cruise control), ALKS (automated lane keeping), is running in real time in the vehicle. While driving, the output of the function is compared to the human driver with the focus of detecting deviations. Once a deviation is observed, the critical situation is recorded and transferred to a data center. In a post-processing step the situation will be converted to be executable in a simulation environment which will enable the possibility to perform diagnosis and further enhance the ADAS/AD function under test by increasing the criticality of the virtual driving scenario through the developed methods.

4.2.2.2 Evaluation metrics

To evaluate the functionality of our demonstrator, we introduced three different categories, i.e., data source, virtualization, and AI training center.

Data Source:

- Deviations between a human driver and an ADAS/AD function need to be detected – comparison for instance with a fallback trigger that can be activated by the driver when a deviation is recognized by the human driver.
- Automated and reliable data transfer is available – comparing processed data in the vehicle with the available data in the data center.
- Reduced data transfer and storage – comparison between data storage needed for collecting all driving data during a test run and the data storage needed for only valuable situations.

Virtualization:

- Virtual scenario is equivalent to the real-world scenarios in terms of traffic participants, road structure and driving area (highway, urban area) – comparison for instance through checking with the recorded video of the critical scenario.

- Open-Source and standardized formats need to be used for virtualization. Virtual scenario must enable concrete test-case generation based on advanced and customizable sampling strategies.

AI Training Center:

- 10 critical scenarios are generated out of the collected, post-processed and virtualized data.
- Critical scenarios will cover specific features depending on the virtual test cases and the ADAS function under test and will provide guarantees on feature coverage.

4.2.3 Demonstrator platform

This section will give an overview of the different platforms that will be used for our SCD1.1 demonstrator to showcase the performance of the developed and implemented methods. Within our demonstrator, different platforms for demonstration purposes are planned, i.e., a driving simulator platform, a demonstrator vehicle and a combination of both.

4.2.3.1 Demonstrator specification

Within our demonstrator, we plan to introduce two different demonstrator platforms. Figure 6 depicts a simplified schematic of the **demonstration platform 1**, where the developed method which is monitoring deviations between a human driver and an ADAS/AD function is validated in a simulation environment.

FIGURE 6: DRIVING SIMULATOR PLATFORM

In addition to that, within the **demonstration platform 1** (the driving simulator) the conversion of real-world driving data to scenarios which are executable within the simulation environment will be demonstrated. Furthermore, the criticality enhancements of collected scenarios generated in the AI training center will be demonstrated within the driving simulator and, based on the generated new scenarios, diagnosis and analysis tasks will be performed.

Demonstration platform 2 extends our **demonstrator platform 1** by including a demonstrator vehicle. With this we plan to demonstrate the complete toolchain starting from the deviation detection between a human driver and an ADAS/AD function in real-time during driving, to the data transfer to a data center, the post-processing which is responsible for the conversion of the scenario to be executable within the driving simulator, the execution of the criticality enhanced scenarios within the simulator and their diagnosis and analysis.

FIGURE 7: DEMONSTRATOR VEHICLE (AUDI Q5)

4.2.3.2 Test plan for evaluation

In the following paragraphs an overview of the test plan is given:

Demonstration Y1: Simulation (virtual approval) – virtual approval of the passive testing approach, i.e., the identification of deviations between a human driver and an ADAS/AD function, are demonstrated in a simulation environment. In addition to that the virtualization of already available real-world data in a simulation environment is shown.

Demonstration Y2: Simulation (virtual approval) – virtual approval of the overall demonstrator toolchain in a simulation environment. This includes the virtualization of already available real-world data, the criticality enhancements in the AI training center and first steps towards the analysis and diagnosis of the generated critical scenarios.

Demonstration Y3: During year three an evaluation of the complete toolchain is planned. The first block of the toolchain deals with the demonstrator vehicle on a test track, urban area or highway where real - time data collection utilizing the passive testing approach (deviation detection between human driver and ADAS/AD function) is performed. The following building blocks of the toolchain are performed within a simulation environment. Here, the collected real-world scenarios get virtualized, and the developed methods for criticality enhancements will be used to generate a diverse set of critical scenarios which will be analyzed and diagnosed in the last step.

4.3 SCD1.2 – Robo-taxi

The major target of this demonstrator is to develop appropriate edge environment perception and edge vehicle intelligence algorithms for the automated operation of a robo-taxi in challenging urban use cases. Section 4.3.1 gives an overview on the respective key building blocks (software modules), which are developed by VIF. Dedicated, challenging scenarios are defined in section 4.3.2.1 (urban overtaking, crosswalk handling and customer fetch-up). and section 4.3.2.2 defines the associated evaluation metrics (KPIs). Finally, section 4.3.3 outlines the applied demonstration platforms and the intended validation plan. The demonstrator furthermore shall serve as proof-of-concept for bidirectional communication approaches between cloud and edge intelligence. An communication platform (hardware and software), which is developed within SC5 by TTTAUTO using electric components developed by IFAG, is planned to be integrated into the robo-taxi demonstrator vehicle. This communication can be used on the one hand to provide edge information (e.g. perceived environment or maneuver intentions) to the cloud, as basis for a fused digital urban twin and sophisticated routing or traffic guidance modules. On the other hand it enables the application of enriched cloud information (e.g. perception or routing information) to improve the final edge device performance, safety and efficiency.

To enable reliable, checkable and efficient V2V and V2X communication of the Robo-taxi, VGTU will develop a communication protocol, i.e. an abstract protocol language based on parametric-mnemonic commands and parameter classifications). Its development is based on an extensive literature analysis (more than 100 references), accomplished within Task 1.1. Furthermore, VGTU will provide communication dataflow simulations, to simulate the impact of different qualities of communication success.

Hence, this demonstrator directly supports several SC1 objectives **Edge** (edge perception and vehicle intelligence functionalities for dynamic and uncertain urban environments), **Connectivity** (interconnection of cloud and edge perception and vehicle intelligence approaches via new communication techniques satisfying high demands concerning data transfer, latency, bandwidth, and availability; Aligned interfaces between edge and cloud solutions) and **Cloud** (fused digital urban twin considering all perceived edge environments)

On a more general scale the demonstrator contributes to the following project objectives:

- **O1** – Develop robust and reliable mobile platforms
- **O2** – Develop scalable embedded intelligence for edge and edge/cloud operation
- **O6** – Build ECAS vehicles for Green Deal for future connected shared mobility

The demonstrator aims to improve the state of the art on different frontlines. First, the developed perception modules are based on promising novel concepts (in particular structured end-to-end learning for ground segmentation and semantic occupancy grid based on Lidar data). The combination of a classical object list and a semantic grid enables opportunities to increase the safety and robustness of the AD system, e.g., by redundant maneuver safety assessment. Secondly, a real-world validation of a complete AD system (perception + motion planning and control) for a Robo-taxi in dedicated scenarios is pending. The demonstrator will contribute towards this target, supported by the intended perception concept.

4.3.1 Key building blocks

4.3.1.1 Specification of AI4CSM building blocks

Figure 8 shows the proposed edge architecture of the robo-taxi demonstrator consisting of hardware (sensors and actuators) and edge software modules (edge perception and edge vehicle intelligence).

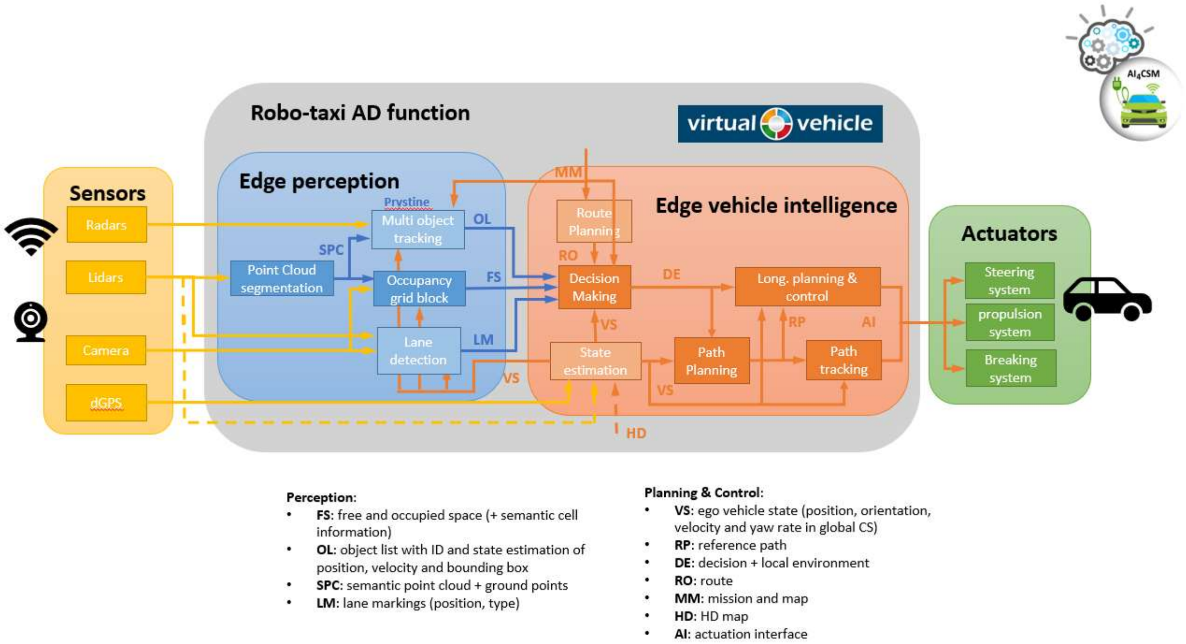

FIGURE 8: HIGH-LEVEL ARCHITECTURE PROPOSAL FOR THE VIF ROBO-TAXI DEMONSTRATOR

Figure 9 illustrates the intended cloud-edge communication structure, which is used to demonstrate a proof-of-concept for bi-directional communication.

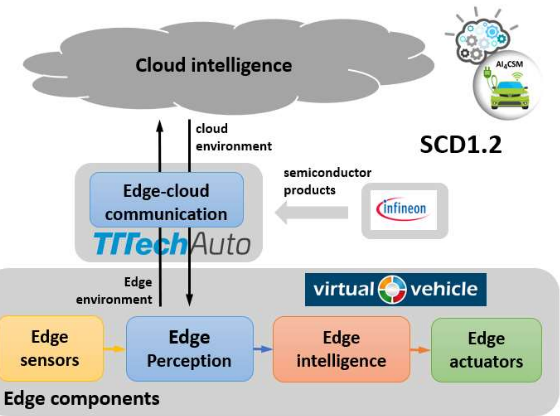

FIGURE 9 CLOUD-EDGE COMMUNICATION CONCEPT

TTTAUTO will, with support by SC1 partner like AVL or VIF, integrate the in-car computing platform into the system setup to demonstrate the communication and connectivity functionalities developed in SC5. The edge/cloud bidirectional communication functionality will enable on-board mobility services to utilize cloud data and/or cloud services together with sensor information from the car. It is planned to host the smart mobility application provided by partner on a performance host on the in-car computing platform. Furthermore, it is planned to test the functionalities concerning fast data channels (SC5) depending on the needs in SC1.

4.3.1.2 Role of previous developed building blocks

The proposed architecture (see Figure 8) allots the application of a multi object tracking module, which has been developed in the PRYSTINE project. It is intended to model the surrounding environment, based on Radar and Lidar data in terms of an object list, which includes the estimated positions, bounding boxes positions and velocities of all detected obstacles, as well as a relation to the previous observations in order to make historic data of object available, e.g., for motion prediction purposes.

Furthermore, an existing perception submodule for lane marking detection will be applied, which concatenates the lane markings, detected in single frames of a camera image, to an internal lane model.

Considering the edge vehicle intelligence, the proposed architecture (see Figure 8) indicates two software modules (Route planning and state estimation) as place holders. They are part of common AD function architectures, but not within the focus of the developments within this demonstrator. With the application of a modular software architecture, a straight-forward integration of corresponding software modules is possible, in order to enlarge the application range of the AD function. With respect to the vehicle state estimation the applied architecture design assumes that it is possible to determine the ego motion states (position, orientation velocity) with an appropriate sensor system in sufficient accuracy in order to enable robust trajectory tracking. The sensor system, which is intended to be used in this demonstrator is a dGPS system (combining several GNSS antennas, correction data and IMU units). It is expected that this system provides sufficient accuracy. As the performance of such a system depends on the surrounding environment (buildings, weather, internet availability,…) the applied software architecture could be improved by including a dedicated state estimation module, which may additionally incorporate further sensor data. The second placeholder is a route planning module. It provides an efficient route based on the current position, the mission and available map data. This route is the basis for the underlying (local, low-level) planning modules. The development of such a module is the major task of demonstrator SCD1.3 (see section 4.4) focusing on urban environments. Therefore, this demonstrator is restricted to the interface definition and the application of routes provided by external (cloud) routing modules.

4.3.2 Validation concept

4.3.2.1 Scenario specification

This section describes the targeted scenarios for the intended robo-taxi use case. These scenarios are furthermore used to evaluate the performance of the edge vehicle intelligence.

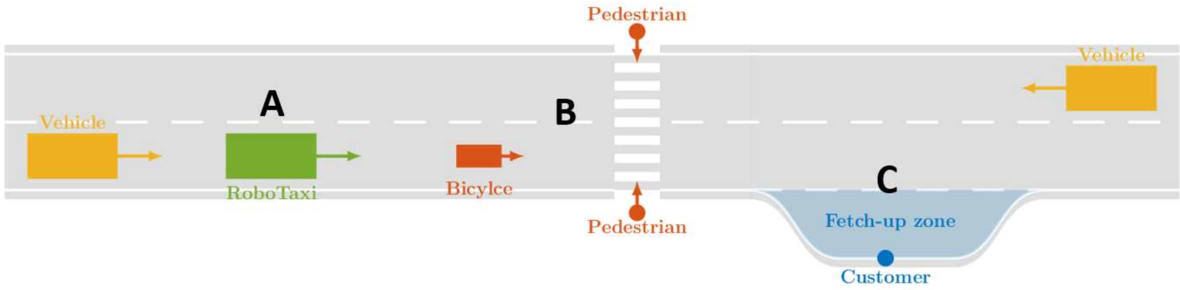

FIGURE 10: SCENARIOS OF THE URBAN ROBO-TAXI USECASE (A: OVERTAKING, B: CROSSWALK HANDLING, C: CUSTOMER FETCH-UP)

Scenario A – Overtaking:

Scenario overview:

The Robo-taxi is following a slower traffic participant and has to realize a safe and admissible overtaking maneuver, with oncoming traffic.

Scenario details:

Overtaking maneuvers are of importance particularly in mixed traffic as it occurs in cities (e.g. if there are no separated lanes for motorized and vulnerable traffic participants) in order to increase the overall traffic throughput. At the same time these maneuvers are of special risk for all the involved traffic participants, yielding many accidents, since it requires a good prediction of the motion of all involved participants. Hence, in order to accomplish an overtaking maneuver with an autonomous system, a precise and accurate estimation of the position, bounding boxes and predicted motions of all involved traffic participants, particularly the oncoming traffic and the object to overtake as the basis to handle such a scenario safely and successfully. Further major challenges arise for the decision-making module of the system: First, it has to decide if it is possible to overtake, on the one hand without any endangerment of other traffic participants and violation of applicable traffic rules (lateral distance, safety gaps, speed limits) and on the other hand without being too conservative (avoid overtaking). After the initiation of an overtaking maneuver, the second challenge is the continuous, reliable and traceable monitoring of the overtaking process accompanied by the preparation of minimal risk abortion strategies and maneuvers, which could be activated in best case at any time during the maneuver.

Scenario B – Crosswalk:

Scenario overview:

The Robo-taxi is approaching a crosswalk. If a pedestrian attempts to cross the road at the crosswalk, the Robo-taxi has to stop and continue the drive as the crosswalk is free again.

Scenario details:

Crosswalks are a frequently occurring traffic guidance elements particularly in urban environments. Especially, if they are not regulated by an appropriate traffic light system they represent another important point of risk for accidents, as they involve vulnerable road users. In order to achieve a safe handling of crosswalks the AD system in a first step has to reliably detect the crosswalk, e.g. by detecting the respective traffic sign, lane markings or using map data. In a second step a decision has to be made if it is necessary to stop in front of the crosswalk, as a pedestrian intends to cross the road.

If this is the case a safe, accurate and if possible comfortable stooping maneuver has to be triggered and executed. After the crossing the AD system has to comfortable return back to regular driving.

Scenario C – Customer fetch-up:

Scenario overview:

A fetch-up request is received from a costumer while the Robo-taxi is approaching the defined fetch-up zone. If it is possible to safely enter the zone, the Robo-taxi has to leave the road and comfortably stop inside the zone. After the customer boarding the Robo-taxi has to merge back into the traffic in order to pursue the drive towards the customers target destination.

Scenario details:

In contrast to scenarios A and B, this scenario is directly linked to the intended field of operation of the Robo-taxi. However, on a more general perspective, the safe merging into a lane with oncoming traffic, is of significant importance in autonomous urban driving. The major challenges include the estimation of the free space in the parking area, a smooth and regular (w.r.t. traffic rules) merge from the road lane into the parking area, and the accurate stopping inside the area, as well as the safe and if possible comfortable merge back into the lane traffic. Like in scenario A and B a trade-off between comfort and maneuver accomplishment is required, while always obeying safety and traffic rules (e.g. right of way).

Obviously, the set of scenarios does not represent the entire functionalities, needed for a fully autonomous (level) operation of a vehicle in a general urban environment under all conditions. However, the challenges and aspects that are involved by these compact set of three scenarios are quite manifold and important of urban driving. Therefore, the successful autonomous handling of these scenarios can be considered as important mid-term milestone towards the long-term vision of fully autonomous operation.

4.3.2.2 Evaluation metrics

The Robo-taxi metrics for evaluating the functionality are separated into the categories edge perception and vehicle intelligence. The detailed explanations and specific metrics can be found in the annex.

Edge perception:

- Perception accuracy of 80% of ground segmentation and occupancy grid
- Mean Intersection over Union (mIoU) of semantic point cloud and semantic occupancy grid
- Additionally, the related KPIs Precision, Recall, 1-score are considered

The accuracy achieved within the project Prystine, which has been estimated as 70% in occupied space forms the accuracy baseline. The mean intersection over union baseline is defined by the scientific state of the art [1], which can be summarized as approximately 30%.

Edge vehicle intelligence:

- Safety (minimum safety margin and minimum safety gap)
- Compliance to all relevant traffic rules
- Trustworthiness/acceptance (launch time, overtaking behavior)
- Performance (tracking accuracy) and comfort (launch time, planned path curvature)

As major baseline for the defined KPIs a predefined regular, human behavior (safety margins, safety gaps, launch times, traffic rules, …) is considered. In particular the trustworthiness/acceptance KPIs are intended to achieve a "human-like" performance, which is also perceived as "human-like" by the other traffic participants. This is an important aspect, especially in the context of contradicting metrics, e.g. specific performance or comfort KPIs. SotA path tracking controllers are considered as baseline for the tracking performance.

4.3.3 Demonstrator platform

This section gives a general description of the targeted demonstration platforms, which are applied in order to demonstrate the performance of the edge intelligence of the autonomous Robo-taxi in the defined scenarios (see section 4.3.2.1). Section 4.3.3 specifies the demonstrator in terms of the used demonstrator platforms, including component verification (**demonstration platform A**), virtual system verification (**demonstration platform B**), and real-world demonstration (**demonstration platform C**). Section 4.3.3.2 outlines the corresponding intended test plan.

4.3.3.1 Demonstrator specification

The planned demonstration process consists of three stages following the ascending branch in the common V-model. At the first stage the developed edge perception and vehicle intelligence performance is evaluated separately, within the dedicated development frameworks that have been applied in the module development.

The **demonstration platform A1** focuses on the edge perception module development. The individual submodules are developed within a dedicated framework (developed at VIF), which in particular supports the application of datasets (for learning and evaluation) by a developed dataset loader and the result visualization. In combination these two tools enable efficient dataset-based testing, debugging and verification of perception algorithms and will be used to demonstrate the functional performance of the perception submodules.

The **demonstration platform A2** focuses on the edge vehicle intelligence (planning and control) module development. A light-weight development framework (developed at VIF) is used, which focuses on the efficient development, verification and testing of planning & control modules. The framework features modular component libraries of vehicle dynamics on different abstraction levels, as well as a compact planar environment model and respective sensor models. Using these components, it is possible to configure a simulation plant and test single AD modules in a closed-loop setting. This is of particular importance for the development of planning & control modules since their performance mandatorily has to be evaluated in closed-loop simulations.

In contrast the demonstration platforms A1 and A2, **demonstration platform B1** on the one hand transitions from separated simulations to joint simulations of edge perception and edge vehicle intelligence modules. On the other hand, instead of using datasets and development scenarios, the defined target scenarios are simulated. Combining these two aspects the platform is used to gain a virtual approval of the designed modules, which is a major step towards the final integration and testing in the real demonstrator vehicle. Furthermore, the framework complements the real-world demonstration results since it enables the cost-efficient simulation of scenario and parameter variations.

Finally, the developed software is integrated into a demonstrator vehicle (see Figure 12), which represents the final **demonstration platform C.** It is a representative hybrid-electric passenger car (Ford Mondeo), equipped with steer/break-by-wire systems, an environmental perception sensor setup and dedicated computational platforms to perform highly automated driving, owned by VIF. The sensor setup consists of Lidar sensors, short/long range radar sensors, cameras as well as a dGPS and IMUs (see Figure 11). It is intended to demonstrate at least one scenario of the defined scenario setup on a test track, e.g. in Graz/Lebring (see Figure 13) or at the TU Graz-Campus in mixed-reality.

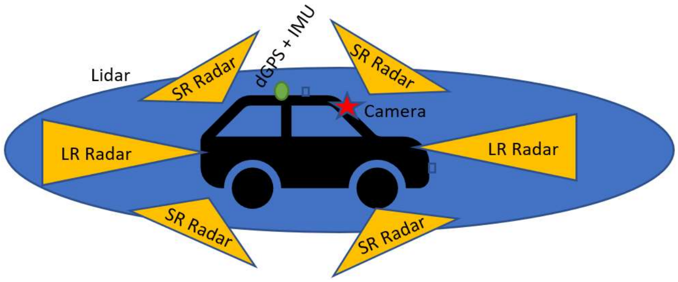

FIGURE 11: GENERAL SENSOR SETUP OF THE DEMONSTRATOR VEHICLE

FIGURE 12 VIF AUTOMATED DRIVING DEMONSTRATOR VEHICLE (FORD MONDEO)

FIGURE 13: POTENTIAL TEST AREA AT THE TEST TRACK IN LEBRING

4.3.3.2 Test plan for evaluation

According to the three-stage demonstration process (see section 4.3.3.1), the following test plan is proposed.

Demonstration Y1: Simulation (virtual approval) – virtual approval of Perception and Vehicle Intelligence components in separated simulation environments. The general performance of the perception and planning & control draft modules is showcased using the defined demonstration platforms A1 and A2 (see section 4.3.3.1) with respect to datasets and development scenarios and evaluation metrics (section 4.3.2.2). The results are intended to be available at the year one review meeting. Besides this showcasing, simulations on both demonstration platforms will accompany the development and integration for the entire project, e.g. in terms of parameter tuning and optimization and implementation of necessary modifications and adaptions, which might arise from the results on the second and third stage of the demonstration concept.

Demonstration Y2: Simulation (virtual approval) – virtual approval of the overall system Robo-taxi AD function. As described in section 4.3.3 the virtual system demonstration platform is a major step towards the real-world demonstration. The results of a first prototype simulation will be evaluated based on the demonstrator requirements and will be available at the year two review meeting. The detailed simulations with respect to all defined scenarios will accompany the remaining demonstration process, as the results are intended to complement the real-world testing.

Demonstration Y3: Demonstrator vehicle on test track – real world approval of the Robo-taxi edge perception and planning & control modules in a real demonstrator vehicle (see demonstration platform C) in a mixed-reality Robo-taxi use case. The actual environment will be extended by virtual information (e.g. pedestrians) to guarantee safety during the tests. The performance of the AD system in the tested use case, will be evaluated with respect to the defined evaluation metrics (section 4.3.2.2).

4.4 SCD1.3 – Virtual city routing

The OTH-AW routing cloud service is supposed to find the most efficient routes for electric vehicles in urban areas regarding the targets of the green new deal while considering dynamic changes of the environment.

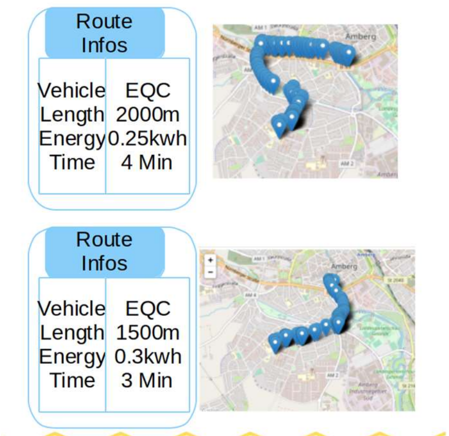

FIGURE 14: EXAMPLE FOR ENERGY OPTIMIZED ROUTE AND COMPARISON

We intend to build a scalable cloud platform with edge parts that can route electric vehicles with an edge part (Project objective **O2**).

The solution supports the green deal objectives for future connected and shared mobility by optimizing. It helps to change the long-term decision-making that the driver or navigation system takes before and while a transportation request is handled towards the green deal objectives of more efficient, secure, and environment-friendly mobility (**O6**).

We will base the research on previous research projects like 1000kmPLUS and 3Ccar.

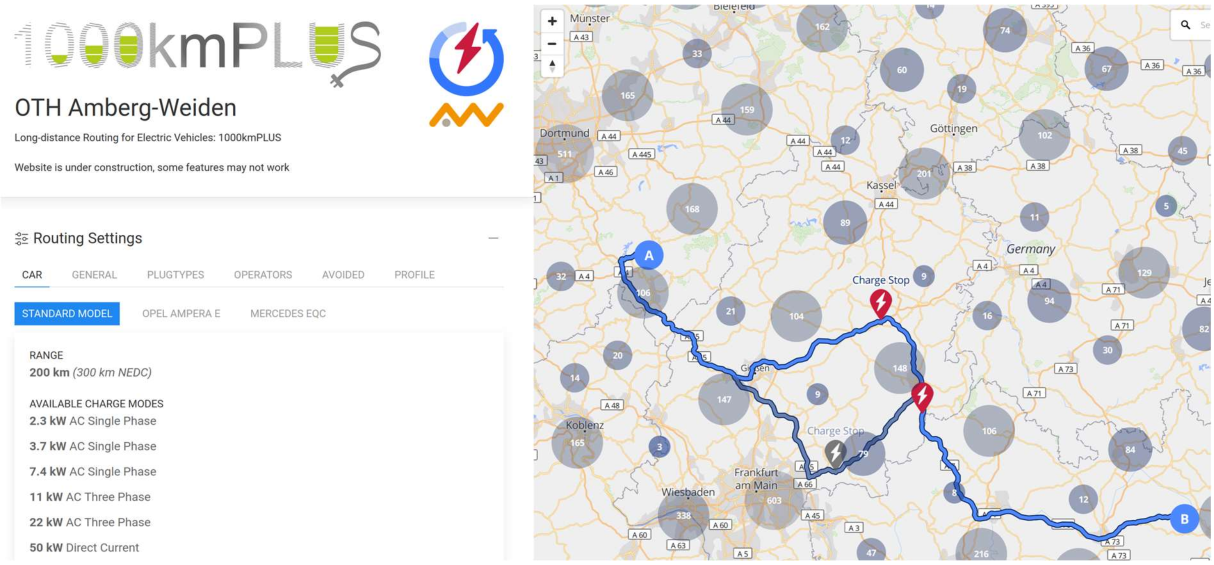

Figure 15: Routing demonstrator from the project 1000kmPLUS

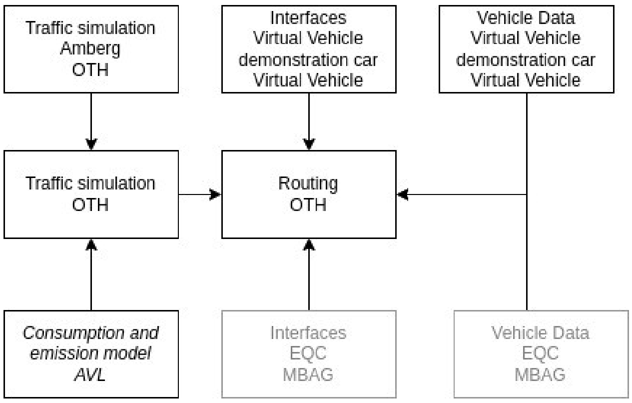

Figure 16: Routing service different components

New aspects like building a digital twin for the routing of autonomous vehicles and validation of energy-optimized routing algorithms will be added. The routing will be able to handle dynamic effects and geofencing. The shared mobility latency will be decreased, and the traffic throughput will increase.

This section is based on the demonstrator description, which you can find in the Annex (AI4CSM_SC1_3_Demonstrator.docx)

4.4.1 Key building blocks

4.4.1.1 Specification of AI4CSM building blocks

The **consumption and emission model** is a simulation that calculates the energy consumption of an electric vehicle in kWh for given distances, velocity curves, height profile, and other input parameters coming from the actual or simulated world or adjustable vehicle parameters.

The purpose of the **routing service** is to operate an autonomous vehicle by providing it with route points. To operate an electric autonomous testing vehicle via the routing service, several **interfaces** are required to access information about the vehicle for routing calculation and data acquisition for testing purposes. An optimized route can be injected to be driven by the vehicle. This includes two vehicles, a Mercedes EQC and a Ford.

The **traffic simulation** is a model of the street environment that includes traffic participants and influences like trucks, busses, pedestrians, traffic lights and so on to model an environment that allows to virtually recreate traffic effects like stop-and-go.

To test the traffic simulation in a location that is near to the task leader we chose Amberg as first supported traffic simulation.

4.4.1.2 Role of previous developed building blocks

This first routing algorithms of the OTH-AW were developed to find optimal EV routes in the 3Ccar *(www.3ccar.eu)* project and is the basis of the further development of routing models in the project 1000kmPLUS *(www.1000kmPLUS.eu).*

The 1000kmPLUS model for the calculation of the energy consumption and the additional requirement of low runtime for each road segment builds the basis for the low emission city routing in AI4CSM.

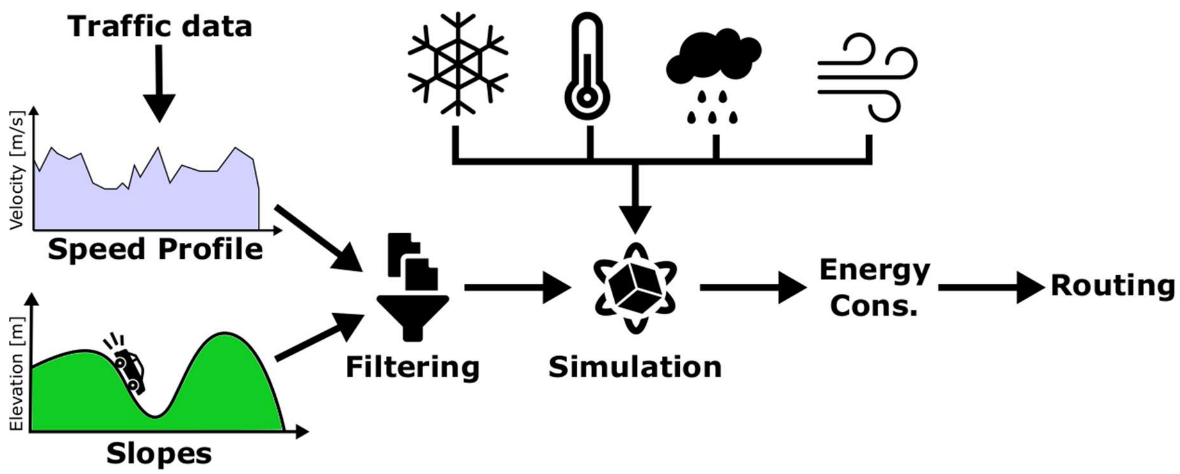

FIGURE 17: SIMULATION STRUCTURE

To achieve the goal of an accurate model, while meeting all requirements, the origin model was developed in the form of a vehicle simulation by the project partner AVL in the 1000kmPLUS project but needs adoptions for the new routing system. Figure 17 shows a structure of the simulation developed to gather road-specific information, the speed profile and the slopes derived of the route's elevation. These items are relevant for the simulation.

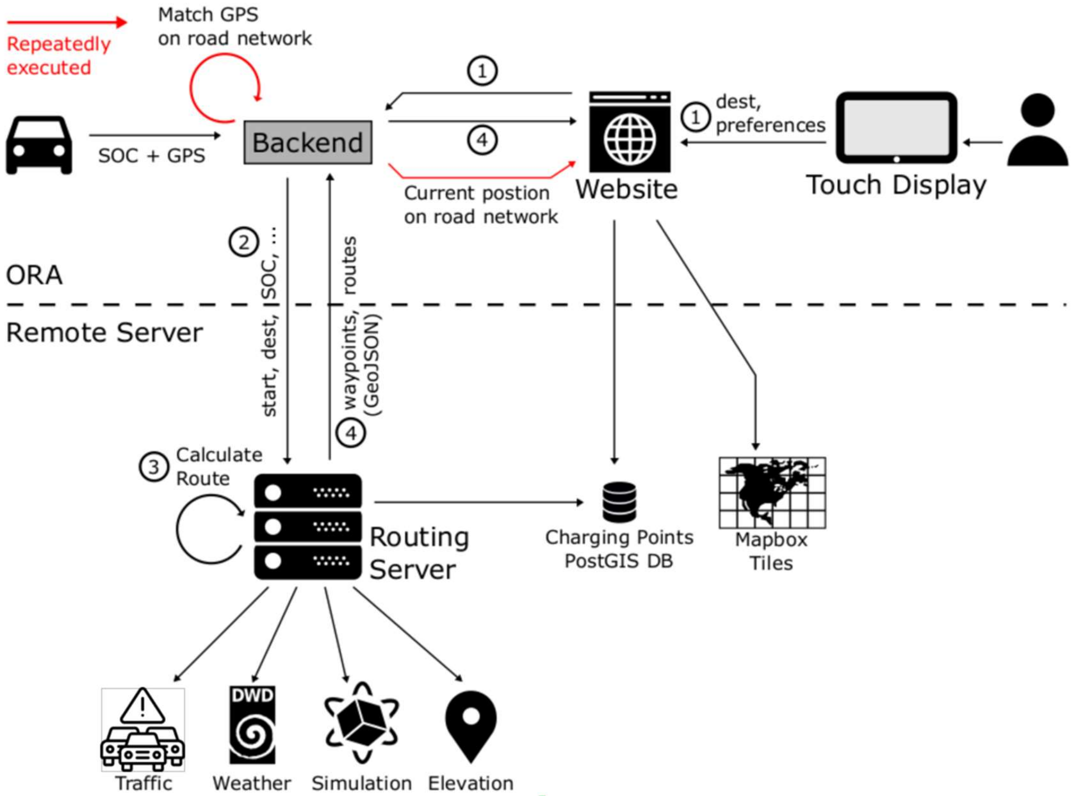

FIGURE 18: COMMUNICATION BETWEEN THE VEHICLE AND THE REMOTE SERVER

The routing algorithm to be developed should find optimal routes for EVs with (partial) en-route charging and the incorporation of non-linear charging curves. The term 'optimal' thereby refers to the overall travel-time of a vehicle along.

In Figure 18, we show the communication used in 1000kmPLUS between the vehicle, communication box and the remote routing server during navigation. A route request is initiated by the driver on the website through the touch display. The desired destination and routing preferences are then completed with the current position and the SOC (state of charge). The communication with the vehicle as well as the communication with the server is managed by a controller in the back-end of the website. This information flow will be adopted to enable an application in the Robo-taxi demonstrator SCD1.2 described in section 4.3.

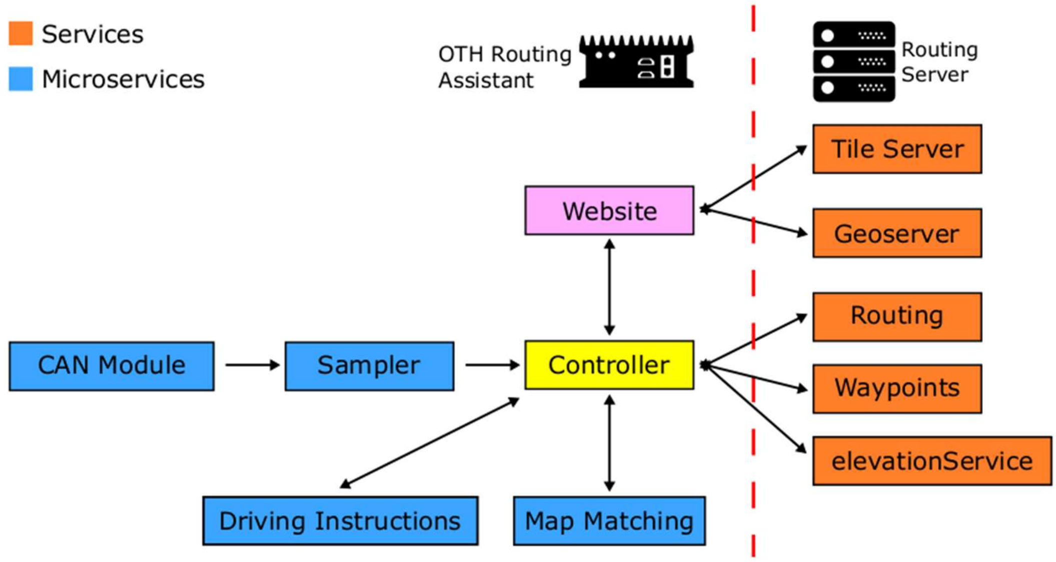

FIGURE 19: BACKEND ARCHITECTURE

In 1000kmPLUS the back-end on the routing system is structured into a micro service architecture, which is depicted in Figure 19. The services are managed by a central controller service. Route requests initiated through the website are forwarded by the controller to the remote server.

In AI4CSM the back-end architecture will need a structure fulfilling the requirements for routing vehicles through cities.

4.4.2 Validation concept

4.4.2.1 Scenario specification

The aim of this work is to implement a traffic routing system an autonomous cab service with electric vehicles will be realized. The main focus is to test routing algorithms for a fleet of electric vehicles. The system will be either implemented in the traffic network of the city of Amberg or in another suitable city.

We want to demonstrate that energy- and time-optimized routes can be found using newly developed algorithms. This includes the fact that the vehicles are autonomous electric vehicles, which means that aspects such as range and charging time have to be taken into account.

The Robo-taxi demonstrator (SCD1.2) will need special areas where they can stop safely. In order to support the application of the service, hence, so-called "pick-up stations" are therefore provided for the simulation. These pick-up stations can basically be thought of as a bus stop for autonomous vehicles, where people can get on and off. In this context, the pick-up stations will be evenly distributed throughout the urban area and the outlying towns, and will be located e.g. in the following areas, see Figure 20:

- residential area, contains residential buildings

- industrial area, contains industrial buildings and factories

- commercial area, contains retail buildings

- educational area, contains schools, colleges and universities

- public area, contains government buildings and churches

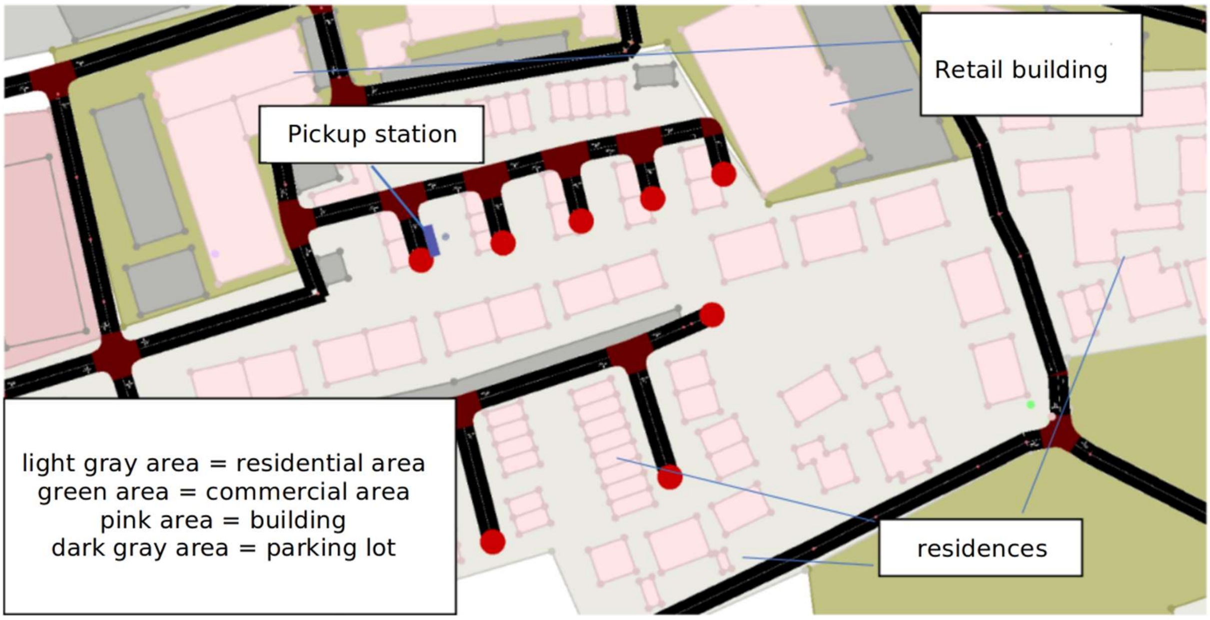

FIGURE 20: EXAMPLE OF ZONING AROUND A PICK-UP STATION

4.4.2.2 Evaluation metrics

The first goal is to reduce energy consumption. It is measured in kWh for a trip between two points. The baseline is the energy consumption for routes which are based on a speed-optimized routing engines that operates on Open Street Map Data (OSM), e.g., Valhalla.

For a fleet, the shared mobility latency time should be reduced, via an optimized policy. It is measured the mean seconds for a group of persons to reach their destination. The baseline is a policy that is based on the fastest route offered by an OSM based routing engine.

4.4.3 Demonstrator platform

4.4.3.1 Demonstrator specification

Simulation
This work aims to show how practicable a traffic simulation with the software "SUMO" can be implemented, where there are discrepancies to reality, and how the simulation can be extended to realize an autonomous cab service with electric vehicles. The main focus of the simulation is to test routing algorithms for a fleet of electric vehicles. In addition, the simulation will be implemented in the traffic network of the city of Amberg (see Figure 21) or in a suitable city e.g., Ingolstadt, as there are important city traffic data needed for the simulation already available. SUMO is the basic framework of this work. The software package offers numerous tools out of the box to start a traffic simulation without much effort. For example, map data can be read directly from "OpenStreetMap", road traffic can be generated entirely randomly or specifically, and there is the interface "TraCI", with which the simulation can be influenced in every step.

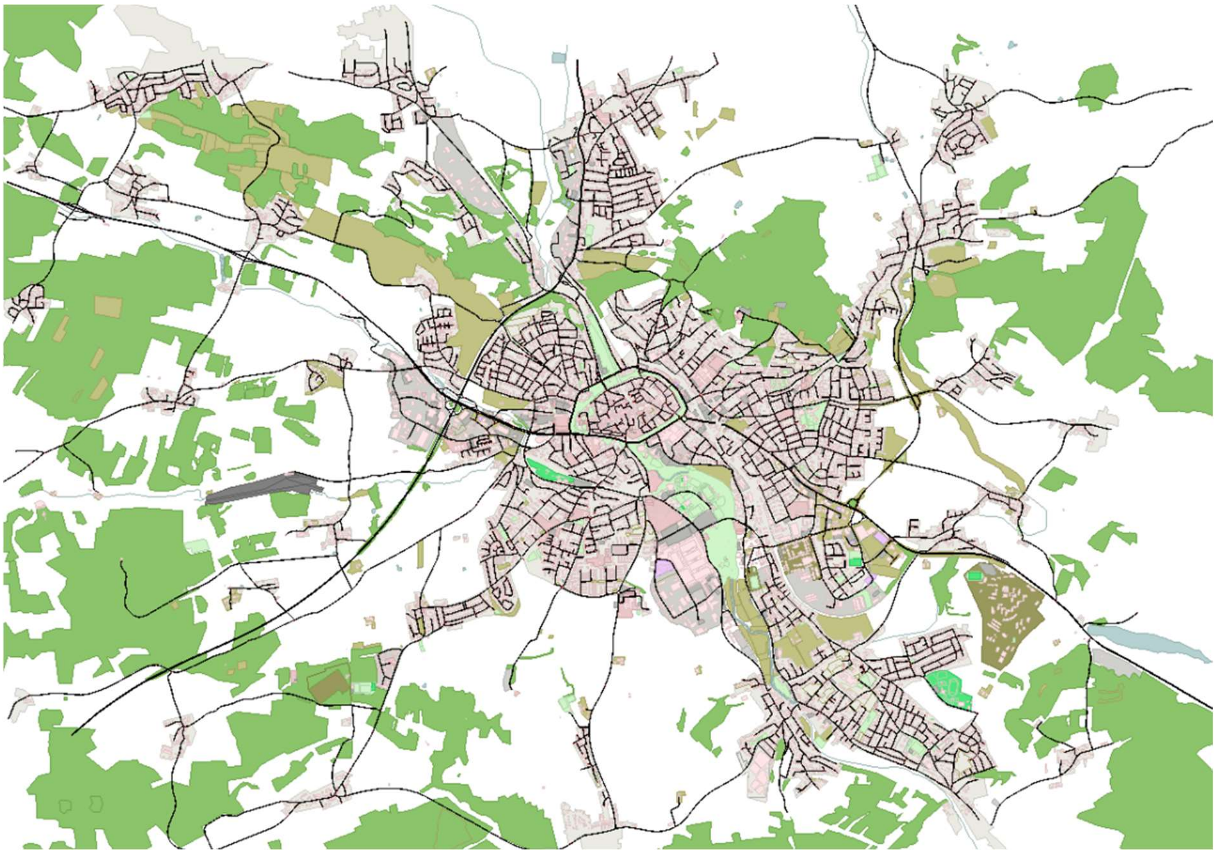

FIGURE 21: OVERVIEW OF THE ROAD NETWORK OF THE SIMULATION SHOWN IN SUMO

Edge Devices
Edge devices will be introduced to simulate an actual vehicle with a physical device. Signals that are easy to emulate like GPS will be provided by external circuits. More complicated signals like SoC will be simulated.

Demonstrator vehicle on a test route for the Robo-taxi
Goal is to develop algorithms for a route planner. The vehicles in this carpooling service are autonomous vehicles and get their schedules dynamically and continuously adjusted, depending on passenger volume and other parameters, such as passenger waiting time, origin and destination.

4.4.3.2 Test plan for evaluation

The demonstration of the routing service is split into three parts.

The **Simulation Demonstrator** (see Figure 22) is based on a simulation. The environment, which includes other vehicles, pedestrians, traffic influencing objects like signals, changing traffic volume, weather is simulated via the software Simulation of Urban Mobility (SUMO).

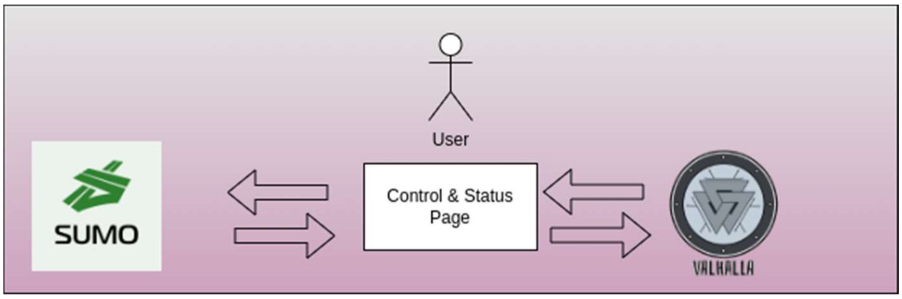

FIGURE 22: SIMULATION DEMONSTRATOR

The **Edge Device Demonstrator** (see Figure 23) is based on edge devices that can generate the live signals of a vehicle without the connection to the interfaces of an actual vehicle. The prototype can generate the required signals via additional circuits. E.g., an external GPS component. More complicated to simulate signals like SoC will be simulated.

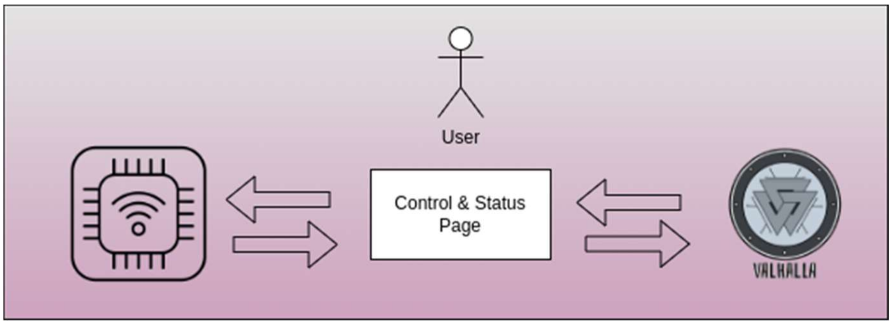

FIGURE 23: EDGE DEVICE DEMONSTRATOR

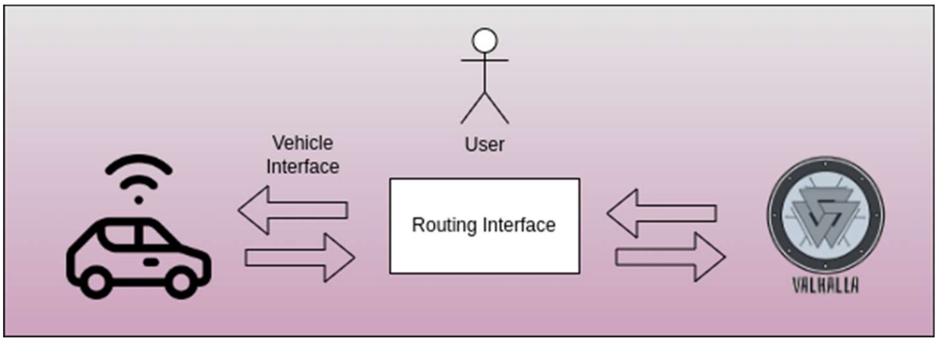

FIGURE 24: VEHICLE DEMONSTRATOR

The third Demonstrator (see Figure 24) is the **Robo-Taxi** build in SCD1.2. The vehicle will have an interface to the routing service that can read live signals and input a computed energy-efficient route in a suitable format, e.g., lanelet.

5 Conclusion

5.1 Contribution to overall picture

This deliverable provides requirements and specifications relevant for the design, integration, and verification of the targeted smart edge- and cloud-based building bricks for autonomous urban mobility interconnected with secure communication architectures and systems.

In summary, T1.1 partners delivered requirements for all specified demonstrators SCD 1.1, SCD 1.2 and SCD 1.3:

Demonstrator SCD 1.1 - Lessons-learned based (critical scenario) update of ADAS/AD controller

- 7 requirements for simulation platform,
- 3 requirements for demonstrator vehicle,
- 6 requirements for virtual testcase abstraction and model-based diagnosis.

Demonstrator SCD 1.2 - Robo-taxi

- 7 requirements from VIF for edge environment perception building bricks,
- 16 requirements from VIF for edge vehicle intelligence building bricks.
- 3 requirements from TTTAUTO with respect to the communication platform developed and evaluated within SC5
- 6 requirements from IFAG with respect to the ECS in the communication platform developed and evaluated within SC5
- 3 requirements from VGTU with respect to the development of a communication protocol

Demonstrator SCD 1.3 - Virtual city routing

- 5 requirements for energy simulation,
- 9 requirements for routing service,
- 3 requirements for traffic simulation.

All specified requirements are linked to function blocks within the demonstrators to be able to track them during the development process efficiently and to avoid misunderstandings which partner is the specific owner of the requirements. All partner contributions are linked to individual demonstrators in the urban area. The developed software building bricks are continuously evaluated with KPIs in the field of safety, efficiency, and compliance with the Green-Deal. All defined KPIs are evaluated against a specified baseline.

All specified requirements for the targeted SC1 edge-, cloud-, and communication building bricks are synchronized with the technology enabler supply chains SC4 to SC7, where the performance is evaluated on component and subsystem level before the integration on entire system level into the real-world demonstrators of SC1. In that manner the developed components and subsystems are transferred and integrated into a dedicated vehicle demonstrator owned by e.g., Virtual Vehicle.

To ensure consistent integration of SC4 to SC7 components, especially within the output enabler supply chain SC1, all interfaces to the other technology enabler SCs are clearly defined and synchronized during the requirements collection process.

5.2 Relation to the state-of-the-art and progress beyond it

Table 2 briefly lists the state of the art related to Task 1.1, and briefly clarify the achieved progress beyond it. The table is organized per topic (demonstrator).

TABLE 2: OVERVIEW STATE-OF-THE-ART AND PROGRESS BEYOND IT

Partner/Topic	Description
SCD 1.1	**State-of-the-art:** Test-track based validation of ADAS/AD functions. **Progress beyond:** Real-world validation of ADAS/AD functions in a safe manner through passive testing approach.
SCD 1.1	**State-of-the-art:** Brute force test track and road testing. **Progress beyond:** Reduction of road testing through the virtualization and criticality enhancement of collected real world data.
SCD 1.1	**State-of-the-art:** Classical v-model driven ADAS/AD development process. **Progress beyond:** Improvement of ADAS/AD functions by establishing a complete workflow from intelligent data collection to virtualization and diagnosis.
SCD 1.2	**State-of-the-art:** Classical occupancy grid filter (Prystine project). **Progress beyond:** Enrich classical occupancy grid filter with semantic information based on semantic Lidar point clouds.
SCD 1.2	**State-of-the-art:** Elevation-map based ground segmentation. **Progress beyond:** Structured end-to-end learning for ground segmentation.
SCD 1.2	**State-of-the-art:** Real-world validation of parts of the ADAS/AS software stack, e.g., sensing, perception, planning or control. **Progress beyond:** Real-world validation of a complete AD system (perception + motion planning and control).
SCD 1.3	**State-of-the-art:** Map-based routing of vehicles. **Progress beyond:** Digital City Twin for routing of autonomous vehicles.
SCD 1.3	**State-of-the-art:** Time- and distance-optimal routes without a dedicated energy consumption evaluation. **Progress beyond:** Validation of energy optimized routing algorithms.
SCD 1.3	**State-of-the-art:** Time optimal routes through cities based on current traffic situation. **Progress beyond:** Smart city routes decreasing the shared mobility latency in connection with a traffic throughput increase based on geofencing and smart charging in urban areas with a limited number of chargers.

5.3 Impacts to other WPs, Tasks and SCs

Table 3 briefly lists in which WP's, tasks, and SC's the outcome of task 1.1 will be used later in the project. The table is organized per partner or per topic.

TABLE 3: OVERVIEW OF WP, TASK AND SC INTERCONNECTIONS

Partner/Topic	Description
VIF	The results of WP1 task T1.1 are feeding directly into WP2 and WP4 and integrated and verified by WP5 and WP6, respectively. Task 2.1 (WP2, SC1) focuses on the development of simulation architectures to virtually assess the performance of

	the developed software solutions based on the requirements of task 1.1. Task 4.1 (WP4, SC1) concentrates on software development by itself in line with the specified requirements of Task 1.1. Task 5.1 (WP5, SC1) deals with the integration of the SC1 software blocks into the demonstrators to be verified within Task 6.1 (WP6, SC1).
AIT	The results of WP1 Task 1.1 build the basis for the upcoming tasks within WP2 dealing with the system level design and WP4 responsible for the implementation of the proposed computing algorithms. The results are later integrated and verified within WP5 Task 5.1 and are verified within WP6 Task 6.1.
AVL	The results of WP1 Task 1.1 build the basis for the upcoming tasks within WP2 dealing with the system level design and WP4 responsible for the implementation of the proposed computing algorithms. The results are later integrated and verified within WP5 Task 5.1 and are verified within WP6 Task 6.1.
OTH	The results of WP1 Task 1.1 build the basis for the upcoming tasks within WP2 dealing with the system level design and WP4 responsible for the implementation of the proposed computing algorithms. The results are later integrated and verified within WP5 Task 5.1 and are verified within WP6 Task 6.1.
TUGRAZ	The results of WP1 Task 1.1 build the basis for the upcoming tasks within WP2 dealing with the system level design and WP4 responsible for the implementation of the proposed computing algorithms. The results are later integrated and verified within WP5 Task 5.1 and are verified within WP6 Task 6.1.
TTTAUTO	While the actual development of the communication platform is part of SC5, its application will be showcased in the SCD1.2 demonstrator. The results of WP1 Task 1.1 build the basis for the upcoming tasks within WP2 dealing with the system level design and WP4 responsible for the implementation of the proposed computing algorithms. The results are later integrated and verified within WP5 Task 5.1 and are verified within WP6 Task 6.1.
IFAG	IFAG will develop electric components for the communication platform developed within SC5. Within Task 1.1 they specified cross supply chain requirements. The components will be integrated in WP 5 Task 5.1.
VGTU	Participation of VGTU in WP2, WP4-WP6 covers car2car and car2infrastructure connections. Participation in the Tasks 2.1 4.1 5.1 6.1 intended to analyze existing solutions, define requirements, generate new solutions, based on existing experience, build simulations, develop operational algorithms and experimentally test selected simulation results.
Requirements, scenarios, KPIs, demonstrators and evaluation plans.	Links to the other technology enabler SCs (SC4 to SC7) are established to ensure consistent interfaces that are of particular interest during the integration of the developed components and subsystems into SC1 demonstrators, which focus on the joint integration of the advanced technologies of SC4 to SC7.

5.4 Contribution to demonstration

Table 4 briefly describes the relation between task 1.1 and the planned demonstrators. The table is organized per partner.

TABLE 4: OVERVIEW OF CONTRIBUTIONS TO DEMONSTRATORS

Partner/Topic	Description
VIF	The requirements of the edge perception and vehicle intelligence building bricks represent the foundation to build the specified Robo-taxi demonstrator SCD 1.2. The requirements and KPIs specified serve as a basis to validate the targeted demonstrator SCD 1.2 consistently. In addition, Task 1.1 defines a detailed testing and validation plan of the demonstrator SCD 1.2.
AIT	AIT will contribute to SCD1.1. with testcase generation using probabilistic programming language Scenic and will work towards defining innovative sampling strategies to achieve coverage guarantees w.r.t. critical parameters.
AVL	The requirements and KPIs generated within Task 1.1 serve as basis to validate the passive testing methodology, the intelligent data collection and virtualization of collected data within the SCD1.1 demonstrator. Furthermore, a testing and validation plan for the demonstrator SCD1.1 is outlined.
OTH	The requirements provide the basis for the next development steps of the demonstrator. The building blocks provide a framework and requirements and KPIs are the basis for validation of the demonstrator. The test plan lays out the planned steps towards the final demonstrator.
TUGRAZ	Within Task 1. 1 TUGRAZ works on requirements for utilizing the concept of Digital Twins for sensor fusion, diagnosis, and control. Many of these requirements serve as basis for the model-based diagnosis framework planned in SCD1.1.
TTTAUTO	TTTAUTO will develop a platform for bidirectional edge-cloud communication (developed within SC5), which will be showcased in the Robo-taxi demonstrator SCD1.2
IFAG	IFAG will develop electric components (chips and boards) for the communication platform which is showcased within SCD1.2
VGTU	VGTU will provide requirements and possible data for Robo-taxi demonstrator SCD 1.2. in the terms of data flow, reaction of infrastructure and provide required Robo-taxi behavior to environment.

5.5 Other conclusions and lessons learned

Table 5 briefly describes other conclusions and learnings derived during the execution of Task 1.1 described in this deliverable.

TABLE 5: CONCLUSIONS AND LESSONS LEARNED

Partner/Topic	Description
Consistent interfaces	An essential aspect of ensuring consistent interfaces between the technology enabler and output enabler SCs is the fact that all key partners are represented in the requirements specification process in WP1 and task 1.1 respectively. Represented means that they take part in all related tasks even if their entire project contribution focuses on a specific SC.

6 References

[1] Y. Cai, H. Huang, K. Wang, C. Zhang, L. Fan, and F. Guo, “Selecting optimal combination of data channels for semantic segmentation in city information modelling (CIM),” Remote Sens., vol. 13, no. 7, 2021.

[2] P. Weissensteiner, G. Stettinger, J. Rumetshofer, and D. Watzenig, “Virtual Validation of an Automated Lane-Keeping System with an Extended Operational Design Domain,” Electronics, vol. 11, no. 1, p. 72, Dec. 2021.

7 Appendices

The Appendix contains the consolidated requirements and the demonstrator descriptions. Content is publishable.

1. Demonstrator descriptions:
    a) AI4CSM SC1_1 Demonstrator
    b) AI4CSM SC1_2 Demonstrator
    c) AI4CSM SC1_3 Demonstrator
2. Key building block requirements:
    a) AI4CSM SC1 Requirements

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Appendix 1a – AI4CSM SC1.1 Demonstrator

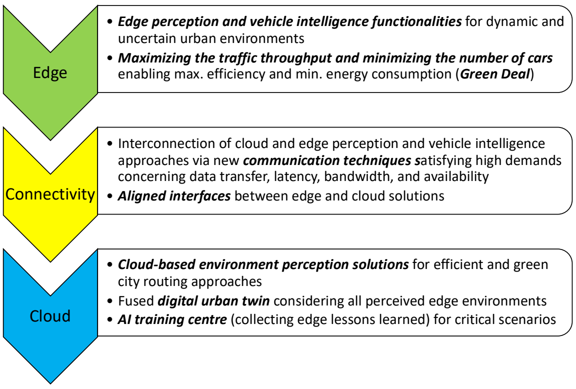
Demonstrator SCD 1.1: Lessons-learned based (critical scenario) update of ADAS/AD Controller

Description

Short general description (main target of the demonstrator)

- Detection of valuable situations for the verification and validation of new driving functions.
- Valuable situations are recorded, sent to a datacenter and in a post-processing step converted into virtual driving scenarios.
- AI training center for safety-critical scenarios is used to further enhance the ADAS/AD function under test.

Link to SC1 objectives:



- Edge – 1st objective
- Connectivity – 1st and 2nd objective
- Cloud - 2nd objective

Beyond state of the art:

- Real-world validation of ADAS/AD functions in a safe manner through passive testing approach.
- Reduction of road testing through the virtualization and criticality enhancement of collected real world data.
- Improvement of ADAS/AD functions by establishing a complete workflow from

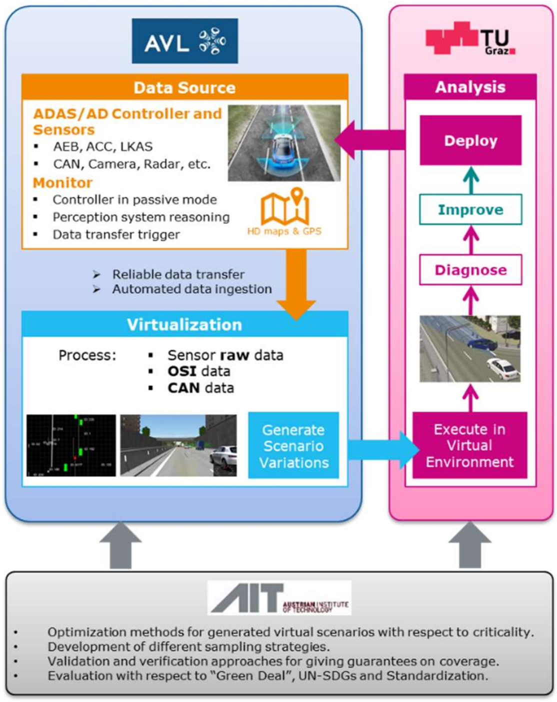
Link to entire project objectives

x	**O1** – Develop robust and reliable mobile platforms
x	**O2** – Develop scalable embedded intelligence for edge and edge/cloud operation
	O3 – Design silicon for deterministic low latency and build AI-accelerators for decision and learning
	O4 – Solve complexity be trustable AI, in functional integrated systems
	O5 – Design functional integrated systems
	O6 – Build ECAS vehicles for Green Deal for future connected shared mobility

Start TRL	2	**End TRL**	4-5

Block Diagram (Partner roles)

intelligent data collection to virtualization and diagnosis.	
Lead	
AVL	
Partners	
TUG, AIT	



Scenario description
The demonstrator vehicle is driven by a human in an urban area or highway. During the operation of the car, an ADAS/AD function, i.e., AEB, ACC, LKAS, is running in real time in a passive mode. That means that the output of the function is not passed to the actuators. While driving, the output of the function is compared to the human driver with the focus of detecting deviations. Once a deviation is observed, the situation is recorded and transferred to a data center. In a post-processing step the situation will be converted into a virtual driving scenario that can be executed in a co-simulation environment and which will enable the possibility to perform diagnosis and further enhance the ADAS/AD function under test by increasing the criticality of the virtual driving scenario.

Evaluation KPIs	**Baseline**
3 main categories: **<u>Data Source:</u>** • Deviations between human driver and ADAS/AD function are detected. • Reliable data transfer. • Automated data transfer.	With respect to a specified baseline (SoTA link!) **<u>Data Source:</u>** • Data storage needed for collecting all driving data. **<u>AI Training Center:</u>**

• Reduced data transfer and storage. **Virtualization:** • Virtual scenario is equal to the real-world scenarios in terms of traffic participants, road structure and driving area (highway, urban area). • Open-source formats are used for virtualization. **AI Training Center:** • 10 critical scenarios generated.	• Comparison to random testing – time to find a misbehavior.

Demonstrator platform
Demonstrator category (Simulation, Driving Simulator, HiL simulation, demonstrator vehicle including targeted test track/public road etc.) **Demonstration Y1:** Simulation (virtual approval) – virtual approval of the passive testing approach as well as the virtualization of already available real-world data in separate simulation environments. **Demonstration Y2:** Simulation (virtual approval) – virtual approval of the overall demonstrator in co-simulation. **Demonstration Y3:** Demonstrator vehicle on test track, in urban area and on highway.

DEMONSTRATOR VEHICLE

Appendix 1b – AI4CSM SC1.2 Demonstrator

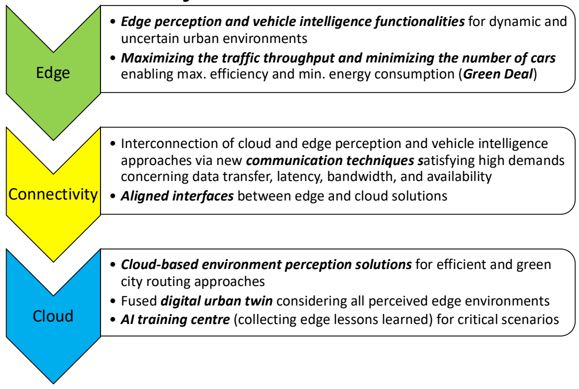
Demonstrator SCD 1.2: Robo-taxi

Description

Short general description (main target of the demonstrator)

- Demonstration of edge environment perception and vehicle intelligence algorithms for a Robo-taxi use case
- Definition of challenging and representative Robo-taxi scenarios and corresponding KPIs for evaluation
- Proof-of-concept for bidirectional communication approaches to the cloud

Link to SC1 objectives:



- Edge – 1st objective
- Connectivity – 1st and 2nd objectives
- Cloud – 2nd objective

Beyond state of the art:

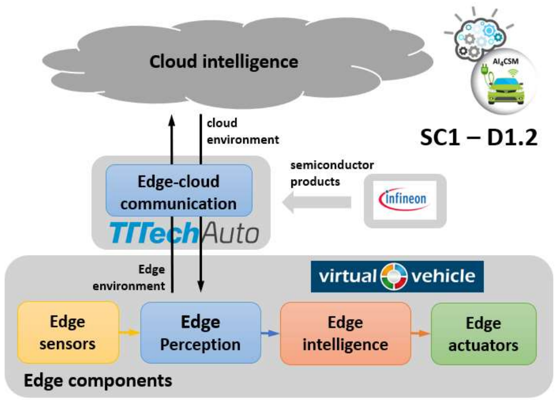
- Real-world validation of a complete AD system (perception + motion planning and control) for a Robo-taxi use case
- Structured end-to-end learning for ground segmentation
- Semantic occupancy grid based on Lidar data

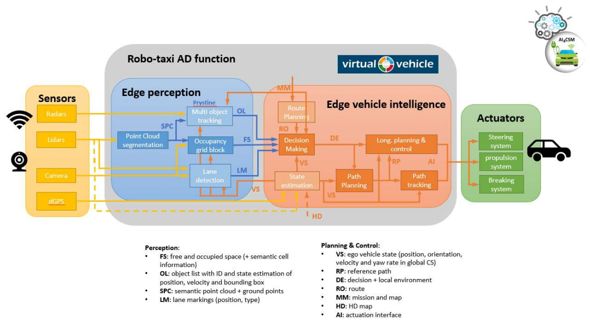
Lead
VIF
Partners
TTTAUTO, IFAG

Link to entire project objectives

X	**O1** – Develop robust and reliable mobile platforms
X	**O2** – Develop scalable embedded intelligence for edge and edge/cloud operation
	O3 – Design silicon for deterministic low latency and build AI-accelerators for decision and learning
	O4 – Solve complexity be trustable AI, in functional integrated systems
	O5 – Design functional integrated systems
X	**O6** – Build ECAS vehicles for Green Deal for future connected shared mobility

Start TRL	3	End TRL	5



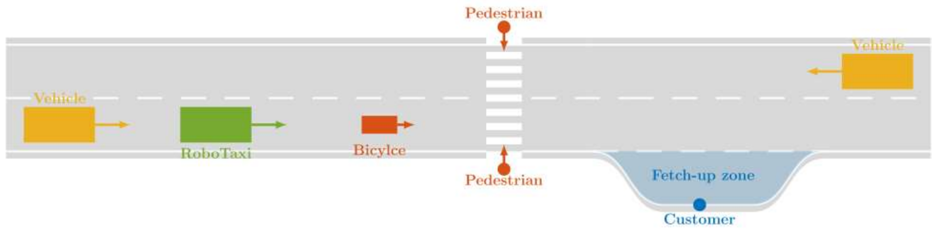


Scenario description

The target ODD of the Robo-taxi is an urban environment with mixed traffic (vehicles, bicycles, pedestrians). Its mission is to fetch-up customers on request at pre-defined fetch-up zones and to take them to their target destinations. In order to demonstrate an automated driving function design for such a task three explicit, characteristic scenarios, which cover many challenging aspects:

- **Scenario A – Overtaking:** The Robo-taxi is following a slower traffic participant and has to realize a safe and admissible overtaking maneuver, with oncoming traffic.
- **Scenario B – Crosswalk:** The Robo-taxi is approaching a crosswalk. If a pedestrian attempts to cross the road at the crosswalk, the Robo-taxi has to stop and continue the drive as the crosswalk is free again.
- **Scenario C – Customer fetch-up:** A fetch-up requested while the Robo-taxi is approaching the defined fetch-up zone. If it is possible to safely enter the zone, the Robo-taxi has to leave the road stop inside the zone. After the customer boarding the Robo-taxi has to merge back into the traffic in order to pursue the drive towards the customers target destination.

The following figure illustrates the scenarios A-C in a sequential manner.



Evaluation KPIs	Baseline
The Robo-taxi KPI for evaluating the functionality are separated into the categories edge perception and vehicle intelligence: **Edge perception:** • Perception accuracy of 80%: ground segmentation and occupancy grid • Mean Intersection over Union (mIoU): semantic point cloud and semantic occupancy grid • Additionally, the following related KPIs will be evaluated: Precision, Recall, 1-score **Edge vehicle intelligence:** • Safety (minimum safety margin and minimum safety gap) • Compliance to all relevant traffic rules • Trustworthiness/acceptance (launch time, overtaking behavior) • Performance (tracking accuracy) and comfort (launch time, planned path curvature)	**Edge Perception:** • Perception accuracy 65-75% (PRYSTINE results) • Mean intersection over Union: 30% (SotA) **Edge vehicle intelligence:** • Predefined "regular, human" behavior (safety margins, safety gaps, launch times, traffic rules, …) for scenarios • Common SotA path tracking controllers

Demonstrator platform

Demonstrator category (Simulation, Driving Simulator, HiL simulation, demonstrator vehicle including targeted test track/public road etc.)

Demonstration Y1: Simulation (virtual approval) - virtual approval of Perception and Planning & Control components in separated simulation environments.

Demonstration Y2: Simulation (virtual approval) - virtual approval of the overall system Robo-taxi AD function in the defined scenarios.

Demonstration Y3: Demonstrator vehicle on test track (e.g., Graz/Lebring or Graz/TU-Campus) - real-world approval in mixed-reality Robo-taxi use case in at least one dedicated scenario.

ROBO-TAXI DEMONSTRATOR VEHICLE & TEST TRACK

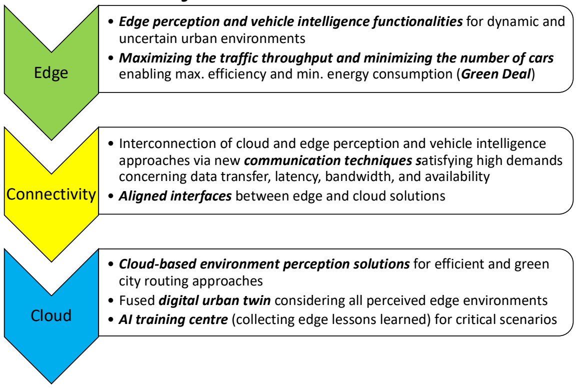
Appendix 1c – AI4CSM SC1.3 Demonstrator

Demonstrator SCD 1.3: Virtual city routing

Description

The demonstrator shows that energy and time efficient routes can be found in the urban area of Amberg can be found using the OTH-AW routing cloud service

Link to SC1 objectives:



- Edge
- Connectivity
- Cloud

Beyond state of the art:

- Digital Twin for routing of autonomous vehicles
- Validation of energy optimized routing algorithms
- Decrease the shared mobility latency
- Increase the traffic throughput
- Geofencing
- Smart charging in urban areas with a limited number of chargers

Lead

OTH-AW

Partners

Contributing partner

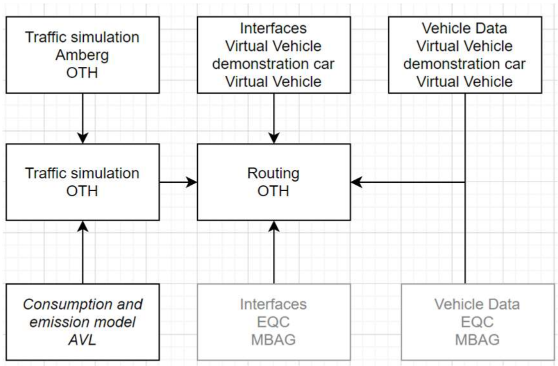
- AVL
- Virtual Vehicle
- MBAG (from SC2)

Link to entire project objectives

	O1 – Develop robust and reliable mobile platforms
x	**O2** – Develop scalable embedded intelligence for edge and edge/cloud operation
	O3 – Design silicon for deterministic low latency and build AI-accelerators for decision and learning
	O4 – Solve complexity be trustable AI, in functional integrated systems
	O5 – Design functional integrated systems
x	**O6** – Build ECAS vehicles for Green Deal for future connected shared mobility

Start TRL	2-3	**End TRL**	4-5

Block Diagram (Partner roles)



Scenario description

It will be demonstrated that energy and time-optimized routes can be found for urban areas using the newly created routing service. In detail, the key objective of the city routing demonstrator is to optimize energy efficiency - which will lead to reduced CO2 emissions if the energy mix is not completely renewable - and decrease the shared mobility latency time and to increase the traffic

throughput. Generated traffic data of the digital city twin will be loaded in the routing service, which will generate fitting routes for a fleet of vehicles. Taking into account geofencing and smart charging, suitable routes needs to be generated and provided for each connected and simulated vehicle. In order to demonstrate this, edge devices will represent vehicles that communicate via the internet with a server that processes the traffic situation and creates the routes. Three kinds of cars will be supported – the virtual vehicle demonstration car (electric drive mode), the Mercedes EQC and a third type of cars that are represented by edge devices and/or simulations are guided through the downtown of Amberg. Several scenarios with different kinds of traffic density are tested	
Evaluation KPIs	**Baseline**
Optimize energy efficiency Decreased shared mobility latency time by 20%; traffic throughput increased by 20%	Simulation scenario without intelligent routing

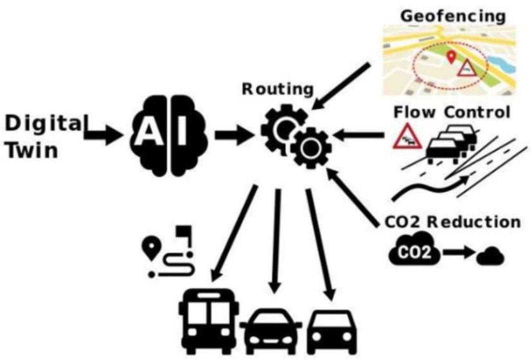
Demonstrator platform

Demonstrator category (Simulation, Driving Simulator, HiL simulation, demonstrator vehicle including targeted test track/public road etc.)

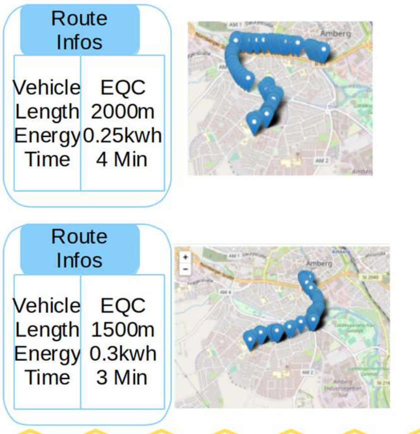
Demonstration Y1: Simulation (virtual approval)

Demonstration Y2: Edge Devices (virtual approval)

Demonstration Y3: Demonstrator vehicle on a test route for the Robo-taxi/EQC use case (Amberg)



CONCEPT OF THE DEMONSTRATOR

Routes city		**with a different optimization target: Energy/Time through the inner**
		**Virtual Vehicle Demonstrator vehicle**

Appendix 1a – AI4CSM SC1 Requirements

***ID* : AI4CSM_WP1_SCD1.1_1**

Name : ADAS/AD function availability - Simulation

Description : An ADAS/AD function (i.e., AEB, ACC, ALKS) is available either as blackbox or white box.

Rationale : Necessary to perform deviation detection (passive testing).

Metrics : yes/no

Owner : AVL

Reference UC : SCD1.1

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.1_2**

Name : ADAS/AD function availability - Demonstrator Vehicle

Description : An respective ADAS/AD function (i.e., AEB, ACC, ALKS) which is similar than the functions used in simulation is also available within the demonstrator vehicle.

Rationale : Necessary to transfer the deviation detection methods (passive testing) used in simulation to the demonstrator vehicle.

Metrics : yes/no

Owner : AVL

Reference UC : SCD1.1

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.1_3**

Name : ADAS function integrateability - Simulation

Description : The ADAS/AD function (i.e., AEB, ACC, ALKS) under test can be integrated into the simulation environment.

Rationale : Necessary to set up the passive testing approach within simulation.

Metrics : yes/no

Owner : AVL

Reference UC : SCD1.1

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.1_4**

Name : Signal availability - Simulation

Description : Ego vehicle related signals as well as the ADAS/AD function related signals can be accessed during simulation.

Rationale : Necessary to compare the human driver behaviour to the ADAS/AD function behavior within the simulation environment.

Metrics : yes/no

Owner : AVL

Reference UC : SCD1.1

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.1_5**

Name : Signal availability - Demonstrator Vehicle

Description : Demonstrator vehicle signals and ADAS/AD function related signals available in the vehicle can be accessed during driving.

Rationale : Necessary to compare the human driver behaviour to the ADAS/AD function behavior during driving.

Metrics : yes/no

Owner : AVL

Reference UC : SCD1.1

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.1_6**

Name : Deviation Detection (Passive Testing) - Simulation

Description : The developed method for passive testing is able to detect deviations between a human driver and an ADAS/AD function within the simulation environment based on the monitored signals.

Rationale : Necessary to identify critical scenarios and initiate data collection process within simulation.

Metrics : yes/no

Owner : AVL

Reference UC : SCD1.1

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.1_7**

Name : Deviation Detection (Passive Testing) - Demonstrator Vehicle

Description : The developed method for passive testing is able to detect deviations between a human driver and an ADAS/AD function in real-time during driving within the demonstrator vehicle based on the monitored signals.

Rationale : Necessary to identify critical scenarios and initiate data collection process during driving.

Metrics : yes/no

Owner : AVL

Reference UC : SCD1.1

Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.1_8**
Name : Data Collection Buffering
Description : A data buffer is implemented within the simulation environment and the demonstrator vehicle.
Rationale : Necessary to collect the complete critical scenario as soon as a deviation is detected by passive testing.
Metrics : yes/no
Owner : AVL
Reference UC : SCD1.1
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.1_9**
Name : Virtualized Critical Scenarios Format
Description : The collected data needs to be converted into an open source format (e.g., OSI, OpenScenario, OpenDrive) to be further processed within the simulation environment.
Rationale : Necessary to be able to perform criticality enhancements within the simulation environment.
Metrics : yes/no
Owner : AVL
Reference UC : SCD1.1
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.1_10**
Name : Virtual Testcase abstraction level
Description : The semantics of a virtual testcase needs to be translateable to an abstract scenario in Scenic
Rationale : Necessary to be able to perform testcase generation
Metrics : yes/no
Owner : AIT
Reference UC : SCD1.1
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.1_11**
Name : Identification of critical virtual testcase parameters

Description : We need to identify which are the measurable critical parameters of a virtual testcase, so that we know how to optimize for coverage guarantees based on criticality.

Rationale : Necessary for coverage guarantees

Metrics : yes/no

Owner : AIT

Reference UC : SCD1.1

Dependencies : none

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.1_12

Name : SCD1.1 Partners (AVL-AIT-TUG) Blocks Interoperability

Description : The partners agree on a common data format in order to sustain full interoperabiliy of the key building blocks (see Fig.5 , D1.1).

Rationale : Necessary to avoid additional mapping/addaption steps in the work flow.

Metrics : yes/no

Owner : TUG

Reference UC : SCD1.1

Dependencies : none

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.1_13

Name : Availability of expected values for all the parameters

Description : Concrete expected values for all the parameters of the virtual testcases should be available (expected values vs. observed values).

Rationale : Neccesary for the diagnosis process.

Metrics : yes/no

Owner : TUG

Reference UC : SCD1.1

Dependencies : none

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.1_14

Name : Model-based Diagnosis Completeness

Description : Given a formal model of a virtual scenario, the diagnosis algorithm has to be able to compute at least all minimal diagnoses up to some desired cardinality.

Rationale : Necessary to validate the virtual scenarios.

Metrics : 100% diagnosis completeness

Owner : TUG

Reference UC : SCD1.1

Dependencies : none

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.1_15
Name : Model-based Diagnosis Correctness
Description : Given a formal model of a virtual scenario. All diagnoses computed by the diagnosis algorihm are correct w.r.t. the given model.
Rationale : Necessary to validate the virtual scenarios.
Metrics : 100% diagnosis correctness
Owner : TUG
Reference UC : SCD1.1
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.1_16
Name : Model-based Diagnosis Performance
Description : Diagnosis algorithm shall be fast enough for the given application scenario.
Rationale : Necessary to validate the virtual scenarios.
Metrics : yes/no
Owner : TUG
Reference UC : SCD1.1
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_1
Name : AD function - minimum safety margin
Description : The vehicle must obey a minimum safety margin to the observed bounding boxes of all obstacles
Rationale : Ensure save operation.
Metrics : 0.2 meter
Owner : VIF
Reference UC : SCD1.2
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_2
Name : AD function - traffic rules
Description : The vehicle must obey all traffic rules, which are relevant in the present traffic situation (speed limits, right of way, lateral distance while overtaking) at any time.
Rationale : Ensure compliance with traffic rules
Metrics : yes/no
Owner : VIF

Reference UC : SCD1.2
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_3
Name : Decision making - IO interface
Description : Based on a complete environment perception (all relevant obstacles) the decision making module has to provide abstract longitudinal and road-based lateral decisions (incl. decision parameters, e.g. maneuver distance) in order to enable the system to handl
Rationale : This output data is defined by the proposed software architecture.
Metrics : yes/no
Owner : ViF
Reference UC : SCD1.2
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_4
Name : Decision making - overtaking feature
Description : The decision making module has to provide respective decision to enable safe overtaking of slower traffic participants, if possible.
Rationale : This feature is necessary to handle the defined scenarios.
Metrics : yes/no
Owner : VIF
Reference UC : SCD1.2
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_5
Name : Decision making - customer fetch-up feature
Description : The decision making module has to provide respective decision to enable the fetch-up of a customer from a defined fetch-up zone and to merge back into the traffic.
Rationale : This feature is necessary to handle to defined scenarios (customer fetch-up).
Metrics : yes/no
Owner : VIF
Reference UC : SCD1.2
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_6
Name : Path planning - IO interface

Description : The path planning module has to provide a continuous reference path representation, with respect to the maneuver (abstract decision) intended by the decision making module.

Rationale : The data formats are defined by the proposed software architecture.

Metrics : yes/no

Owner : VIF

Reference UC : SCD1.2

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.2_7**

Name : Path planning - minimum look-ahead time

Description : The path planning module has to compute a reference path of minimum length defined by a minimum look-ahead time.

Rationale : Necessary to enable a safe operation of the path tracking module

Metrics : > 4 sec

Owner : VIF

Reference UC : SCD1.2

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.2_8**

Name : Path planning - maximum curvature

Description : The path planning module has to provide reference paths (e.g. for smooth lane change or transition to a requested offset distance to the lane centerline), with a limited curvature.

Rationale : The limited curvature is necessary in order to provide a drivable path to finally increase operation safety

Metrics : < 0.2 1/meter

Owner : VIF

Reference UC : SCD1.2

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.2_9**

Name : Path planning – minimum safety margin

Description : The planned path must have a safety distance to lane borders and all static, detected obstacles, in the absence of a on-going lateral maneuver (e.g. overtakin).

Rationale : Enable a safe operation despite a maximum maximum tracking error nd the general minimum safety margin

Metrics : > 0.6 m

Owner : VIF

Reference UC : SCD1.2

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.2_10**

Name : Path tracking - IO interface

Description : The path tracking module has to translate a requested reference path into appropriate steering commands.

Rationale : The data formats are necessary to realize the intended lateral vehicle motion, according to the steering system and the proposed software architecture.

Metrics : yes/no

Owner : VIF

Reference UC : SCD1.2

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.2_11**

Name : Path tracking - accuracy

Description : The path tracking module has to achieve a maximum tracking error between the observed vehicle position and the reference path.

Rationale : Necessary for a safe lateral operation.

Metrics : < 0.4 meter

Owner : VIF

Reference UC : SCD1.2

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.2_12**

Name : Path tracking – steering comfort

Description : The path tracking module has to provide steering command that does not deviate more than a given limit from the nominal steering angles according to the reference curvature, in regular (non-emergency) operation.

Rationale : Ensure comfortable steering, by reducing unnecessary steering effort.

Metrics : < 0.3 rad

Owner : VIF

Reference UC : SCD1.2

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.2_13**

Name : Longitudinal motion - IO interfaces

Description : The long. motion module has to translate long. decision (required speed, stop or launch) into pedal (break and accelerator) positions. *Rationale* : The data formats data are necessary to realize the intended long. vehicle motion according to the made long. decisions and the long. actuation system. *Metrics* : yes/no *Owner* : VIF *Reference UC* : SCD1.2 *Dependencies* : none *Conflicts* : none

***ID* : AI4CSM_WP1_SCD1.2_14**
Name : Longitudinal motion - stopping accuracy *Description* : The long. motion module has to accomplish a full stop with a maximum long. displacement error *Rationale* : Necessary to ensure safe long. operation. *Metrics* : < 1 meter *Owner* : VIF *Reference UC* : SCD1.2 *Dependencies* : none *Conflicts* : none

***ID* : AI4CSM_WP1_SCD1.2_15**
Name : Longitudinal motion - launch time *Description* : The long. motion module has to perform a vehicle launch (0-30km/h) in an reasonable time. *Rationale* : Necessary to increase acceptance and trustworthyness of the system. *Metrics* : 3 - 6 sec *Owner* : VIF *Reference UC* : SCD1.2 *Dependencies* : none *Conflicts* : none

***ID* : AI4CSM_WP1_SCD1.2_16**
Name : Longitudinal motion - safety time *Description* : The long. motion module has to ensure a safety time range in regular driving conditions w.r.t. a vehicle ahead in the same lane. *Rationale* : Necessary to ensure safe long. operation. *Metrics* : 2-3 sec *Owner* : VIF *Reference UC* : SCD1.2 *Dependencies* : none

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_17
Name : Occupancy grid - output interface
Description : The occupancy grid module outputs, a grid, where each cell contains the information if it is occupied or free and a semantic label, based on a list of ground points and a semantic point cloud.
Rationale : Necessary according to the proposed perception system and software architecture.
Metrics : yes/no
Owner : VIF
Reference UC : SCD1.2
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_18
Name : Ground Segmentation– output interface
Description : The point cloud segmentation module outputs a list of ground points based on Lidar data.
Rationale : Necessary according to the proposed perception system and software architecture.
Metrics : yes/no
Owner : VIF
Reference UC : SCD1.2
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_19
Name : Point cloud segmentation – output interface
Description : The point cloud segmentation module outputs a semantic point cloud based on Lidar and Camera data.
Rationale : Necessary according to the proposed perception system and software architecture.
Metrics : yes/no
Owner : VIF
Reference UC : SCD1.2
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_20
Name : Occupancy grid - accuracy
Description : The occupancy grid module has to provide cell information with a minimum accuracy.
Rationale : Necessary for reliable environment perception and hence safe decision making and vehicle motion.

Metrics : > 80 %
Owner : VIF
Reference UC : SCD1.2
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.2_21**
Name : Ground segmentation - accuracy
Description : The ground segmentation module has to detect the ground points with a minimum accuracy.
Rationale : Necessary for a reliable environment model using an occupancy grid.
Metrics : > 80 %
Owner : VIF
Reference UC : SCD1.2
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.2_22**
Name : Semantic point cloud - Mean Intersection over Union
Description : The semantic point cloud module has to achieve a minimum "mean Intersection over Union (mIoU)" value.
Rationale : Necessary for reliable environment perception.
Metrics : > 30 %
Owner : VIF
Reference UC : SCD1.2
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.2_23**
Name : Semantic occupancy grid - Mean Intersection over Union
Description : The semantic occupancy grid module has to achieve a minimum "mean Intersection over Union (mIoU)" value.
Rationale : Necessary for reliable environment perception.
Metrics : > 30 %
Owner : VIF
Reference UC : SCD1.2
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.2_24**

Name : Availability of Standard Platform on Edge Locations

Description : The chosen edge location needs to support the developed tools and allow the methods to implement the relevant provisioning. Verify that the node allows a Kubernetes-like cluster to be deployed (static analysis of the platform).

Rationale : The state-of-the-art industry standard will be used for development of the optimized provisioning and task-distribution (Managed Kubernetes by cloud providers is acceptable)

Metrics : yes/no

Owner : TTTAUTO

Reference UC : AI4CSM_SC5_D1-41

Dependencies : Details, implementation and evaluation within SC5

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_25

Name : Architectural support for Cloud to Edge communication

Description : Design and architecture for the system has to support the cloud to edge approach to ensure data exchange in future smart mobility solutions. Architecture evaluation of the selected sub-system design and comparing alternative E/E architectures, including e

Rationale : Design Concepts for Communication and Connectivity.

Metrics : yes/no

Owner : TTTAUTO

Reference UC : AI4CSM_SC5_D1-12

Dependencies : Details, implementation and evaluation within SC5

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_26

Name : Mixed Criticality Functionality

Description : Separation, i.e. freedom from interferences, among applications with different criticality levels (as defined in ISO 26262) shall be ensured in one and the same ECU. (Correct functionality under different network and application loads)

Rationale : Safety relevant functions and performance applications shall not interfere with each other on a single ECU.

Metrics : A predefined safety function is not affected by other performance applications.

Owner : TTTAUTO

Reference UC : AI4CSM_SC5_D1-11

Dependencies : Details, implementation and evaluation within SC5

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_27

Name : AURIX PPU (MCU)

supported applications

Description : For automotive applications, the MCU should cover:

* safety mechanisms

* buil-in self test

* voltage, temperature, timing supervision

* data security

Rationale : Next generation IFAG's AURIX family is intended to cover many of the upcoming automotive control tasks. Therefore there is 1 summary table addressing all AI4CSM Supply chains (except SC7)

Metrics : Coverage of SC system and sub-system requirements

Owner : IFAG

Reference UC : SC5

Dependencies : Details, implementation and evaluation within SC5

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_28

Name : AURIX interfaces

Description : Provision of different dedicated interfaces to link AURIX Chip to sensors, actuators and further control subsystems.

Rationale : As digital as well as analog interfaces ask for extra pincount as well as chiparea and power consumption, optimal selection has to be performed

Metrics : Availability of IF and speed performance. For output ports, also driver performance has to be defined/optimized

Owner : IFAG

Reference UC : SC5

Dependencies : Details, implementation and evaluation within SC5

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_29

Name : AURIX PPU AI code generation effectiveness

Description : Effort and flexibility to implement algorithmic AI functionality on AURIX PPU platforms

Rationale : Implementation of AI functionality asks for an efficient design flow

Metrics : Availability of adequate design flow

Owner : IFAG

Reference UC : SC5

Dependencies : Details, implementation and evaluation within SC5

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_30

Name : AURIX PPU com board

Description : AURIX evaluation board for 28 GHz communication applications

Rationale : Sub system application engineers need efficient access to hardware and software evaluation tooling

Metrics : Availability and ease of use

Owner : IFAG *Reference UC* : SC5 *Dependencies* : Details, implementation and evaluation within SC5 *Conflicts* : none

ID **:** AI4CSM_WP1_SCD1.2_31
Name : AURIX PPU ToF board *Description* : AURIX evaluation board for 360° applications *Rationale* : Sub system application engineers need efficient access to hardware and software evaluation tooling *Metrics* : Availability and ease of use *Owner* : IFAG *Reference UC* : SC5 *Dependencies* : Details, implementation and evaluation within SC5 *Conflicts* : none

ID **:** AI4CSM_WP1_SCD1.2_32
Name : AURIX PPU Radar board *Description* : AURIX evaluation board for Radar applications *Rationale* : Sub system application engineers need efficient access to hardware and software evaluation tooling *Metrics* : Availability and ease of use *Owner* : IFAG *Reference UC* : SC5 *Dependencies* : Details, implementation and evaluation within SC5 *Conflicts* : none

ID **:** AI4CSM_WP1_SCD1.2_33
Name : Meta language for communication *Description* : Meta language for the RoboTaxi V2Vand V2X communication based on parametric-mnemonic commands in representative usecases *Rationale* : Enable verifiable communication *Metrics* : yes/no *Owner* : VGTU *Reference UC* : SCD1.2 *Dependencies* : none *Conflicts* : none

ID **:** AI4CSM_WP1_SCD1.2_34
Name : Communication data flow simulation

Description : Simulation environment for V2V and V2X communication processes with different success (ideal, average, poor, catastrophic)

Rationale : Simulate impact of communication success on RoboTaxi operation

Metrics : yes/no

Owner : VGTU

Reference UC : SCD1.2

Dependencies : none

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.2_35

Name : Communication parameter classification

Description : Definition of obligatory, optional and additional communication parameters for RoboTaxi V2V and V2X communication.

Rationale : Increase communication efficiency

Metrics : yes/no

Owner : VGTU

Reference UC : SCD1.2

Dependencies : none

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.3_1

Name : Energy Simulation Route

Description : The route generated by the energy optimized route engine is more energy efficient compared to the speed optimized route generated by the routing engine

Rationale : Necessary to fulfill the project goal of reducing carbon emissions and saving energy

Metrics : Energy consumption in kwh

Owner : OTH

Reference UC : SCD1.3

Dependencies : none

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.3_2

Name : Time restriction route

Description : The energy optimized route does not take more time than the defined multiple of the time optimized route

Rationale : The user should not be suffer long wait times because of energy efficient routing

Metrics : Switch, which is configurable from 1-10

Owner : OTH

Reference UC : SCD1.3

Dependencies : none

Conflicts : none

ID **:** AI4CSM_WP1_SCD1.3_3
Name : Interface to Energy Simulation
Description : The energy simulation takes speed, height and distance and returns the energy consumption in kwh
Rationale : List of speed data points (km/h): int, list of distance data points (m): int
Metrics : 2-25000 datapoints of (Speed: 0-130 km/h, Distance: distance of OSM nodes in an edge)
Owner : OTH
Reference UC : SCD1.3
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.3_4
Name : Energy Simulation Parameters
Description : The energy simulation can be paramterized by the following values: Vehicle Mass, Drag & Rolling Restistance Values, Wheel Radius Transmission Ratio, Drivetrain efficiency, Min. Velocity for Recuperation
Rationale : The user should be able to do „what if" analysis
Metrics : y/n
Owner : OTH
Reference UC : SCD1.3
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.3_5
Name : Energy Simulation Explainability Module
Description : The system should provide a hint about how the energy consumption is composed. E.g. how much energy is used by heating, friction
Rationale : The user should be able to do „what if" analysis
Metrics : y/n
Owner : OTH
Reference UC : SCD1.3
Dependencies : none
Conflicts : none

ID **:** AI4CSM_WP1_SCD1.3_6
Name : Response time route service
Description : The route service delivers a route from a point A (Geographic coordinates) to point B where the max. distance 40 km is in the operative range
Rationale : Neccessary to provide functionality for the user
Metrics : 0 to 30 seconds calculation time

Owner : OTH
Reference UC : SCD1.3
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.3_7**
Name : Memory constraints
Description : The route service requires at least the specified amount of memory to calculate long routes
Rationale : Neccessary to run the service on current hardware platforms
Metrics : offset+linear scale per user
Owner : OTH
Reference UC : SCD1.3
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.3_8**
Name : Minimum Bandwidth to cloud
Description : The system must be able to have the defined bandwidth
Rationale : Neccessary because otherwise the avaiability of the service cannot be guaranteed
Metrics : 6kB/s – inf
Owner : OTH
Reference UC : SCD1.3
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.3_9**
Name : Min possible requests per minute
Description : The system must be able to repeated compute a route for the user in the defined time frame
Rationale : Due to changes in the environment the needs to be updated every few minutes
Metrics : 0.1 requests per minute
Owner : OTH
Reference UC : SCD1.3
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.3_10**
Name : Scalability
Description : The system must be able to be scalable up to the defined number of users

Rationale : Neccessary to allow the system to cover a fleet of vehicles that allow to transport everyone in a urban area

Metrics : 0-25000 users

Owner : OTH

Reference UC : SCD1.3

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.3_11**

Name : Display Modes

Description : The system shoud support two modes: Simulation mode, where the input is synthetic, generated by a traffic simulation which is configurable, also the static data is configurable, the other one is the vehicle mode, where the input from the vehicle is used a

Rationale : To support simulation as well as vehicle drives

Metrics : yes/no

Owner : OTH

Reference UC : SCD1.3

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.3_12**

Name : Interface to EQC

Description : The interface in the EQC should be able to provide gps position, state of charge, temperature (ourside, inside, motor), current speed, current acceleration, energy consumption, overall and comfort systems, driving mode, charging status. (on/off). The int

Rationale : The vehicle should be able to provide data and display a route

Metrics : yes/no

Owner : OTH

Reference UC : SCD1.3

Dependencies : none

Conflicts : none

***ID* : AI4CSM_WP1_SCD1.3_13**

Name : Interface to Virtual Vehicle Car

Description : The interface in the EQC should be able to provide gps position, state of charge, temperature (ourside, inside, motor), current speed, current acceleration, energy consumption, overall and comfort systems, driving mode, charging status. (on/off). The int

Rationale : The vehicle should be able to provide data and consume the computed route

Metrics : yes/no

Owner : OTH

Reference UC : SCD1.3

Dependencies : none *Conflicts* : none

***ID* : AI4CSM_WP1_SCD1.3_14**
Name : Data sources
Description : The system should use the following data sources: Street network map by Open Street Map, Weather Data from openweathermap, Height Data via Valhalla, Open Charge Map for charging stations and Traffic information from an appropriate provider
Rationale : The system need external data sources to be able to understand the environment
Metrics : yes/no
Owner : OTH
Reference UC : SCD1.3
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.3_15**
Name : Dynamic traffic participants
Description : The traffic simulation should be able to simulate relevant traffic participants and influence factors for a test area. E.g.: Trucks, Busses, Cars, signal lights, traffic rules. Input: Day, Time. Output: Trace of location, speed for each vehicle
Rationale : Required for the simlation mode
Metrics : yes/no
Owner : OTH
Reference UC : SCD1.3
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.3_16**
Name : Traffic simulation
Description : There should be a traffic simulation which is realistic enough to be able to consider traffic effects like stop-and-go
Rationale : Required to virtually test algorithmns
Metrics : yes/no
Owner : OTH
Reference UC : SCD1.3
Dependencies : none
Conflicts : none

***ID* : AI4CSM_WP1_SCD1.3_17**
Name : Traffic simulation Amberg
Description : The town of Amberg exists as a simulated environment

Rationale : Required to virtually test algorithmns in a city which is easily accessible to the task leader *Metrics* : yes/no *Owner* : OTH *Reference UC* : SCD1.3 *Dependencies* : none *Conflicts* : none

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