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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Smart Machine-to-Machine communications (SmartM2M).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

The present document was drafted by ETSI Technical Committee SmartM2M as a starting point for the development of an extension of the SAREF ontology for the automotive domain (SAREF4AUTO). The present document includes the first outcomes of a Specialist Task Force (STF) requested by ETSI SmartM2M; it gives insights into the current landscape of initiatives in the automotive domain, including standardization and research projects. It identifies a set of relevant use cases for this domain, and extracts from those use cases the requirements answering the competency questions that should be satisfied by the SAREF4AUTO extension.

1 Scope

The present document provides the requirements for an initial semantic model in the smart automotive domain based on a limited set of use cases and from available existing data models. The present document is developed in close collaboration with AIOTI, the H2020 Large Scale Pilots, with ETSI activities in the automotive domain and with oneM2M. Further extensions are envisaged in the future to cover entirely the smart automotive domain. The associated technical specification will define the extension (i.e. the semantic model) for the smart automotive domain (SAREF4AUTO) based on the requirements and use cases described in the present document.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] European Commission and TNO: "D-S4 Final Report - SMART 2013-0077 - Study on Semantic Assets for Smart Appliances Interoperability", March 2015.

[i.2] ETSI TS 103 264 (V2.1.1): "SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping".

[i.3] ETSI TR 103 411 (V1.1.1): "SmartM2M; Smart Appliances; SAREF extension investigation".

[i.4] ETSI TS 102 894-2: "Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary".

[i.5] oneM2M-TR-0026-V-4.5.0: "oneM2M; Vehicular Domain Enablement".

[i.6] CEN EN 16157-2:2019: "Intelligent transport systems - DATEX II data exchange specifications for traffic management and information - Part 2: Location referencing".

[i.7] ETSI TR 103 545: "SmartM2M; Pilot test definition and guidelines for testing cooperation between oneM2M and Ag equipment standards".

[i.8] HD Live Map Data Specification, HERE, 2019.

NOTE: Available online at https://developer.here.com/olp/documentation/hd-live-map/topics/hdlm2-logical-road-link.html.

[i.9] "The Benefits of a Common Map Data Standard for Autonomous Driving, White Paper", June 2019.

NOTE: Available online at https://www.nds-association.org/.

[i.10] ISO 11783: "Tractors and machinery for agriculture and forestry -- Serial control and communications data network".

[i.11] ETSI EN 302 637-3: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service".

[i.12] C-ITS Platform, Final report Phase I, January 2016.

[i.13] ETSI TS 103 301: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services".

[i.14] Autopilot: "The Autopilot H2020 Large Scale Pilot".

NOTE: Available at http://autopilot-project.eu.

[i.15] Schema.org markup model for automobiles.

NOTE: Available at https://schema.org/docs/automotive.html.

[i.16] "The DATEX II Parking Publications Extension".

NOTE: Available at https://datex2.eu/implementations/extension_directory/parking-publications-extension-v10a.

[i.17] SENSORIS: "Sensor Interface Specification".

NOTE: Available at https://sensor-is.org/.

[i.18] The SynchroniCity Project.

NOTE: Available at https://synchronicity-iot.eu/.

[i.19] ENSEMBLE project: "Platooning together".

NOTE: Available at https://platooningensemble.eu.

[i.20] The TransAID project:" Transition Areas for Infrastructure-Assisted Driving".

NOTE: Available at https://www.transaid.eu/.

[i.21] ETSI EN 302 665: "Intelligent Transport Systems (ITS); Communications Architecture".

[i.22] ETSI TR 103 300-1 "Intelligent Transport System (ITS); Vulnerable Road Users (VRU) awareness; Part 1: Use Cases definition; Release 2".

[i.23] W3C Automotive Ontology Working Group.

NOTE: Available at https://www.w3.org/community/gao/.

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

ontology: formal specification of a conceptualization, used to explicit capture the semantics of a certain reality

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AEF	Agricultural industry Electronics Foundation
AIOTI	Alliance for Internet of Things Innovation
AVP	Automated (Autonomous) Valet Parking
CAM	Cooperative Awareness Message
CCTV	Closed-Circuit TeleVision
C-ITS	Cooperative ITS
CPS	Cooperative Perception Service
DATEX	Data Exchange
DENM	Decentralized Environmental Notification Message
IBM	International Business Machines (corporation)
IoT	Internet of Things
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems
M2M	Machine to Machine
MAP	Map Data
NDS	Navigation Data Specification
OWL	Web Ontology Language
PMD	Photonic Mixer Device
SAE	Society of Automotive Engineers
SAREF	Smart Applications REFerence ontology
SPAT	Signal Phase And Time
UML	Unified Modeling Language
UTC	Universal Time Coordinated
UUID	Universally Unique IDentifier
V2V	Vehicle to Vehicle
VMS	Variable Message Signs
VRU	Vulnerable Road user
WGS	World Geodetic System 1984

4 SAREF extension for the automotive domain

SAREF is a reference ontology for the IoT created in close interaction with the industry during a study requested by the European Commission in 2015 [i.1] and subsequently transferred into an ETSI Technical Specification [i.2]. SAREF contains core concepts that are common to several IoT domains and, to be able to handle specific data elements for a certain domain, dedicated extensions of SAREF can be created. Each domain can have one or more extensions, depending on the complexity of the domain. As a reference ontology, SAREF serves as the means to connect the extensions in different domains. The earlier document ETSI TR 103 411 [i.3] specifies the rationale and methodology used to create, publish and maintain the SAREF extensions.

The present document specifies the requirements for an initial SAREF extension for the automotive domain. This initial SAREF extension will be based on a limited set of use cases and existing data models identified within available initiatives that will be summarized in dedicated clauses of the present document. The work conducted in the present document has been developed in the context of the STF 566 (https://portal.etsi.org/STF/STFs/STFHomePages/STF566.aspx), which was established with the goal of creating SAREF extensions for the following domains: Automotive, eHealth/Ageing-well, Wearables and Water. This work is expected to be developed in close collaboration with ETSI, oneM2M, AIOTI, automotive-related H2020 Large Scale Pilots and EU projects. However, other initiatives coming from the industrial world and alliances will also be investigated.

STF 566 consists of the following two main tasks:

1) to gather requirements, collect use cases and identify existing sources (e.g. standards, data models, ontologies, etc.) from the domains of interest (Automotive, eHealth/Ageing-well, Wearables and Water) in order to determine the requirements for an initial semantic model for each of the aforementioned domains, based on at least 2 use cases and existing data models; and

2) to specify and produce the extensions of SAREF for each of the aforementioned domain based on these requirements.

The present document focuses on analysing sources, collecting use cases and gathering requirements for an extension of SAREF for the Automotive domain. The present document sets the requirements of an initial semantic model that will result in a new SAREF ontology extension for Automotive, called SAREF4AUTO, that will be published as part of the SAREF extensions technical specifications.

5 Related initiatives

5.1 Introduction

Clause 5 reviews relevant initiatives in the Automotive domain, including initiatives in the standardization bodies and alliances, European research projects, available partial data models and ontologies that can be found in this domain as well as other initiatives such as a technical report for an ETSI pilot test involving agriculture equipment. Each of the selected initiatives is described and how it brings relevant information to this study is described.

5.2 Standardization initiatives and associations

5.2.1 oneM2M

In the automotive domain, oneM2M develops oneM2M-TR-0026 [i.5] which examines how the current oneM2M System can be used in the Vehicular Domain and includes a study of advanced features that the future oneM2M release(s) could support for this vertical domain.

5.2.2 AIOTI

The Alliance for Internet of Things Innovation (AIOTI) was initiated by the European Commission (then moved to a full-fledged association) in order to develop and support the dialogue and interaction among the Internet of Things (IoT) various players in Europe. The overall goal of the AIOTI is the creation of a dynamic European IoT ecosystem to unleash the potentials of the IoT. The work in AIOTI is performed in dedicated working groups. Two of them are relevant to the present document:

- WG03 on IoT standardization, which includes a sub-group on semantic interoperability; and
- WG09 on Smart Mobility.

5.2.3 ETSI TC ITS

The TC ITS of ETSI is in charge of developing and maintaining standards, specifications and other reports related to the implementation of V2V communication and interaction in C-ITS. Its scope goes from wireless access (apart from radiofrequency issues) to generic services and related applications. The security and implementation of tests are also tackled. Its WG1 develops a data dictionary [i.4] to handle all the data elements used in ITS messages such as CAM, DENM and CPS which are relevant for the present document.

5.2.4 DATEX-II

In the road sector, the DATEX standard was developed for information exchange between traffic management centres, traffic information centres and service providers. The second generation DATEX II specification (CEN EN 16157-2:2019 [i.6]) enables applications requiring access to dynamic traffic and travel related information in Europe.

5.2.5 SENSORIS

SENSORIS [i.17] (https://sensor-is.org/) is a result of the cooperation of a number of parties from the automotive domain that proposed data models for exchanging data between vehicles and cloud services. Currently, vehicle sensor data exists in different formats across automakers and it is typically carmaker specific. When connecting vehicles to IoT platforms standardization is needed, as pooling analogous vehicle data from millions of vehicles will be a key enabler for bringing vehicle-to-vehicle and vehicle-to-infrastructure communication to the next level. SENSORIS was initiated by HERE [i.8] in June 2015 when the company published the first open specification for how vehicle sensor data gathered by connected cars will be sent to the cloud (as well as between clouds) for processing and analysis.

5.2.6 W3C - Automotive Ontology Working Group

The Automotive Ontology Community Group in W3C [i.23] (https://www.w3.org/community/gao/) is an informal group aiming to advance the use of shared conceptual structures in the form of web ontologies for better data interoperability in the automotive industry. This group has published an automotive extension of the data markup schema at schema.org [i.15] (referred as auto.schema.org). It is available on the schema.org site at: https://schema.org/docs/automotive.html (see also clause 5.4.1).

5.3 European Projects

5.3.1 SynchroniCity

The SynchroniCity H2020 Large Scale Pilot [i.18] (https://synchronicity-iot.eu/) is working to establish a reference architecture for the envisioned IoT-enabled city market place with identified interoperability points and interfaces and data models for different verticals. This includes tools for co-creation and integration of legacy platforms and IoT devices for urban services and enablers for data discovery, access and licensing lowering the barriers for participation on the market. SynchroniCity pilots these foundations in the reference zones together with a set of citizen-centred services in three high-impact areas, showing the value to cities, businesses and citizens involved, linked directly to the global market.

5.3.2 AUTOPILOT

The Autopilot H2020 Large Scale Pilot (http://autopilot-project.eu) [i.14] focuses on the use of IoT for improving autonomous driving. "Automated driving Progressed by Internet of Things" (AUTOPILOT) will bring IoT into the automotive world to transform connected vehicles - moving "things" in the IoT ecosystem - into highly automated vehicles (towards levels 4 and 5 of driving automation). AUTOPILOT will also make data from autonomous cars available to Internet-of-Things platforms such as oneM2M and IBM Watson. Various use cases are implemented at the six pilot sites (Finland, France, Italy, the Netherlands, Spain and South Korea) in large scale demonstrations in order to evaluate the potential and calculate the related impacts of using Internet of Things for Automated Driving. Examples of use cases are: platooning where vehicles are automatically following each other at a relatively close distance to improve traffic throughput and reduce fuel consumption; and Automated Valet Parking (AVP) where the autonomous vehicle will park itself after the driver has left the car at a drop-off point.

5.3.3 ENSEMBLE

ENSEMBLE [i.19] (https://platooningensemble.eu) is a European project that will lay the foundation for multi-brand truck platooning across Europe, by speeding up the implementation of multi-brand platooning, bringing its real-world deployment within reach. Its final outcome will be a demonstration of a six-truck platoon, each one of a different brand, driving in real-world traffic conditions across national borders in 2021. To allow the transition from single-brand to multi-brand platooning, platoon operation levels need to be defined to harmonize the design of different platooning functionalities and strategies, reflecting the full diversity of trucks with platooning functionality. Thanks to cooperative automated dynamic control between the trucks, truck operations will be safer and less stressful. At highway entries, exits and junctions, platoons will automatically increase vehicle gaps to give way to other road users. Interoperability is a leading design principle. Existing standardized C-ITS message sets will be used to coordinate the trucks, and new message sets will be developed.

5.3.4 TransAID

The TransAID European project [i.20] (https://www.transaid.eu/) develops and demonstrates traffic management procedures and protocols to enable smooth coexistence of automated, connected, and conventional vehicles, especially at Transition Areas, i.e. at areas where it is not allowed or not possible to use a high level of automation due to missing sensor inputs or high complexity situations. A hierarchical approach is followed where control actions are implemented at different layers including centralized traffic management, infrastructure, and vehicles.

5.4 Ontologies and data models

5.4.1 W3C Automotive Ontology Working Group

The Automotive Ontology Community Group [i.23] (https://www.w3.org/community/gao/) is an informal group of individuals and corporations whose objective is to develop web ontologies for better data interoperability in the automotive industry, and this at Web scale. In particular,

- extension proposals for schema.org so that automotive information can be better understood by search engines; and
- OWL Web ontologies for the automotive industry.

So far, the group has mainly published an automotive extension in the schema.org community (https://schema.org/). This schema refers to real-world objects related to popular vehicles like cars, buses (coaches) and motorcycles. However, its main target is on passenger automobiles to enable the elaboration of retail market web sites.

Figure 1 shows an extract of the vehicle properties in this model. The markup model for automobiles is available online at https://schema.org/docs/automotive.html [i.15].

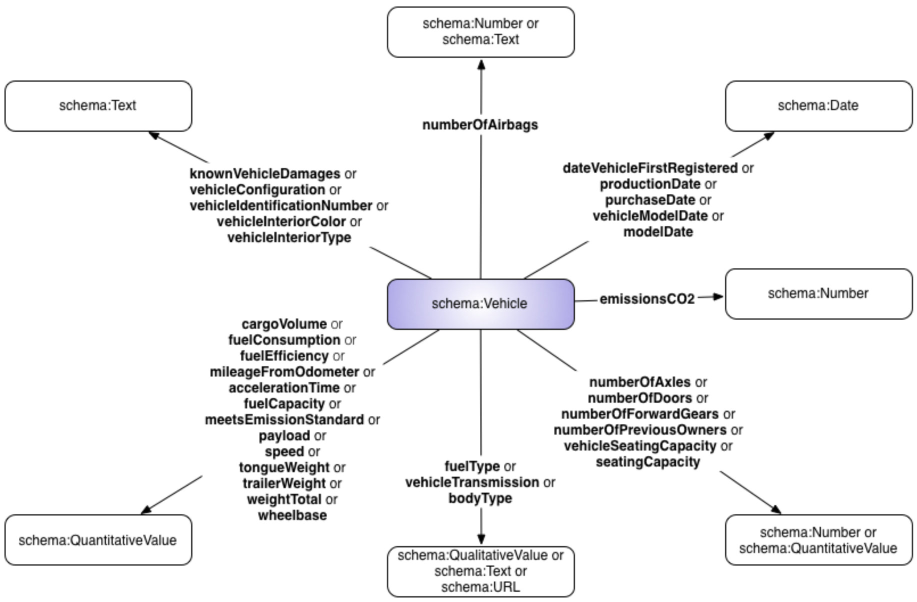

Figure 1: The Vehicle type and its properties in the schema.org extension (from https://schema.org/docs/automotive.html) [i.15]

5.4.2 DATEX II Parking Publications Extension

The DATEX II Parking Publications [i.16] (available at https://datex2.eu/implementations/extension_directory/parking-publications-extension-v10a) is a set of three UML models, extending the DATEX II standard, which allow to specify static and dynamic information about parking sites as well as information on individual parking vehicles:

- ParkingTablePublication

- ParkingStatusPublication
- ParkingVehiclePublication

Figure 2 shows an extract from these UML models related to the ParkingSite class.

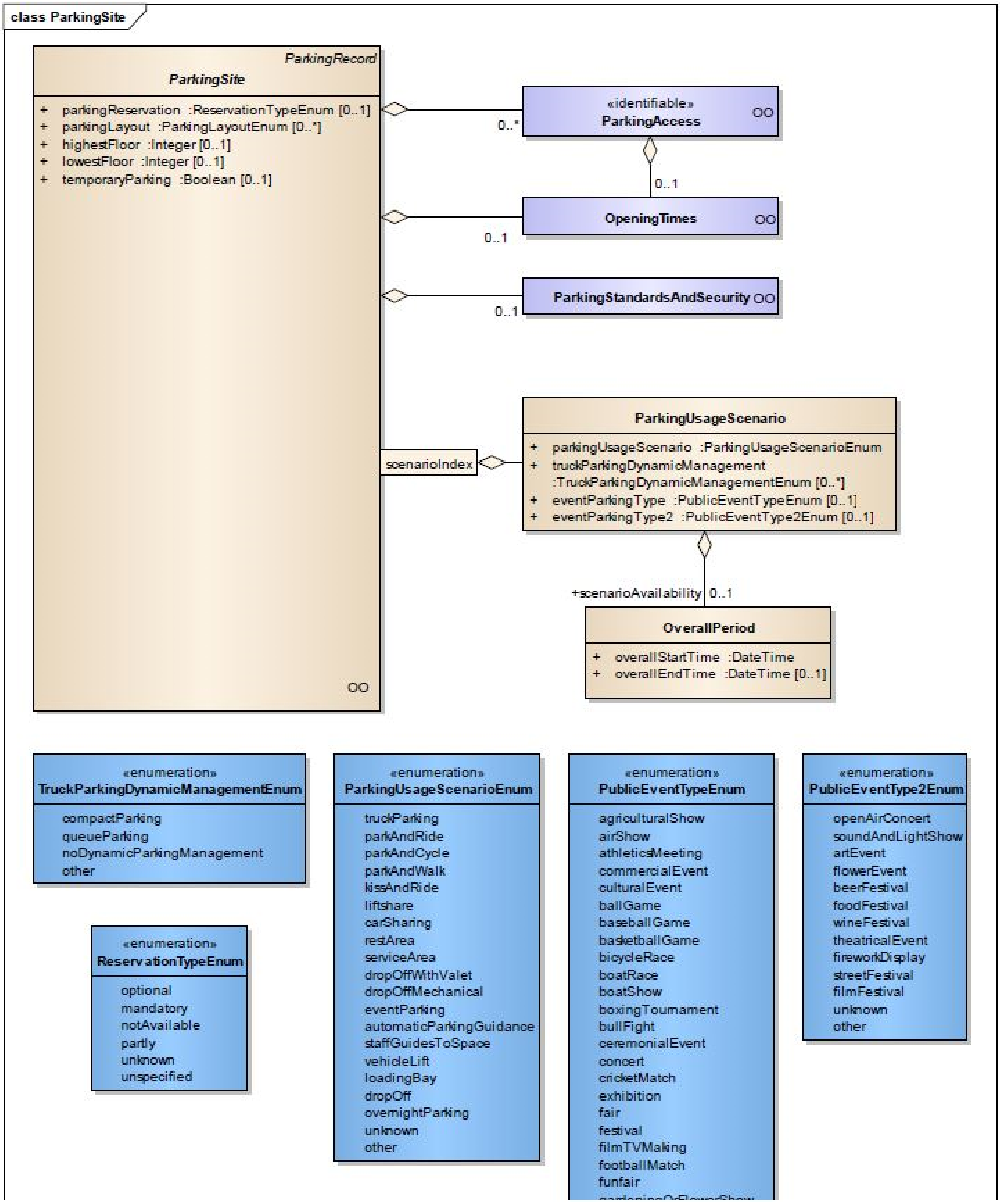

Figure 2: Extract from DATEX II Parking Publications

5.5 Other Initiatives

5.5.1 ETSI Pilot Test for interfacing oneM2M platform with Smart Agriculture (ETSI TR 103 545)

The objective of this pilot test is to validate the possible cooperation between the oneM2M platform and the AEF ISO 11783 (ISOBUS) standards [i.10] implemented for communication inside and between agriculture and forestry machines. ETSI TC ITS standards, such as ETSI EN 302 637-3 (Decentralized Environmental Notification Basic Service), [i.11] are part of this cooperation in the use case to be demonstrated during the pilot.

This pilot test is based on a common data model. The data considered include the parameters of the ITS messages and those required to assess the triggering condition. Each of the parameters is associated to a set of meta-data: parameter name, type, size and valid range for values. a preliminary semantic model that has been defined for the pilot test data, with the objective to remain close to the oneM2M base ontology and SAREF.

6 Use cases

6.1 Proposed use cases

For the purposes of the present document, four common and significative uses case are presented, focusing on the automobile itself as well as on its environment:

- Platooning.
- Automated Valet Parking (AVP).
- Cooperative Perception Service (CPS).
- Vulnerable Road Users (VRU).

More use cases can be found in the oneM2M report for vehicular enablement (see clause 5.2.1) or in the C-ITS Platform final report for phase I [i.12].

6.2 Use case 1: Platooning

Platooning (see Figure 3) is a use case where a vehicle is automatically following another vehicle at a relatively close distance. Driving in a platoon requires vehicles to use intervehicle communications to anticipate timely on maneuvers of other vehicles in the platoon.

Figure 3: Platooning vehicles on public road, lead vehicle is manually driven (source: AUTOPILOT project [i.14])

Several aims and motivations for vehicular platooning exist, such as:

1) improvement of traffic throughput and homogeneity;

2) enhancement of traffic safety due to small speed variations and relative low impact velocities in collisions; and

3) reduction of fuel consumption and emissions due to lowering the air drag.

These objectives can to a certain extent already be achieved by non-automated driving systems (i.e. human driver monitors the environment and may execute e.g. the steering task), although a higher level of automation is considered to contribute in a positive way. Automated driving (system performs all aspects of the dynamic driving task) can offer additional benefits in terms of comfort (relieving the driver from the driving task) and efficiency (no driver required in vehicles). The following vehicles have automated steering and distance control to the vehicle ahead, and the control is supported by advanced Vehicle to Vehicle (V2V) communication extended with additional IoT data. IoT data are especially useful during the platoon formation phase where vehicles are still out of V2V communication range and need to be guided up to a rendezvous location.

6.3 Use case 2: Automated Valet Parking

The concept of Valet Parking is widely used all over the world; for example, by the more luxurious hotels and restaurants, stores and other businesses. Once a customer arrives with his/her vehicle at the hotel, he/she gets out of the vehicle and hands over the car-keys to the hotel personnel, which will then drive the vehicle to its parking spot, relieving the customer from that task. In the meantime, the owner of the vehicle can e.g. check-in or attend a meeting. Likewise, the vehicle is returned by the hotel personnel upon the request of the relevant customer. Utilizing the technology evolution of self-driving vehicles, it is a logical next step to also automate the valet parking concept, referred to as Automated Valet Parking, or AVP.

By deploying this use case several stakeholder types can participate and profit from its value chain, such as: Autonomous Valet Parking application provider, IoT Devices manufacturer, Communication Network supplier/provider/operator and IoT platform provider. In this use case, IoT plays an important role of improving the operation of an autonomous driving vehicle when used in Valet Parking scenarios. In AVP (see Figure 4), the autonomous vehicle will park itself after the driver has left the car (step 1) at a drop-off point, which may be located near the entrance of a parking lot. The autonomous vehicle will find an available parking spot (step 2) and drive and park itself (step 3). When the driver wants to leave the site, he/she will simply request from the autonomous vehicle to return by itself (step 4) to the collect point, using (for example) a Smartphone application.

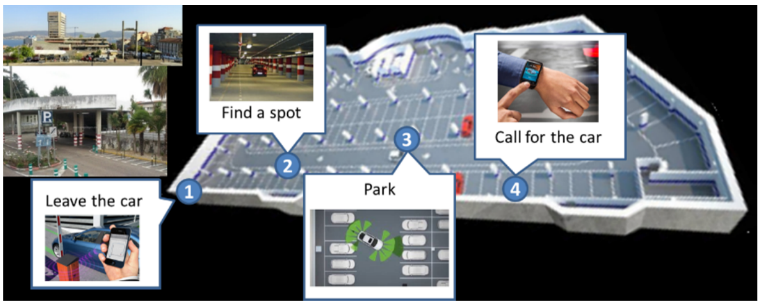

Figure 4: Automated Valet Parking sequence, based on EC H2020 AUTOPILOT project [i.14]

To navigate safely around the parking lot to its destination, the automated vehicle uses driving functions based on knowledge about the environment around the vehicle. An example would be a navigation functionality based on a digital map, positions of the automated vehicle and vacant parking spots. The vehicle can use its own functions and sensors to observe immediate environment, but it can also benefit from gathering additional data going beyond what its sensor can observe - like accessing IoT platforms which can provide data and functions based on IoT enabled sensors like parking cameras, as well as position info from other vehicles driving (or being parked) at parking. Furthermore, IoT platforms may provide information to support services for booking a parking place and arranging (automated) payment. One of the main challenges when using IoT data as additional source, is that a suitable common architecture of sharing information between different sensor systems is needed (e.g. vehicle, garage equipment), such that any vehicle can park itself in any parking garage. For scenarios in which the parking lot is equipped with an extended set of sensors, more accurate information can be shared with the AVP-vehicle, so it can perform its task better (with shorter time to park, less fuel consumed), compared to parking lots that lack additional sensors.

6.4 Use case 3: Cooperative Perception Service

Perception refers to the ability of an autonomous system to collect information and extract relevant knowledge from its environment. Cooperative Perception refers to the concept of sharing information between vehicles about the current context based on perception sensors and reduce the uncertainty about their environment. In this service, the vehicle does not provide information about itself, but rather about neighbouring objects (i.e. other road participants, obstacles and alike) in abstract descriptions. Cooperative Perception is particularly important for autonomous vehicles.

This service is relevant in several scenarios:

- Detection of Non-Connected Road Users, where vehicles share their own perception of road users which are not able to communicate with the ITS system. The own perception range is limited to the field of the sensors view, which is especially critical for objects shadowed by buildings or cars. Receiving the information from neighbour vehicles increases this range and can even improve its accuracy if the information received from several vehicles is processed.

- Detection of Safety-Critical Objects, which targets undesirable objects on the road which are a potential safety risk, such as lost cargo, a tree limb or a dustbin.

- Increasing Awareness using a road side equipment, which may periodically send relevant information about objects in an intersection to passing vehicles, relieving the hidden node challenge.

This knowledge is acquired using different types of sensors, on-board vehicles or attached to road side equipment such as traffic lights, light poles or bus stations: radar, lidar, mono-video, stereovision, night vision, ultrasonic, Photonic Mixer Device (PMD), data fusion, induction loop, spherical camera, or aggregation of cooperative ITS information.

An object is mainly defined by its position in the environment or distance from the sensor, its movement, its 3D dimensions, orientation, classification. Optionally, additional information such as colour or perceived texture may be added to this definition.

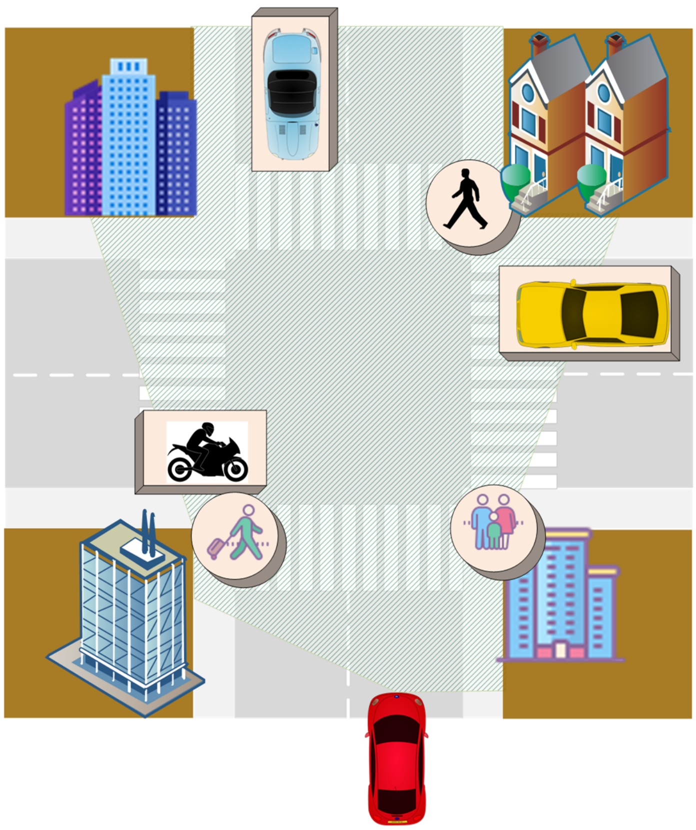

Figure 5: Objects reported in the Cooperative perception service

6.5 Use case 4: Vulnerable Road Users

Vulnerable Road Users (VRUs) are particularly vulnerable to road hazards due to potential traffic conflicts with other road users. VRUs can belong to one of the following groups:

- Pedestrians, i.e. road users not using a mechanical device for their trip. This group includes for example pedestrians on a pavement, but also children, prams, animals, blind persons guided by a dog, riders off their bikes.

- Light vehicles, possibly with an electric engine. This group includes bicycles, but also wheelchair users, skaters, scooters, Segway's, etc. They can move on the pavement or directly on the road and often have lower speeds.

- Motorbikes, which are equipped with engines that allow them to reach speeds similar to other vehicles such as cars, buses or truck. They normally take part in the road traffic.

Intelligent Transport Systems (ITS) have been developed to enable an increase in traffic safety and efficiency but initial focus was on road traffic safety and especially on vehicle safety. VRU applications linked to specific use cases aim at providing relevant information to actors such as humans directly or to automated systems. Such applications can increase the awareness of vulnerable road users, provide collision risk warnings to any other road user or trigger an automated action in a vehicle. These applications make use of data received from other user devices and potentially from the VRU device own sensor systems and other integrated services. ETSI TR 103 300-1 [i.22] recognizes six categories of VRU use cases:

1) VRU to VRU direct communications, where both are equipped with a device able to bring awareness of a risk of collision. This happens for example when a pedestrian walks on a bicycle lane.

2) VRU to vehicle communication, where both are able to exchange directly information, which may lead to a warning issued at the driver on board system or the VRU device. This happens for example on a highway when road workers are active and a vehicle has not changed its lane after the closure of that lane. Another example is when a car triggers an emergency break and a motorcycle several cars behind is informed of the event.

3) Indirect detection of VRUs by vehicle sensors. For example, a small animal starts crossing the road. It is detected by the closest vehicle which happens to be a truck and informs the vehicles behind that they need to slow down. The same could apply to increase the e-visibility of a bicycle on the side of the road.

4) Indirect detection of VRUs by road side equipment. For example, a bus station detects the presence of pedestrians on the road after leaving the bus while a vehicle is arriving at very high speed. A warning is issued to both the vehicle driver (on-board system) and the pedestrians (siren).

5) Detection by a central traffic management centre. This may happen on a highway equipped with Video Collection System (CCTV) that monitors the road and detects the presence of a pedestrian or wild animal inside the highway property. This event is signalled at the highway traffic management centre to an operator or Artificial Intelligence application, which starts broadcasting a warning to relevant drivers through a cluster of road side equipment (road side units, Variable Message Signs (VMS), etc.) located in that zone.

6) VRU to Road side equipment for safety. In this type of use case, disabled people communicating directly with the traffic light (as they identify themselves as disabled) take more time than usual to cross a road. The traffic light triggers a longer period for the red-light phase to ensure that the pedestrian has enough time to cross the road.

Data need to be exchanged between the different IoT and ITS entities involved to ensure the safety of the VRUs. An important challenge is the elimination of false positive and false negative triggers of collision avoidance mechanisms, due to misinterpretation of the information exchanged.

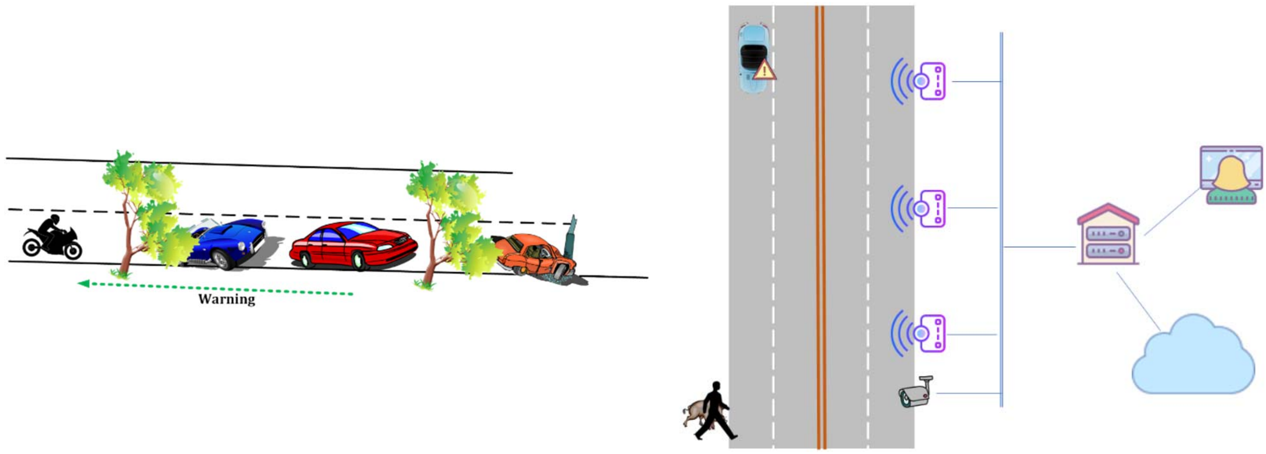

Figure 6: Examples of VRU protection use cases

7 Requirements

The requirements presented in this clause have been derived from the use cases presented in clause 6. Competency questions that have been extracted from these use cases as the basis to create SAREF4AUTO include the following:

- List of requirements for the platooning and AVP use cases provided by the AUTOPILOT project [i.14].
- List of requirements for the platooning use case also provided by the ENSEMBLE project [i.19].
- List of requirements for the vulnerable road user and cooperative perception use cases form standards and the TransAID project [i.20].
- List of requirements provided by standards, specifically from: ETSI TS 102 894-2 [i.4].
- List of requirements provided by other industry initiatives and data models: SENSORIS data model [i.17], W3C Automotive Ontology, DATEX II Parking Publications [i.16], etc.

Different types of data can be taken into account related to these use cases and standards, namely related to:

1) vehicles;
2) road side sensors (e.g. radars, cameras, drones) and actuators (e.g. traffic lights);
3) road topology and geometry (e.g. roads, segments, lanes, parking spots);
4) platoon;
5) vehicle environment (e.g. neighbour vehicles, VRUs, critical objects, notified events); this may be enlarged in a later step with infrastructure information such as contextual speed, traffic signs, traffic light phases, etc.

The associated requirements are presented from Table 1 to Table 5. Due to the fact that some requirements are extracted from the use cases and other requirements are extracted from the standard specifications, these requirements can be defined either as competency questions with answers or as statements.

Table 1: Requirements for vehicles

Id	Competency Question/Statement	Possible answer
AUTO-1	Vehicle is the main object of interest in the automotive domain	Automotive domain also considers other road users such as - pedestrians, cyclists, skaters, etc. with or without an electrical engine; - as well as road side units; and control & monitoring centres.
AUTO-2	What type of vehicles are there?	Example of types of vehicles are passenger car, truck, bus, motorcycle, tractors, etc. (see ETSI TS 102 894-2 spec [i.4] for full list of vehicles, which are type of "stations"), but also the SENSORIS data model [i.17].
AUTO-3	What other objects are relevant in the automotive domain?	All types of Stations, which can be personal, vehicles, road side unit or central stations (as defined in ETSI EN 302 665 [i.21]).
AUTO-4	A vehicle has dimensions	
AUTO-5	What are these dimensions?	Length, width, height.
AUTO-6	The dimensions of a vehicle can change (depending on the load and/or presence of trailers). Therefore, the vehicle can have more than one length, width, height during its existence	
AUTO-7	A vehicle has an identifier	It can be an integer (e.g. stationID as defined in ETSI TS 102 894-2 [i.4]) or an UUID (string), etc. The purpose is to identify a vehicle (station) during data exchange with other devices/stations. This identifier may be a pseudonym. It may change over space and/or over time.
AUTO-8	What type of properties related to vehicles can be monitored, measured or controlled?	Position, speed, direction (heading), acceleration, light status, etc.
AUTO-9	A vehicle has a role	
	What role can a vehicle play in the traffic?	publicTransport, specialTransport, dangerousGoods, roadWork, rescue, emergency, safetyCar, agriculture, commercial, military, roadOperator, taxi.
AUTO-10	A vehicle has a position	
AUTO-11	What types of position are relevant?	- Absolute position, when expressed in terms of global coordinates (lat, long, alt), e.g. according to WGS 84. - Relative position, when expressing coordinates of a detected vehicle in the surrounding (e.g. a car is x,y,z in front of the ego-vehicle). - Position with respect to road topology (e.g. road, segment or lane).
AUTO-12	What is an ego-vehicle?	An ego-vehicle is a vehicle used in automotive as reference point for expressing relative measurements (e.g. position with respect to x,y,z = 0,0,0 or speed).
AUTO-13	Position is always an estimate and therefore it is associated to a confidence (accuracy) about its measurement	
AUTO-14	Position estimate has confidence (accuracy)	
AUTO-15	Position estimate has a measurement and unit of measure	
AUTO-16	A vehicle has speed	
AUTO-17	What type of speed are relevant?	Absolute and relative (similar to the case of position).
AUTO-18	Speed has confidence/accuracy	
AUTO-19	A vehicle has a direction	

Id	Competency Question/Statement	Possible answer
AUTO-20	How is direction measured?	Heading regards to the WGS 84 north (as defined in ETSI TS 102 894-2 [i.4]) measured in degrees (angle).
AUTO-20	A vehicle has acceleration	
AUTO-21	Acceleration can be longitudinal or lateral	
AUTO-22	Acceleration has confidence/accuracy	
AUTO-23	A vehicle has yaw rate/angular direction (i.e. change rate of vehicle's direction)	
AUTO-24	Yaw rate has confidence/accuracy	
AUTO-25	Yaw rate has unit of measure	
AUTO-26	A vehicle has a brake capacity	
AUTO-27	All measurements (e.g. of speed, position, direction, acceleration etc.) have a timestamp	
AUTO-28	How is the time expressed?	The time is expressed as a UTC timestamp in milliseconds.
AUTO-29	All measurements (e.g. of speed, position, direction, acceleration, etc.) have a unit of measure	
AUTO-30	All measurements (e.g. speed, position, direction, acceleration, etc.) have confidence/accuracy	
AUTO-31	A vehicle has a destination	
AUTO-32	What types of destinations are relevant?	Geo-point (latitude, longitude, altitude) or address including information such as street name, number, postcode, city, country, etc. The destination can also be a parking spot location.
AUTO-33	A vehicle can have a route	
AUTO-34	What is a route?	A list of geo-points including start and destination points defining the route followed by the vehicle.
AUTO-35	A vehicle can be at different phases during parking	
	What phases during parking are relevant?	At drop-off spot, at pick-up spot, driving to parking spot, driving to pick up spot, parking, parked, charging.
AUTO-36	A vehicle has a level of automation	
AUTO-37	How is the level of automation defined?	According to SAE J3016, there are five levels of automation: - Level 0: No Driving Automation. - Level 1: Driver assistance. - Level 2: Partial driving automation. - Level 3: Conditional driving automation. - Level 4: High driving automation. - Level 5: Full Driving automation.

Table 2: Requirements for platoon

Id	Competency Question/Statement	Possible answer
AUTO-38	What is a platoon?	A group of vehicles automatically following each other at a relatively close distance.
AUTO-39	A platoon has an identifier	It can be an integer (such as with stationID as defined in ETSI TS 102 894-2 [i.4]) or an UUID (string), etc. The purpose is to identify a platoon during data exchange with other devices/stations. This identifier may be a pseudonym. It may change over space and/or over time.
AUTO-40	A platoon can be at different states	
AUTO-41	Which platoon states are relevant?	Examples of states are: unknown, standalone, assembling, platooning, disengaging, etc.
AUTO-42	A platoon has a destination	
AUTO-43	How is the destination of a platoon defined?	The current platoon leader defines the platoon destination. Following vehicles will share (partially) the route of the leader and can, therefore, have different final destinations.
AUTO-44	A platoon has a route	

Id	Competency Question/Statement	Possible answer
AUTO-45	How is the route of a platoon defined?	It is the route of the current vehicle leader in the platoon that other follower vehicles (partially) share.
AUTO-46	A platoon consists of one or more vehicles	
AUTO-47	What roles can a vehicle assume in a platoon?	A vehicle can assume roles such as: unknown, leader, follower, ready-for-leading, trailing, etc.
AUTO-48	A vehicle member of a platoon can be at different states	
AUTO-49	What states are relevant for a vehicle in a platoon?	Examples of states are: unknown, standalone, engaging, platooning, disengaging, searching, forming.
AUTO-50	During the forming state, a vehicle member of a platoon is given an estimated rendezvous location and estimated time for joining	
AUTO-51	What is a rendezvous location?	It is the estimated location where the vehicle member joins the platoon.
AUTO-52	How is the rendezvous location expressed?	In global coordinates (lat, long, alt), e.g. according to WGS 84.
AUTO-53	A vehicle member of a platoon has a platoon position	
AUTO-54	How is this platoon position defined?	The position is defined as the index of the vehicle in the platoon starting from zero (leader) up to N (trailing vehicle).
AUTO-55	A vehicle can join a platoon at different platoon positions	
AUTO-56	All state information (e.g. platoon state, vehicle role, vehicle mode, etc.) have a timestamp	
AUTO-57	A platoon has a size	
AUTO-58	How is the platoon size defined?	- The total number of vehicles currently in the platoon. - Length of the platoon (sum of all vehicles' length + inter-vehicle distance)
AUTO-59	The platoon can have a maximum size	Maximum number of vehicles allowed to join the platoon due to safety requirements.
AUTO-60	A vehicle has a level of automation for platooning	
AUTO-61	How is the level of automation for platooning defined?	In the ENSEMBLE project [i.19] (see clause 5.3.3), there are currently three levels of automation for platooning being defined: Level A, Level B, Level C. Level C represents the highest level of automation for platooning in terms of longitudinal and lateral control, shortest time gap supported, wider range of situations handled and support for merging of entire platoons.

Table 3: Requirements for road side sensors and actuators

Id	Competency Question/Statement	Possible answer
AUTO-62	What is a road side sensor?	Sensors such as cameras, radars that are deployed along the road (e.g. at intersections and at poles along a highway).
AUTO-63	Road side sensors perform measurements	
AUTO-64	What is measured by road side sensors?	Speed, position (relative or absolute), dimension, direction, etc. of road objects.
AUTO-65	What types of road objects are relevant?	Pedestrian, vehicles, obstacles, traffic signs, etc.
AUTO-66	What is a road side actuator?	Devices deployed along the road that produce signals based on road side sensor data measurements.
AUTO-67	What types of road side actuators are relevant?	Devices such as traffic light controllers changing from red to green based on detected vehicles.
AUTO-68	What is a traffic light?	A device that automatically operates coloured lights, typically red, amber, and green, for controlling traffic at road junctions, pedestrian crossings, and roundabouts.
AUTO-69	What types of road side measurements can traffic light use?	Speed, position of detected road objects such as bicycles, vehicles.
AUTO-70	A traffic light controller may provide predicted phase-change events such as time-to-green, time-to-red to other vehicles nearby	For example, via SPAT/MAP messages (as defined in ETSI TS 103 301 [i.13]).

Table 4: Requirements for road topology and geometry

Id	Competency Question/Statement	Possible answer
AUTO-71	What is a road topology?	Road topology is a representation form to describe how roads are connected within the road network.
AUTO-72	What types of road topology models are there?	Representation of a road topology differs according to different map specifications. In the present document, the specification defined by HERE [i.8] is adopted as reference.It uses two models which are based on NDS (Navigation Data Specification [i.9]): - Road centreline model: uses the concepts of links and nodes, 2D geometry based on polylines and shape points, and attributes. - Lane model: uses the concepts of lane groups, lane group connectors, individual lanes and lane connectors. It includes 3D polyline geometries of lane boundaries and lane paths, as well as lane-level attribution. The two models can be logically connected in both directions. Each Lane Group Connector (Lane Model) has a position on a Link in the Road Centreline Model. And every portion of a Lane Group is associated with a Link in the Road Centreline Model.
AUTO-73	What is a node?	A node is a point with latitude and longitude position used to form links.
AUTO-74	What is a link?	A Link is a directed polyline connecting two nodes with optional intermediate shape points
AUTO-75	What is a shape point?	A shape points is a geo-point with latitude and longitude providing generalized road centreline geometry.
AUTO-76	What is a lane group?	It is a set of one or more lanes.
AUTO-77	What is a lane?	A lane is a part of a road that is designated to be used by a single line of vehicles. The place at which lanes begin or end is called a lane group connector.
AUTO-78	What is a lane group connector?	It is a line between two 3D geo-points. Each Lane Group Connector has a unique identifier.

Id	Competency Question/Statement	Possible answer
AUTO-79	What types of geometries are relevant?	2D (latitude, longitude) and 3D geometry based on polylines of geo-points (latitude, longitude, altitude).
AUTO-80	What is a parking spot?	A location that is designated for parking.
AUTO-81	A parking spot has an identifier	It can be an integer (such as with stationID as defined in ETSI TS 102 894-2 [i.4]) or an UUID (string), etc. The purpose is to identify a parking spot within a parking area during data exchange with other devices/stations.
AUTO-82	A parking spot can have a description name	
AUTO-83	A parking spot has dimensions	
AUTO-84	What are these dimensions?	Length, width, height.
AUTO-85	A parking spot has a geometry defining the parking area boundaries and its centre point	
AUTO-86	A parking spot has a status	
AUTO-87	What status values can a parking spot have?	Free, occupied, reserved, closed
AUTO-88	What types of parking spot are there?	Normal parking or electric charging parking, charging or free, reserved for special permits (authorities, disabled, blue Zone, resident ...)
AUTO-89	What types of vehicles are allowed in the parking spot?	Cars, trucks, hazardous materials, camping-car
AUTO-90	What is the opening time availability?	Day, Night, 2h max…

Table 5: Requirements for vehicle environment

Id	Competency Question/Statement	Possible answer
AUTO-91	What is the vehicle environment?	The vehicle environment is made of entities which are present on the road in the neighbouring area.
AUTO-92	What classes of entities are part of the vehicle environment?	road side equipment, neighbour vehicles, VRUs, critical objects, notified events
AUTO-93	What are neighbouring vehicles?	Neighbouring vehicles are described as in Table 1.
AUTO-94	What are the types of neighbouring vehicles?	passenger car, bus, light truck, heavy truck, trailer, special vehicles, tram, emergency vehicle, agricultural.
AUTO-95	What are VRUs?	VRUs are vulnerable road users.
AUTO-96	What are the types of VRUs?	Pedestrians, light vehicles, e.g. bicycles, motorbikes.
AUTO-97	What are the sub-types of a pedestrian VRU?	adult, child, elderly person, pram, animal, blind person guided by a dog, rider off its bike.
AUTO-98	What are the sub-types of a light vehicle VRU?	bicycle, wheelchair user, skater, scooter, Segway, mounted horse.
AUTO-99	What are critical objects?	small object, medium object, large object.
AUTO-100	What are the types of events on the road?	trafficCondition, accident, roadworks, impassability, adverseWeatherCondition-Adhesion, aquaplannning, hazardousLocation-SurfaceCondition, hazardousLocation-ObstacleOnTheRoad, hazardousLocation-AnimalOnTheRoad, humanPresenceOnTheRoad, wrongWayDriving, rescueAndRecoveryWorkInProgress, adverseWeatherCondition-ExtremeWeatherCondition, adverseWeatherCondition-Visibility, adverseWeatherCondition-Precipitation, slowVehicle, dangerousEndOfQueue, vehicleBreakdown, postCrash, humanProblem, stationaryVehicle, emergencyVehicleApproaching, hazardousLocation-DangerousCurve, collisionRisk, signalViolation, dangerousSituation.

Id	Competency Question/Statement	Possible answer
AUTO-101	An entity has dimensions	
AUTO-102	What is the overall shape of an entity?	Sphere, Torus, Cylinder, Cone, Ellipsoid, Cube, Cuboid, Pyramid, Prism, Multiple shapes
AUTO-103	What are these dimensions?	3D: length, height, width
AUTO-104	An entity has a position	
AUTO-105	What types of position are relevant	- Absolute position, when expressed in terms of global coordinates (lat, long, alt), e.g. according to WGS 84. - Relative position, when expressing coordinates of a detected vehicle in the surrounding (e.g. an entity is x,y,z in front of the ego-vehicle or xyz from the road side sensor). - Position with respect to road topology (e.g. road, segment or lane) and lane characteristics (highway lane, road lane, bicycle lane, pavement, off-road).
AUTO-106	An entity has movement	
AUTO-107	What types of movement are relevant?	Static (position only), moving in same direction (speed, acceleration), moving in reverse direction (speed acceleration), crossing (speed, acceleration, direction).

8 Conclusions

The present document describes the use cases taken into account for the development of the SAREF4AUTO extension, namely:

1) platooning;
2) automated valet parking;
3) cooperative perception service;
4) vulnerable road users' protection.

The present document further defines the final requirements to be implemented in the SAREF4AUTO extension (107 requirements). These requirements are split into the following categories:

- vehicles (37),
- platoon (24),
- road side sensors and actuators (9),
- road topology and geometry (20) and
- vehicle environment (17).

Validation of these requirements is expected to be carried out formally while creating the SAREF4AUTO extension, leveraging the related initiatives identified in the present document. However, the validation has started by presenting subsets from the requirements table at an "Open Data Access" workshop held during the ITS European Congress on June 5 2019 and to the ETSI ITS WG1 (Application and Facilities layer standardization group) on July 9 2019.

Annex A: Bibliography

- ETSI TS 103 267: "SmartM2M; Smart Appliances; Communication Framework".
- ETSI TS 118 101: "oneM2M; Functional Architecture".
- ETSI TS 118 102: "oneM2M Requirements".

Annex B: Change History

Date	Version	Information about changes
February 2019	0.0.1	Creation of the preliminary Table of Content
April 2019	0.0.9	Early draft delivered to SmartM2M
July 2019	0.1.9	Stable draft delivered to SmartM2M
August 2019	0.2.0	Final Draft
September 2019	0.2.1	updated Figure 6
18 September 2019	1.1.1	Review by Technical Officer for publication

History

Document history		
V1.1.1	October 2019	Publication