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ESRIUM

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Deliverable 2.1
Use Case Definition

ESRIUM
SAFE AND EFFICIENT ROADS

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European Global Navigation Satellite Systems Agency

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Abstract
ESRIUM is a multi-national project with the common goal to increase the safety and resource efficiency of mobility on the road. The key innovation will be formed by a homogeneous, accurate and recent digital map of road surface damage and road wear. Further addressed as “road wear map”, it will contain unique information, which is of value to multiple stakeholders: road operators will be able to lower the road maintenance effort by optimal planning. Further, road operators will be able to lower road wear and increase traffic safety especially for heavy vehicles: considering the market introduction of partly automated truck fleets and platoons, the precise track of these vehicles can be adjusted by communicating precise routing recommendations in- and cross-lane. Truck fleet operators following these recommendations can receive tolling benefits, and increase the general safety for their vehicle fleet. Especially with the increasing levels of autonomy, systems will utilize infrastructure support to handle the requirements of the automated driving task and additional external requests. In ESRIUM, these opportunities are addressed by utilizing C-ITS infrastructure and EGNSS based localization in planning the trajectories of such automated vehicles. Key to the ESRIUM innovation is a precision localization service, which provides reliable locations of road damages and of the vehicles using the roads. Considering a European-level business-case, only Galileo may provide such a service in homogeneous quality, even at very remote locations on the European continent.

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EXECUTIVE SUMMARY

Road damages on highways and freeways lead to numerous construction sites and maintenance operations every year, which cause congestion, increased pollution and costs. Additionally, road damage also exposes road users to an increased risk of accidents. ESRIUM services shall help reduce the number of construction sites and reduce the associated problems by using digital services for smart road infrastructure utilization and predictive maintenance. By creating virtual road wear maps using artificial intelligence, road damage is to be detected at an early stage and preventive measures for equal and graceful degradation of the surface can be taken. With the help of compatible adaptive ADAS/AD systems and smart routing solutions, vehicles shall receive the necessary routing recommendation information while driving to avoid road damage zones in the form of lane-change manoeuvres or in-lane offsets.

In the context of the ESRIUM project, WP2 serves to define relevant requirements and specifications as well as to describe the specific use cases for the above-mentioned exemplary services. Accordingly, several objectives are pursued within the scope of this work package as listed below:

- Define core use cases to be investigated
- Derive detailed technical requirements from the defined use cases
- Derive detailed non-technical requirements (organizational, environmental) from the defined use cases
- Define system interfaces and specifications based on the requirements analysis
- Derive the baseline for the business case from the defined use cases

In order to achieve these goals, five tasks were defined. T2.1 aims to identify relevant use cases by describing how ESRIUM services can be applied in practice. T2.2, T2.3 and T2.4, which are based on T2.1, are subsequently used to define the requirements and specifications for such services, with T2.2 and T2.3 serving to identify both technical and non-technical requirements and T2.4 being carried out to define the system interface design. Furthermore, the baseline for the business case is derived in T2.5. The results of WP2 will subsequently be used as input for the next steps in the project or in the respective related work packages.

As part of WP2, Task 2.1 begins the process of defining needs and requirements by considering the full range of service offerings of the ESRIUM project. For this purpose, four use cases of ESRIUM services, including their benefits and potential audiences as well as their respective realization prerequisites and challenges, have been defined by collaborative input and contribution of all project partners.

These four use cases are: ‘AI-based road damage prediction to support enhanced road maintenance planning’ (UC1), ‘Routing Recommendations based on the road wear map, provided via C-ITS messages’ (UC2), ‘C-ITS Message ‘GNSS-correction data’ provision’ (UC3), and ‘Wear map content provision’ (UC4).

The use cases developed in this task serve as the main input for the subsequent tasks dealing with the definition of the corresponding technical and non-technical requirements and are intended to help bridge the gap between customer and development perspectives.

DOCUMENT REVISION

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ACRONYMS USED

Acronym	Explanation
AD	Autonomous Driving
ADAS	Advanced Driver Assistance Systems
AI	Artificial Intelligence
C-ITS	Cooperative Intelligent Transport Systems
DoW	Description of Work
EGNSS	European Global Navigation Satellite Systems
Galileo OS-NMA	Galileo Open Service – Navigation Message Authentication
OEM	Original Equipment Manufacturer
RTK	Real Time Kinematic

SECTION 1: INTRODUCTION / SCOPE

1.1. ESRIUM at a glance

The ESRIUM project is a joint multinational effort to improve the safety and resource efficiency of road transport. The goal of the project is to create an accurate digital map of road surface damage and road wear, which will enable stakeholders to proactively take resource-saving measures. Thus, routing recommendations in terms of lane changes or lane offsets can both reduce road wear and increase traffic safety. At the same time, preventive measures of this kind can avoid or delay any road maintenance measures, and artificial intelligence can be used to identify potential road damage at an early stage. Accordingly, ESRIUM's innovation offers significant advantages in terms of road safety, road user satisfaction, financial aspects as well as ecological benefits (e.g. by avoiding road works). In order to be able to develop target-oriented services that are suitable for practical use, various use cases were developed within the framework of the project to illustrate the range of services for the individual target groups. The results of these use cases are presented in more detail below.

1.2. Objective

The objective of this document is to communicate the results of Task: “T2.1: Use Case Definition” as a part of the work package: “WP2: Use Cases and Requirements Analysis”. In this task different application scenarios (use cases) for ESRIUM services were developed. The use cases were thereby based on potential target groups such as road operators, logistics providers and end users and serve as an illustration of ESRIUM services and as a foundation for the development of technical and non-technical requirements as well as the system interface design.

1.3. Intended audience

The dissemination level of “D2.1: Use Case Definition” is public. This document is intended to be a guideline for the definition of the technical and non-technical requirements as well as the system interface design for ESRIUM services.

1.4. Document Structure

The following chapters are organised as follows:

- SECTION 2: discusses the methodological approach (use cases) to describe the full range of ESRIUM service capabilities. In addition to the general procedure for developing respective use cases, the general structure of these use cases is briefly described.
- SECTION 3: describes the respective use cases based on the predefined structure. The chapter is divided into four subsections, each of which represents a separate use case.
- SECTION 4: presents the contribution of said use cases to other tasks as well as work packages within the ESRIUM project.

SECTION 2: METHODOLOGY

From a methodological approach, the use case description is based on the ESRIUM project proposal and business plan.

Due to the Covid-19 pandemic situation we changed the methodological approach to validate our use cases. Instead of a validation approach within one stakeholder workshop (as stated in the DoW), we moved to a stepwise approach for coming-up with the use cases and its validation from several point of views as follows.

(1) Based on the DoW, the team of FHO performed a use case analysis to develop a detailed description of the services that can be offered by ESRIUM. Within this analysis, four application scenarios of ESRIUM services including their potential target groups and application requirements, as well as the respective challenges were defined and developed.

(2) This internal view has been validated first with the key customer (road operator) ASFINAG.

(3) After this bilateral workshop with ASFINAG and the integration of related feedback in an advanced version of the use cases, another internal validation process with all project partners took place to develop a consolidated consensus within the diverse and multidisciplinary team of the ESRIUM project. One of the main advantages of the ESRIUM team is the coverage of the different parts of the necessary value chain - including the potential customer and road operator role of ASFINAG.

(4) Furthermore, obtaining external feedback from ASECAP confirmed the relevance and importance of use cases, which is also stated in ASECAP's C-ITS Manifesto (cf. ASECAP 2021, p.6)[1].

During the formulation process of the use cases, legal rules (GDPR) have been discussed with regard to road sensing procedure with project partners VIF and JR (EUC-001). C-ITS-related legal questions (EUC-002 and EUC-003) have been discussed with ASFINAG as message provider. However, C-ITS messages do not contain any GDPR-related information, as they only contain recommendations and actions that have to be taken by the driver or the automated vehicle. Therefore, until automation level 3, the responsible entity is the driver. Furthermore, EUC-004 also does not contain any GDPR-relevant information. Maintenance processes were also involved into the validation process with ASFINAG.

All four use cases have been described in detail with the following structure:

Use Case Description	
Use Case #	<Defined Use Case ID>
Name	<Title of the respective use case>
Preliminary pain points	<Pain points addressed by the ESRIUM service>
Short description	<Textual description of the use case>
State of Practice	<Textual description of the state of practice>
Preliminary target group	<Target group of the respective ESRIUM service>
Demo-site	<Site for Use Case demonstration>
Key assumption	<Key assumptions necessary for service realization>

[1] ASECAP (2021): ASECAP C-ITS MANIFESTO. URL: http://www.asecap.com/images/News/PDF/2021_ASECAP_CITS_MANIFESTO_final.pdf

Involved stakeholder roles	<Stakeholders contributing to the service realization>
Involved project partners	<Project partners contributing to the service realization>
Realisation prerequisites	<Prerequisites regarding physical and digital infrastructure as well as data availability>
Challenges / Barriers / Open issues	<Potential obstacles of points still to be clarified>
Target / Evaluation metric	<Methods for measuring the results of the Use Cases>
Preliminary USP	<Unique Selling Point created by the Use Case>
Technical requirement (T2.2)	<Technical requirements related to the Use Case>
Non-technical requirements (T2.3)	<Non-technical requirements related to the Use Case>
System interface design (T2.4)	<System interface design aspects related to the Use Case>
Business case baseline (T2.5)	<Business Case aspects related to the Use Case>

Table 1: ESRIUM use case description structure.

Before describing to the use cases in detail, a short description of the involved demo-sites will be provided. More information will follow in WP5 – Proof of concept and in-vehicle validation. Two Austrian testing areas are the basis for ESRIUM pilot demonstrations: AlpLab and DigiTrans. Additionally, the Finnish test track is described where EUC-001 will be implemented.

AlpLab

The Austrian Test site AlpLab is located in the Graz area on the motorway A2 between Graz West and Lassnitzhöhe. More than 20 km of the motorway segment are equipped with both state-of-the-art and innovative sensory equipment. The Austrian test site is equipped with gantries in 12 positions. Most of the special sensory equipment is mounted on these gantries. 12 roadside units are installed on the Austrian test site mounted on already existing gantries on the ASFINAG Network.

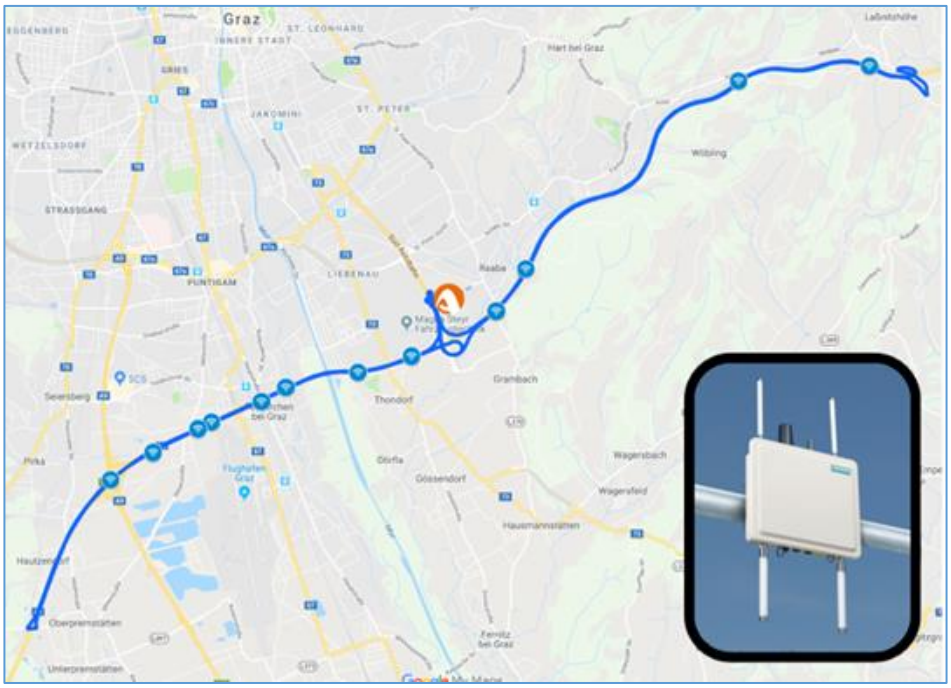

Figure 1 - Austrian Test site AlpLab (20km) is located in the Graz area on the motorway A2 between Graz West and Lassnitzhöhe

Along a stretch of about 1.5 km, traffic data sensor sets have been installed. They cover both driving directions and each of the lanes. In 29 positions, sensory equipment for weather and environmental data is installed. 26 cameras with incident detection are located on the Austrian test site in both driving directions. In the southern part of the test track radar sensors are installed covering a stretch of around 1.5 km with high resolution. The radar equipment is currently being upgraded in order to support the creation of collective perception messages (CPM) within the following months.

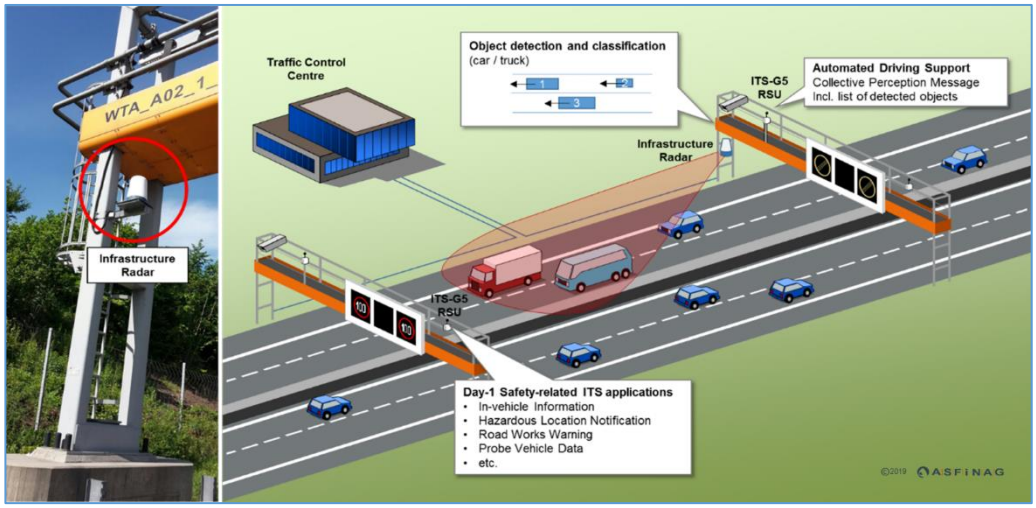

Figure 2 - Traffic data sensor sets have been installed along a stretch of about 1.5 km

Mobile warning trailers are indispensable aids in securing road work areas. The most important features are the display panel and the well-visible warning lights. Approaching vehicles are warned visually by these means. Securing road work zones is essential for traffic safety and for the safety of the workers. In 2017, ASFINAG has acquired so called IMIS mobile warning trailers. IMIS stands for "Intelligent Mobile Information System". The expanded functions of this new generation of mobile warning trailers are:

- LED graphic panel,
- Remote configuration and remote control by the traffic management centre,
- Video camera,
- Support of travel time assessment,
- Traffic detection,
- CB radio warning, and
- Car-to-X communication.

These functions will enable the mobile warning trailers to support even more use cases.

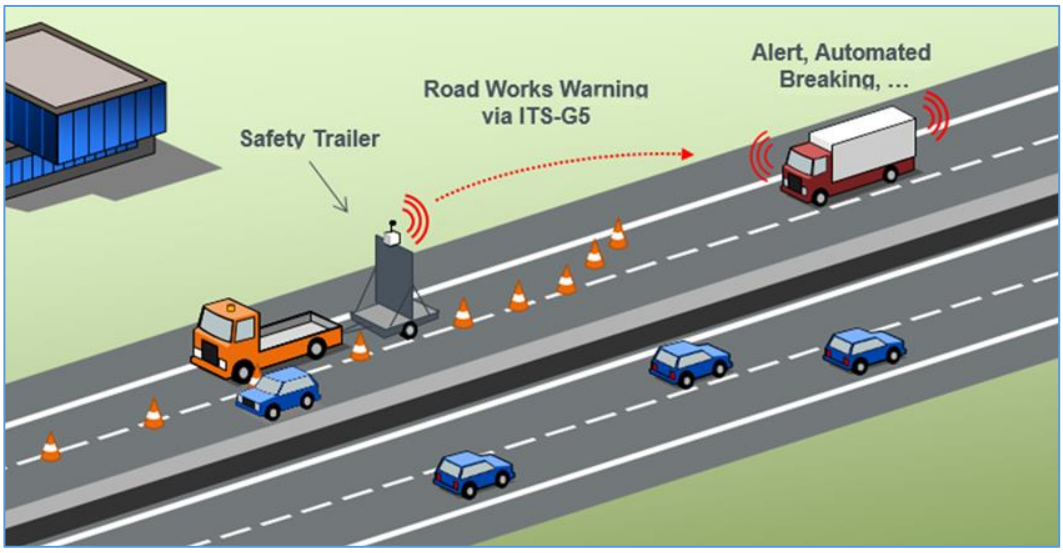

Figure 3 - Mobile warning trailers are indispensable aids in securing road work areas

The DENM roadworks warning by the IMIS Trailer is the first ASFINAG C-ITS service already available in the end-user vehicle, as can be seen in the picture below.

Figure 4 – End-user vehicle shows C-ITS message roadworks warning

The Austrian Test site AlpLab also includes the ÖAMTC (Austrian Automobile, Motorcycle and Touring Club) test area which is located in Lang/Lebring, about 30 km south of the city of Graz, Austria. The facility is normally used as a basic & advanced driver training centre as well as a proving ground for vehicle evaluations. The FT4 section of the proving ground, as shown in Figure 5, is used as a test track for the project demonstrations and features a straight road section with an approximate usable length of 250 m and width of at least 10 m.

Figure 5: The FT4 section is used as a test track for the in-lane change manoeuvres.

Within the FT4 section, 3 virtual lanes with a width of 3.5m each plus additional manoeuvre space are usable. In the middle section, 5 lanes can be modelled along a 50m section, where one lane has a switchable high-slip surface. The natural bottleneck section down the stretch allows modelling of roadworks zone and on-ramp scenarios within the test track.

Figure 6: Within the FT4 section, several virtual lanes as well as a natural bottleneck are available.

DigiTrans

The Austrian test site DigiTrans (www.digitrans.expert) provides know-how and test infrastructure and accompanies the testing, validation, research and implementation of autonomous commercial vehicles and their various applications. The DigiTrans team is thus helping to shape the future of autonomous transport sustainably. The focus is on automated and autonomous vehicles and driving functions as well as driverless mobility and transport systems in the field of municipal services, logistics and heavy traffic.

The following figure shows the fields of competence of the testing region DigiTrans.

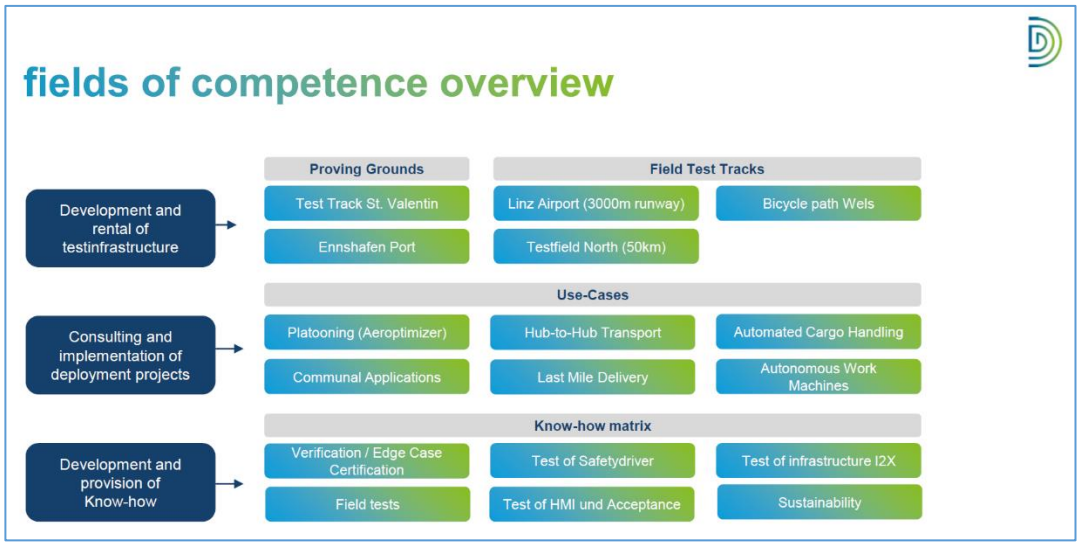

Figure 7 – DigiTrans fields of competence overview

On the DigiTrans field test routes (motorway junction: A1 / A7, as well as Linz Airport and Enns harbour), data can be obtained for the development of the approval processes for autonomous driving. In addition, intelligent infrastructures can be developed and automated transport modes can be tested in real traffic. The closed test area – the test track in St. Valentin shown in the figure below – also offers additional options for testing autonomous vehicles and commercial vehicles on asphalt and off-road routes.

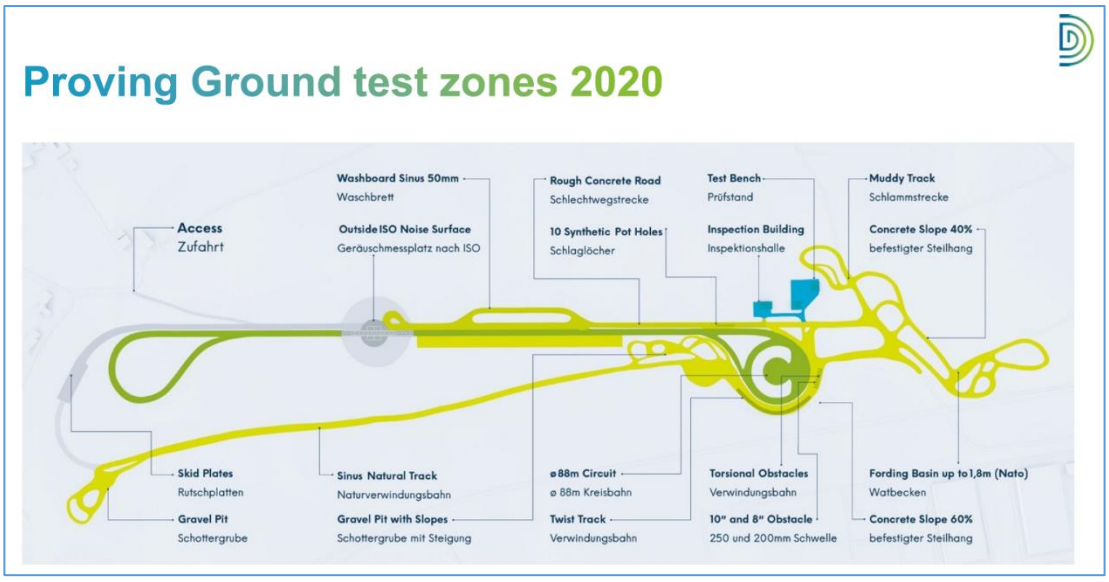

Figure 8 – DigiTrans proving ground test area in St. Valentin

The user acceptance testing will take place in the "North test field" between motorway A1 and A7 which is in a development phase and have the following corner stones:

- 15 km real test environment on motorways
- Highly digitized infrastructure including four C-ITS ITS-G5 roadside units on the motorway
- Complete equipment of various ISAD levels
- Up to 3 lanes and entry and exit lanes
- Different speed limits (80/100/130)
- High truck density / daily traffic jams
- Variety of complex traffic scenarios (intersections / pedestrians / cyclists)
- Ideal for testing logistics scenarios in the city zone

Finnish test site

The Finnish test site is located in the municipality of Muonio in the Finnish Lapland, on the road E8 and is also known as road 21 or Aurora when referring to the test environment for autonomous driving. The exact test sections will be selected when collecting the ground truth data. If the road on the E8 is in too good a condition, alternative road sections are chosen on road 79, which is also in Muonio and has a lot of sections classified as bad or very bad pavement condition. The advantage of selecting these sections as late as possible is that if there were any local repairs during the summer, most of them would be finished by then.

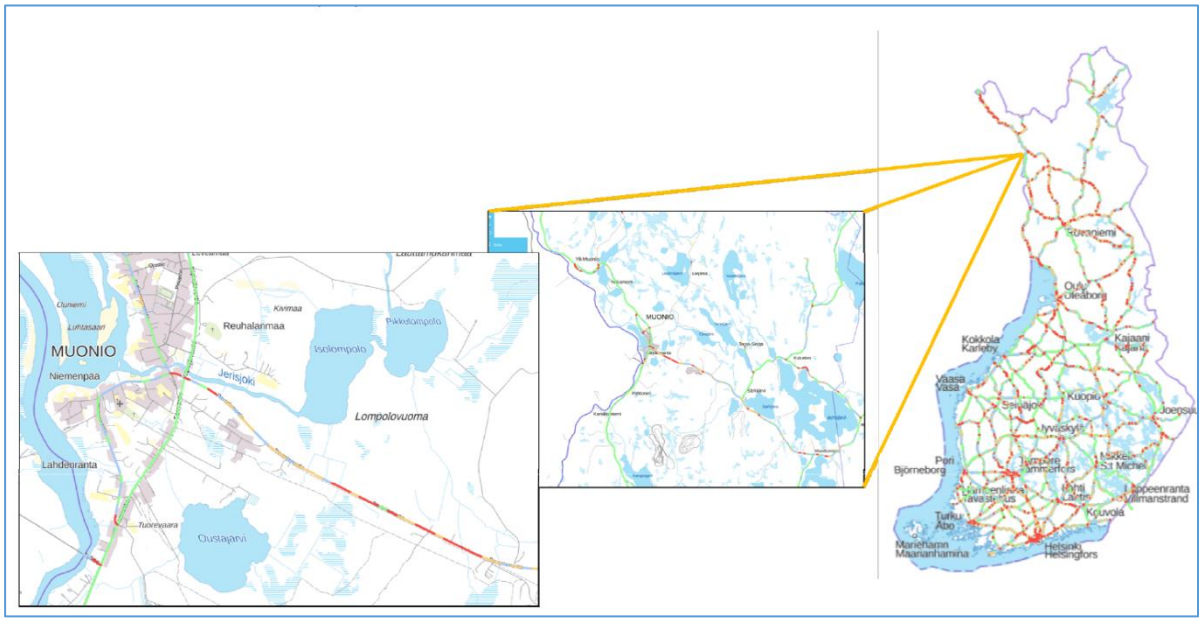

Figure 9: Finnish test site

SECTION 3: ESRIUM USE CASES

During the course of the development of the use case descriptions, specification of potential areas of application for ESRIUM services along with several important and related components were identified by the project team, which shall be implemented in the course of the project. The planned functionalities and developmental steps identified in the process can be listed as follows:

- Road sensing and damage mapping system development
- Road damage map / road wear map creation
- C-ITS based RTK-correction message standard development for EGNSS
- An intra- and in-lane position recommendation system concept and prototype demonstration utilizing the Road Wear Map information
- Development of ADAS/AD functions that are capable to utilize the routing and position recommendations
- Integration of Galileo OS NMA based position authentication

The following figure illustrates the ESRIUM technical components and responsible project partners to better understand the upcoming use cases.

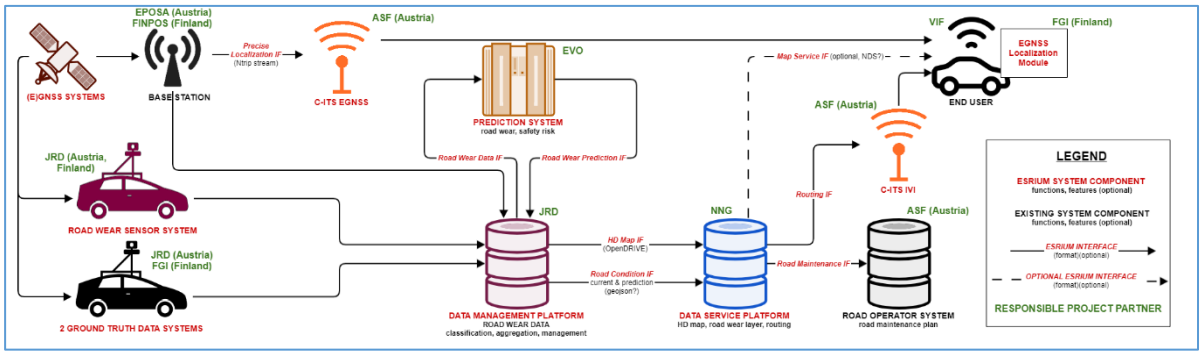

Figure 10 – ESRIUM technical system components

The (E)GNSS System will provide high accuracy positioning using RTK technology, and will contain a sensors system and a user car platform. Both GNSS systems foster EGNSS differentiators, including dual frequency measurements and OS-NMA. The systems will target centimetre-level positioning accuracy leveraging on RTK and corrections from local reference stations. RTK signal data will be converted into a corresponding C-ITS based on the ETSI TS 103 301 and the ISO/TS 19091:2019 standards to enhance END USER services such as lane recommendations. High accuracy position, velocity and attitude data will be provided for post processing road wear data. The GROUND TRUTH DATA SYSTEM will use algorithms or train neural networks for the automated detection and classification of road wear, training data of highest quality is needed. This system will take care of the collection of survey grade road surface data of defined test tracks in Austria and in Finland, as well as the semi-automatic labelling and geo-referencing of road wear to produce a ground truth dataset. The ROAD WEAR SENSOR SYSTEM will be a calibrated solution for the collection of road surface data, which consists of several cameras, one or more LiDAR sensors and a lower-cost EGNSS-enhanced inertial navigation system. The sensor platform will be fitted to test vehicles provided by JRD and ASF (Austria) and FGI (Finland) in order to collect road surface data in Austria and in Finland during an extensive data collection phase. Based on acquired road surface measurements (from the Ground Truth Data System and the Road Wear Sensor System) the DATA MANAGEMENT PLATFORM will automatically detect and classify road surface damage. Detection and classification will be primarily done on image data. It will serve input data for the PREDICTION SYSTEM (via Road Wear Data Interface) that will provide a description and depiction of road performance indicators with suitable deterioration models, reliability calculation approaches and forecast models with a clear connection between time-dependent and mechanical parameters as well as other influencing variables. The results will be sent back to the DATA MANAGEMENT PLATFORM via the ROAD WEAR Prediction Interface. Detected, classified and geo-referenced road wear features will be aggregated in the DATA MANAGEMENT PLATFORM too. Processed data including the prediction data will be provided for the DATA SERVICE PLATFORM via the Road Condition Interface. The HD base map shall be served through a dedicated HD Map Interface. Aggregated, verified and validated data on road wear conditions shall be stored and provisioned by the DATA SERVICE PLATFORM. Standardized road wear information with routing recommendations shall be provided (Routing Interface) for the road operator as the input of the C-ITS IVI service. The Road Maintenance Interface shall provide road damage and prediction information for the road operator road maintenance planning system in a pre-processed format. The road operator will operate the C-ITS services (EGNSS and IVI) for the END USERS.

These features to be implemented in the course of the project were subsequently used as a basis for identifying potential target groups. In doing so, three key target groups were identified, namely (1) road operators, (2) B2B customers like OEMs, wear map providers and navigation service providers and (3) end users (e.g., truck drivers, logistics service providers, automated vehicle owners, etc.). As a result, both the planned functionalities as well as the identified target groups were used to formulate appropriate application scenarios, with a total of four use cases being formed.

Within Task 2.1 the following four ESRIUM use cases have been investigated in detail:

- *Use Case 1: AI-based road damage prediction to support enhanced road maintenance planning*
- *Use Case 2: Routing Recommendations based on the road wear map, provided via C-ITS messages:*
    - *Manoeuvres between lanes*
    - *Manoeuvres within the lane*
    - *User compliance-based incentive concepts (e.g. tolling)*
- *Use Case 3: C-ITS Message 'GNSS-correction data' provision*
- *Use Case 4: Wear map content provision*

3.1. Use Case 1 – AI-based road damage prediction to support enhanced road maintenance planning

The following table explains the description of ESRIUM's first use case. Based on the ESRIUM use case description structure in the previous section all respective information is provided.

Use Case ID	EUC-001
Name	**AI-based road damage prediction to support enhanced road maintenance planning**
Preliminary Pain points	● High costs due to late detection of road damages ● Long-term construction sites are the worst case for all road operators. Negative impact on traffic efficiency, traffic safety and CO2-emissions must be avoided for better planning. ● High costs and impacts due to safety risk and caused incidents ● Traffic jams and related customer complaints
Short description	Based on the developed road sensing and damage mapping system, a Road Wear Map layer utilizing AI-based road damage predictions is to be developed and provided to the road operator. Based on the predicted onset of road damages the road operator can set up a derived predictive road maintenance and action plan to proactively reduce more severe road damages.
State of Practice	Current road condition measurement is costly and can only take place in appropriate weather conditions to capture all desired data. In Austria, the highways are surveyed in a 4-year cycle (lane 1, lane 2, ramps, spare year). Predictive systems for road maintenance are currently not yet available
Preliminary Target group	Road operators (e.g. ASFINAG)
Demo-site	Austria (Graz, Linz): All use cases will be implemented in the demo site in Graz (AlpLab) and all user acceptance evaluation with end users will take place in the demo-site in Linz (DigiTrans) - including C-ITS testing. More information on demonstration issues is part of WP5.Additionally, this use case will be implemented in the Finnish demo-site.
Key assumptions for successful demonstration during the project	● EGNSS supported (accurate and authenticated) positioning of the road sensing vehicle available ● Road sensing vehicle equipped with EGNSS supporting system available ● Machine learning algorithm to quickly identify damages via the road sensing vehicle available ● Map-layer with identified damages available

	• Algorithm for translating detected damages into maintenance actions available • Map-layer with maintenance actions available
Involved stakeholder roles	EGNSS data/service provider, ground truth data system provider, road wear sensor system provider, prediction system provider, data management platform provider, data service platform provider (wear map service provider), road operator (asset management)
Involved project partners	ASF, EVO, NNG, FGI, JRD, VIF, FHO (Evaluation), POLIMI (Evaluation)
Realisation Prerequisites (physical infrastructure, digital infrastructure, data availability)	**Physical infrastructure:** • Road sections with visible damages on the road surface • EGNSS supported sensing system • Road sensing vehicle **Digital infrastructure:** • Machine learning software to predict road damages **Data availability:** • Road surface data
Challenges/Barriers/Open issues	• Is historical information on traffic density (including mix of traffic, speed, lanes used) available for prediction of surface degradation? Is it planned to be added? • Is road weather related historical information available? • Are road materials and structure information taken into account? • Are framework conditions taken into account that cause impulsive driving manoeuvres such as sudden braking and thus, leading to increased road wear (e.g., speed reductions zone, on- and off-ramps, etc.)?

Target/Evaluation metric	• Quantity of identified damages (type, classification, total percentage distribution)
	• Quality of classification of the identified damages
	• Precision of the identified damages
	• Context information regarding road damages (asphalt type, traffic frequency (vehicles/min), weather, etc.)
	• Time/km for operating the sensor vehicle
	• Costs/km for operating the sensor vehicle
	• Saved costs due to avoiding construction works
	  ○ Labour hours (road maintenance, control trips, administrative effort, etc.)
	  ○ Material costs
	  ○ External costs (congestion costs, noise costs, air pollution costs, climate costs, etc.)
	• Saved CO2-emissions due to avoiding construction work
	• Expected type of maintenance activities for the identified damage including information on e.g. length, duration, time of the day, or time of the year
	• Expected traffic volumes during the maintenance activity (by vehicle type)
	• Historic data about accidents on this road stretch and for similar construction zones
	• Travel times on the stretch without road works

Expected benefits	Allows enhanced road maintenance planning which could lead to a reduction of overall maintenance activities and therefore to a possible reduction of CO2-emissions (avoidance of construction zones which lead

	to traffic jams and increased CO2-emissions). It has to be investigated if an increased number of lane changes based on ESRIUM service recommendations leads to more incidents and respective increased travel time.[2]
Preliminary Unique Selling Proposition (USP)	Our road maintenance service is safe (due to high validity of the service), delightful (due to helping to make our world better with regard to CO2-emission reduction) and effective (due to using the right tools and cost-efficient measures when it comes to road maintenance actions leading to safer roads).
Technical requirements (T2.2)	After setting-up the technical requirements in T2.2, the respective technical requirements for this use case will be provided in D2.2.
Non-technical requirements (T2.3)	After setting-up the non-technical requirements in T2.3, the respective non-technical requirements for this use case will be provided in D2.2..
System interface design (T2.4)	After setting-up the system interface design in T2.4, the respective systems for this use case will be provided in D2.3..
Business case baseline (T2.5)	After setting-up the business case baseline in T2.5, the respective information for this use case will be provided in D2.4..

Table 2: Use Case 1 – AI-based road damage prediction to support enhanced road maintenance planning.

The following figure shows the basic principle of EUC-001 in illustrative form.

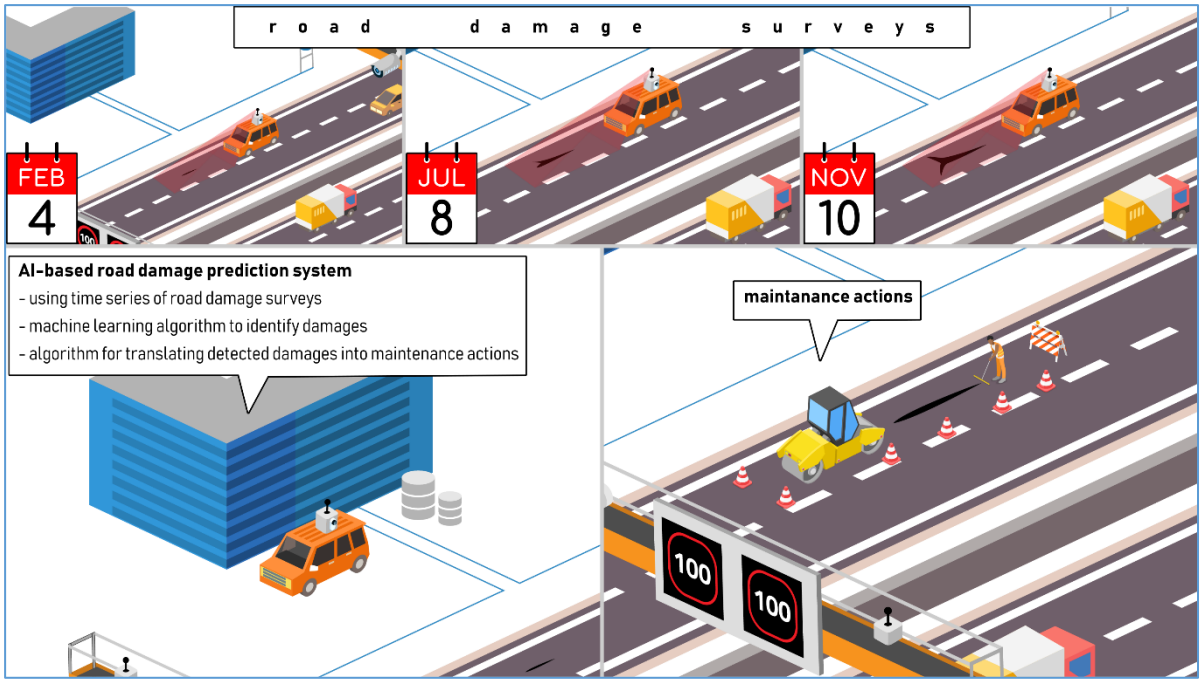

Figure 11: Visualization EUC-001

[2] Testing the impact of lane changes on traffic in terms of incidents and increased travel time is not the focus of the project and is therefore not carried out within ESRIUM.

3.2. Use Case 2 – Routing recommendations within and between lanes based on the road wear map, provided via C-ITS messages.

The following table explains the description of ESRIUM's second use case. Based on the ESRIUM use case description structure in the previous section all respective information is provided.

Use Case ID	EUC-002
Name	**Routing recommendations within and between lanes based on the road wear map, provided via C-ITS messages.**
Preliminary Pain points	• Additional costs for on-board unit (for receiving messages) • Specific vehicle characteristics are not available for broadcast services - only generic recommendations may be provided (meaning that the business logic is on the infrastructure side). • Safety risk due to road damages • Safety risk due to driver distraction from complex C-ITS messages
Short description	Based on very early damage prediction, the road operator can derive an enhanced action plan to proactively avoid severe road damages. One of the actions is to provide EGNSS-based lane change or in-lane offset recommendations for the drivers and end users in general, in order to avoid severe road damages and critical safety-related situations (vehicle side damage avoidance). User compliance-based incentive concepts (e.g. tolling) will be investigated in this scope.
State of Practice	Use cases from ASFINAG for the transmission of construction site information via C-ITS message to the vehicle; C-ITS messages for lane change or in-lane offset recommendations due to road damage are not yet available.
Preliminary Target group	End users (drivers of automated trucks and passenger cars), OEMs, logistics operators
Demo-site	Austria (Graz, Linz): All use cases will be implemented in the demo site in Graz (AlpLab) and all user acceptance evaluation with end users will take place in the demo-site in Linz (DigiTrans) - including C-ITS testing. More information on demonstration issues is part of WP5.
Key assumptions for successful demonstration during the project	• Map-layer with identified damages available • Algorithm for translating detected damages into maintenance actions and avoidance recommendations available • Map-layer with maintenance actions and avoidance recommendations available (e.g. routing recommendations within and between lanes) • C-ITS messages available for routing recommendations (within and between lanes) • C-ITS infrastructure (roadside units) available • Automated demo-car (VIF) available (receiving C-ITS messages, triggering adaptable automated vehicle actions) • Trucks (manual driven) with C-ITS on-board units available for assessing user acceptance
Involved stakeholder roles	EGNSS data/service provider, ground truth data system provider, road wear sensor system provider, prediction system provider, data management platform provider, data service platform provider (wear

	map service provider), road operator (C-ITS provider, traffic management), end user of this service (e.g. logistics provider, truck driver, automated vehicle), OEM
Involved project partners	VIF; ASF, JRD, FHO (Evaluation), POLIMI (Evaluation), NNG
Realisation Prerequisites (physical infrastructure, digital infrastructure, data availability)	**Physical infrastructure:** ● C-ITS roadside unit ● C-ITS on-board unit ● Automated demo-car (VIF) ● Trucks (manual driven) with C-ITS on-board units **Digital infrastructure:** ● Traffic management centre providing C-ITS messages **Data availability:** ● Map-layer with current road wear ("maintenance actions" are derived from the first use-case)
Challenges/Barriers/Open issues	● How do lane changes based on routing recommendations affect road safety and road efficiency? ● How do we inform other road users about potential lane changes, especially those who cannot receive C-ITS messages? ● What are the conditions for lane change manoeuvres (e.g. number of lanes, traffic density, weather conditions, etc.)? ● How do recommendations within a lane take into consideration the different size of vehicles?
Target/Evaluation metric	● Quantity and quality of C-ITS messages (routing recommendations) received in the VIF demo-car (including accuracy, latency) ● Deviation between recommended trajectory and driven trajectory of the VIF demo-car ● Quantity and quality of received C-ITS messages (routing recommendations) in fleets during test week (including accuracy, latency) ● Monitoring of drivers' behaviour (percentage of vehicles following the recommendations like lane changes). Deviation between recommended trajectory and driven trajectory of the driver (during test week) ● Users' acceptance of routing recommendation-related C-ITS messages (qualitative assessment) ● Reasons for ignoring C-ITS message: e.g. not enough space for manoeuvre, message unclear, benefit unclear, etc.
Expected benefits	Prevention of severe road damage by proactively set measures in a very early phase of the expected road damage; equal/gradual utilisation of the road to prevent unequal road-surface wear (e.g. recommended lane changes and randomised lane offsets via C-ITS).
Preliminary Unique Selling Proposition (USP)	With this service, all the end users, particularly the logistics operators and truck drivers feel safe (due to high validity of the service), relaxed (due to user-friendly service integration), and effective (due to getting benefits from complying with road operators' recommendations)

Technical requirements (T2.2)	After setting-up the technical requirements in T2.2, the respective technical requirements for this use case will be provided in D2.2.
Non-technical requirements (T2.3)	After setting-up the non-technical requirements in T2.3, the respective non-technical requirements for this use case will be provided in D2.2.
System interface design (T2.4)	After setting-up the system interface design in T2.4, the respective systems for this use case will be provided in D2.3.
Business case baseline (T2.5)	After setting-up the business case baseline in T2.5, the respective information for this use case will be provided in D2.4.

Table 3: Use Case 2 - Routing Recommendations within and between lanes based on the road wear map, provided via C-ITS messages.

The following figure shows the basic principle of EUC-002 in illustrative form.

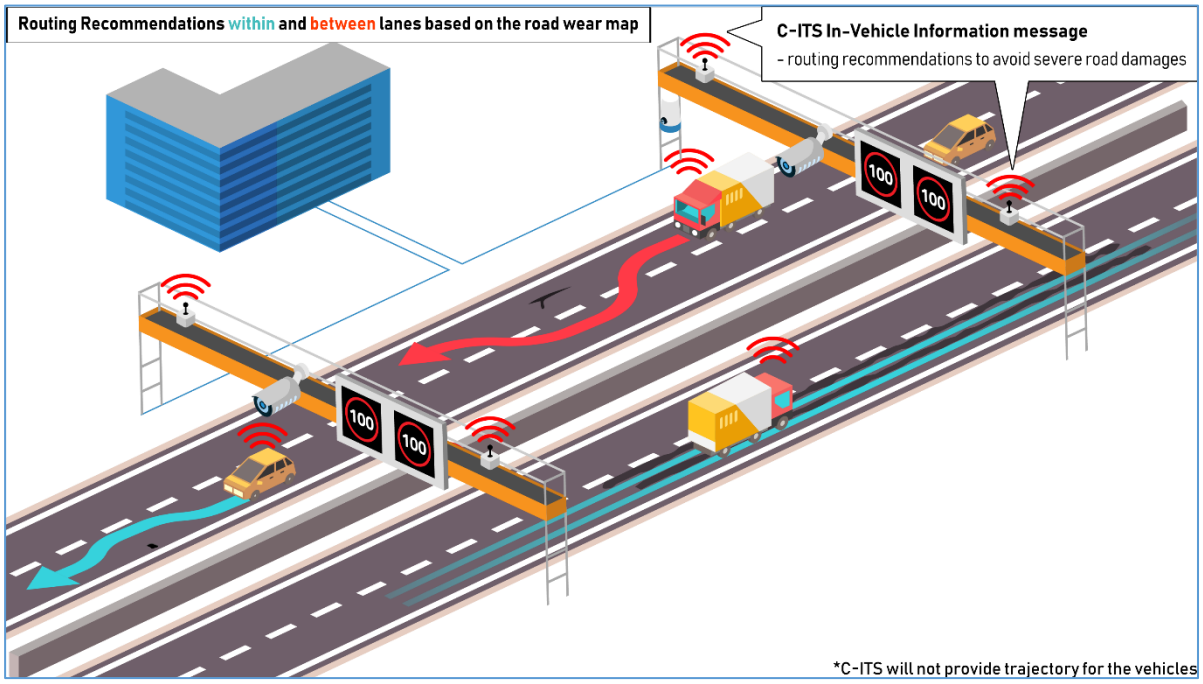

Figure 12: Visualization – EUC-002

3.3. Use Case 3 - C-ITS Message 'GNSS-correction data' provision

The following table explains the description of ESRIUM's third use case. Based on the ESRIUM use case description structure in the previous section all respective information is provided.

Use Case ID	EUC-003
Name	**C-ITS Message 'GNSS-correction data' provision**
Preliminary Pain points	● Loss of high-precision positioning and therefore ADAS systems are not working correctly ● Increased safety risk due to loss of high-precision positioning ● Liability costs in case of accidents
Short description	The road operator provides EGNSS-correction data to end users for enhancing the positioning accuracy of end users' vehicles. Furthermore, vehicles carrying the sensor array use that service.
State of Practice	EGNSS-supported localization systems are currently not used to determine the position of the vehicle. The mainstream commercial automotive localization solutions are based on the GPS system alone and provide only a rough localization capability (using the civilian L1 carrier signal) on the order of 3m, which is only suitable for global navigation purposes. With the provision of GNSS correction data through C-ITS, the localization accuracy can be increased to ~10 cm to allow new applications, some of which are analyzed and demonstrated in this project
Preliminary Target group	End users (drivers of automated trucks and passenger cars) and vehicle provider (carrying sensor array), OEMs for optimising their ADAS systems (e.g. lane assist, C-ACC)
Demo-site	Austria (Graz, Linz): All use cases will be implemented in the demo site in Graz (AlpLab) and all user acceptance evaluation with end users will take place in the demo-site in Linz (DigiTrans) - including C-ITS testing. More information on demonstration issues is part of WP5.
Key assumptions for successful demonstration during the project	● GNSS-correction information available for road operator ● C-ITS messages available for providing the EGNSS-correction data for both accurate and authenticated positioning ● C-ITS infrastructure (roadside units) available ● Automated demo-car (VIF) available (receiving C-ITS messages, triggering adaptable automated vehicle actions)
Involved stakeholder roles	EGNSS data/service provider, road operator (Traffic Management, C-ITS provider), end user of this service (e.g. logistics provider, truck driver, automated vehicle), OEMs
Involved project partners	FGI, ASF, VIF, JRD, FHO (Evaluation), POLIMI (Evaluation)
Realisation Prerequisites (physical infrastructure, digital infrastructure, data availability)	**Physical infrastructure:** ● C-ITS roadside unit ● C-ITS on-board unit ● Automated demo-car (VIF) **Digital infrastructure:** ● Traffic management center providing C-ITS messages **Data availability:** ● EGNSS-correction data

Challenges/Barriers/Open issues	• What to do in case of failure, e.g. if no correction data can be provided?
Target/Evaluation metric	• Quantity and quality of C-ITS messages (EGNSS-correction data) received in the VIF demo-car • Reduction of vehicle position error in meters, compared to uncorrected GNSS position • Better positioning but also better lane level map matching of the ego vehicle
Expected benefits	• Precise positioning of vehicles allows following the lane change or in-lane offset recommendations issued by the road operator and proactive avoidance of road wear geo-located in the road wear map layer (if available in the vehicle). • Providing the EGNSS correction data via C-ITS acts as an additional source of correction information and adds redundancy for requirements of functional safety for automated mobility.
Preliminary Unique Selling Proposition (USP)	We provide supportive localisation information to your infrastructure operations so that your customers feel safe (due to high validity of the service) with high convenience.
Technical requirements (T2.2)	After setting-up the technical requirements in T2.2, the respective technical requirements for this use case will be provided in D2.2.
Non-technical requirements (T2.3)	After setting-up the non-technical requirements in T2.3, the respective non-technical requirements for this use case will be provided in D2.2.
System interface design (T2.4)	After setting-up the system interface design in T2.4, the respective systems for this use case will be provided in D2.3.
Business case baseline (T2.5)	After setting-up the business case baseline in T2.5, the respective information for this use case will be provided in D2.4.

Table 4: Use Case 3 - C-ITS Message 'GNSS-correction data' provision.

The following figure shows the basic principle of EUC-003 in illustrative form.

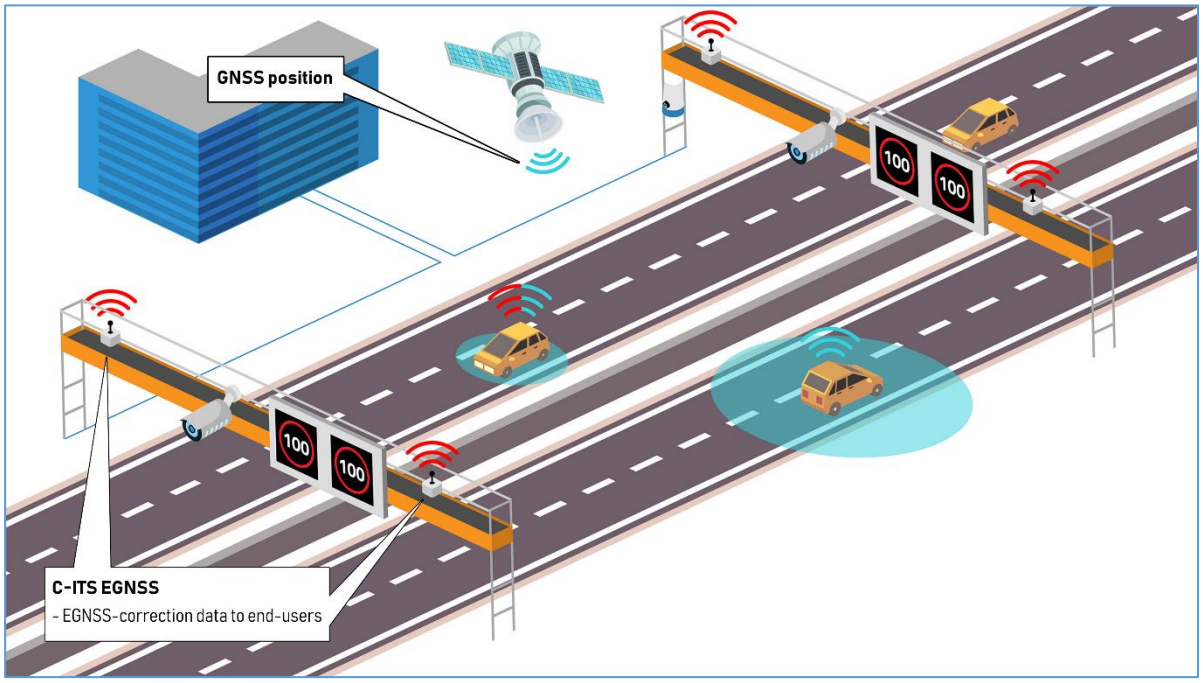

Figure 13: Visualization – EUC-003

3.4. Use Case 4 - Wear-map content provision

The following table explains the description of ESRIUM's fourth use case. Based on the ESRIUM use case description structure in the previous section all respective information is provided.

Use Case ID	EUC-004
Name	**Wear-map content provision**
Preliminary Pain points	● Traffic safety risks due to construction works ● Traffic safety risks due to damages on the road surface
Short description	Based on the developed road sensing and damage mapping system a road wear map is provided to e.g. navigation service providers, OEMs and road operators to form a basis for convenient routing decisions.
State of Practice	Road wear maps are not yet available and existing data on road wear from road operators is not shared with navigation service providers.
Preliminary Target group	End users (drivers of automated trucks and passenger cars, autonomous vehicle, logistics operators)
Demo-site	Austria (Graz, Linz): All use cases will be implemented in the demo site in Graz (AlpLab) and all user acceptance evaluation with end users will take place in the demo-site in Linz (DigiTrans) - including C-ITS testing. More information on demonstration issues is part of WP5.
Key assumptions for successful demonstration during the project	● Road sensing vehicle equipped with EGNSS supporting system available for accurate and authenticated vehicle positioning ● Machine learning algorithm to quickly identify damages via the road sensing vehicle available ● Map-layer with identified damages available
Involved stakeholder roles	EGNSS data/service provider, ground truth data system provider, road wear sensor system provider, data management platform provider, data service platform provider (wear map service provider), OEMs, MNOs, Navigation service providers
Involved project partners	NNG, EVO, JRD
Realisation Prerequisites (physical infrastructure, digital infrastructure, data availability)	**Physical infrastructure:** ● Road sections with damages ● EGNSS supported sensing system ● Road sensing vehicle **Digital infrastructure:** ● Machine learning software ● Map software for integrating map-layer with identified damages **Data availability:** ● Road surface data
Challenges/Barriers/Open issues	● Format of the data (dynamic map data layer) is questionable: several options of different data types may be suitable for different data service types (C-ITS, TPEG2, DATEX II - for DATEX Light, NDS volatile data, etc.)

Target/Evaluation metric	• Precision of the wear map (including detected damages) • Frequency of map-updates needed for long-term road assessment (including what kind of data needs to be updated) • Integrability of the wear map into target customers' operating systems
Expected benefits	• Increase driver convenience and traffic safety by proactive avoidance of road wear geo-located in the road wear map layer.
Preliminary Unique Selling Proposition (USP)	We support map providers to make the life of drivers safer and more convenient.
Technical requirements (T2.2)	After setting-up the technical requirements in T2.2, the respective technical requirements for this use case will be provided in D2.2.
Non-technical requirements (T2.3)	After setting-up the non-technical requirements in T2.3, the respective non-technical requirements for this use case will be provided in D2.2.
System interface design (T2.4)	After setting-up the system interface design in T2.4, the respective systems for this use case will be provided in D2.3.
Business case baseline (T2.5)	After setting-up the business case baseline in T2.5, the respective information for this use case will be provided in D2.4.

Table 5: Use Case 4 - Wear-map content provision.

The following figure shows the basic principle of EUC-004 in illustrative form.

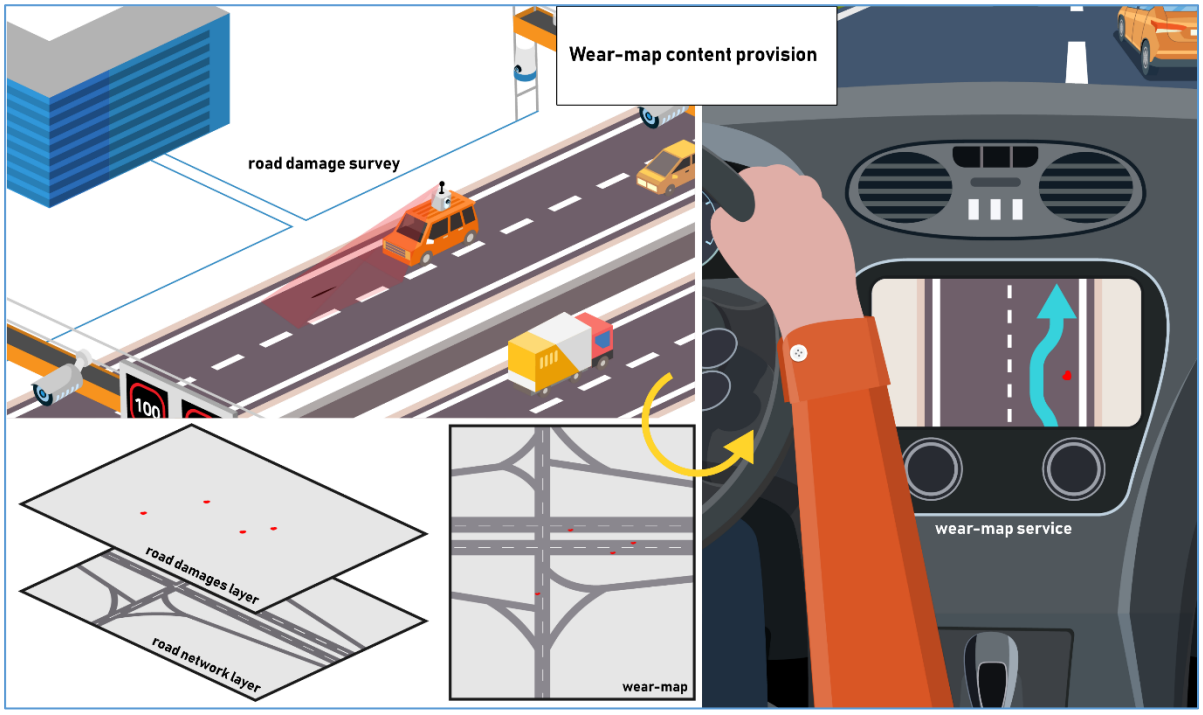

Figure 14: Visualization – EUC-004

3.5. Interrelationship of the Use Cases

The relationships between the individual use cases as well as their relation to the respective target groups can be observed in Figure 15 and Figure 16. Said relationships are subsequently used as a basis for the business cases carried out in T2.5.

The diagram in Figure 15 describes the interaction of the individual use cases and the identified stakeholders using a UML diagram, and serves as a rough visualisation of who provides which services ("C-ITS provider"- provision via C-ITS messages), who uses which services ("uses") and which use cases employ other use cases as their basis ("include"). As illustrated in Figure 15, road operators have a link with EUC-001, EUC-002 and EUC-003 as they use machine learning algorithms for the purpose of predicting potential road damage and consequently use this information to make routing recommendations (in-lane or between lanes) using C-ITS Messages. Such routing recommendations require the availability of both accurate and authenticated vehicle positions, whereby GNSS correction data is also sent to the vehicles by the road operators. The subsequent users of such routing services and GNSS correction services are OEMs as well as end users such as truck drivers, logistics operators, etc. Additionally, End Users can employ the digital road wear map in order to make general routing decisions such as choosing the most convenient route to drive on.

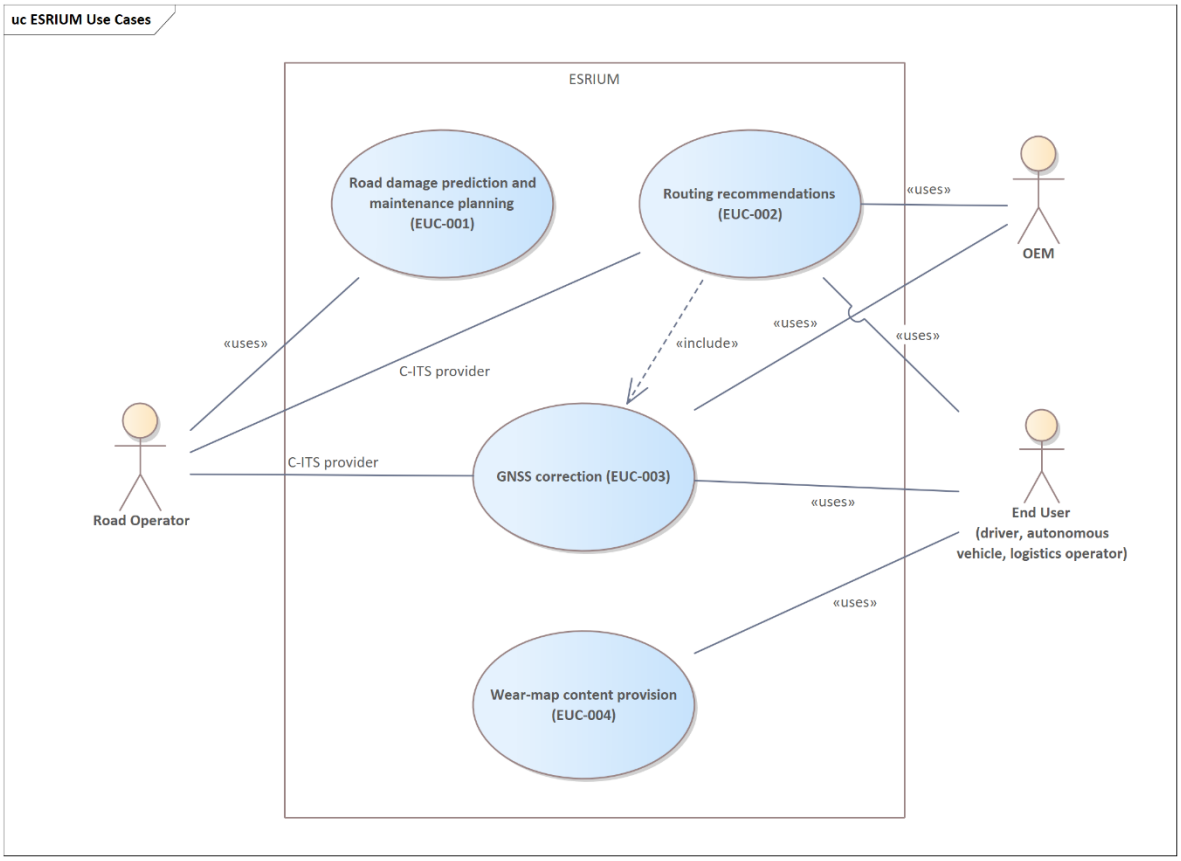

Figure 15: ESRIUM use cases UML.

Another way of visualising the interrelationships and impacts of the individual use cases and stakeholders can be seen in Figure 16. Road damage prediction and maintenance planning (EUC-001) have a direct influence on the routing recommendations, as suggestions in the form of lane changes (in-lane and between-lanes) are made based on potential road damages detected as well as predicted ones by machine learning algorithms. In addition, EUC-001 also has a direct impact on EUC-004, as the road wear predicted by machine learning is the basis for the creation of the wear map. In addition to the influence of EUC-001, EUC-002 is also related to the GNSS adjustments, since routing recommendations in the form of lane changes, in particular in-lane offsets, can only be realised on

the basis of precise position data of the respective vehicles. In addition to the connections between the individual use cases described above, Figure 16 also describes the relationships between use cases and their potential target groups. For example, road operators use road damage prediction and maintenance planning services to make routing recommendations based on GNSS-corrected vehicle positions. Both the routing recommendations and the GNSS correction data are thereby sent to end users via C-ITS messages. At the same time, by providing the road wear map based on EUC-001 and EUC-003, end-users can make general routing decisions such as choosing the most convenient route to drive on.

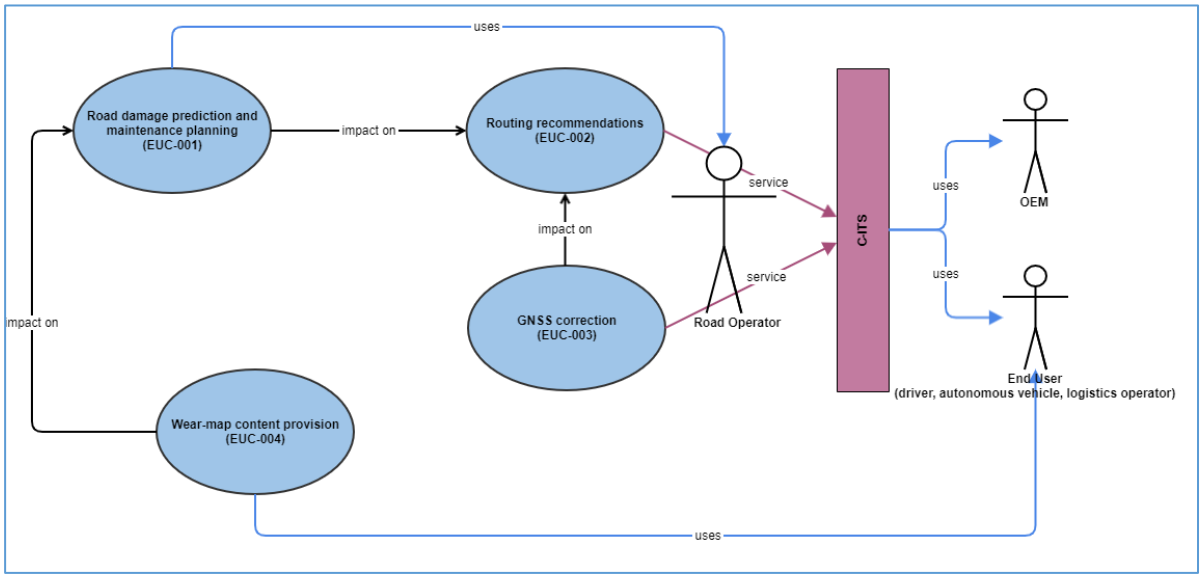

Figure 16: ESRIUM use cases interrelations and result usage.

SECTION 4: RELATION TO OTHER TASKS / WORK PACKAGES

The use case description serves as a foundation for the future development, as well as testing and assessment of tasks within the project. Moreover, the described use cases serve as a basis for the formulation of both technical and non-technical requirements as well as system interface design aspects for ESRIUM services. In particular, the relationships between the individual use cases and their respective target groups are needed for the Task “T2.5: Business Case” in WP2. However, it has to be mentioned that some information with regard to business aspects is just in a preliminary stage. This preliminary information helps to close the gap between customer and development view. After setting-up the detailed business plans in the respective tasks, this information needs to be updated.

Furthermore, since the use case description is considered as basis for further tasks of WP2, there are also relations to other work packages, since these are also based on WP2 results. Both development work packages (“WP3: EGNSS Localization + I2V Communication” and “WP4: Wear Map Creation, Integration and Upkeeping”) take the use case description, technical- and non-technical requirements as well as the system description as starting point for their work. The business-related Task T2.5 sets the scene for all further market-related work in ESRIUM (e.g. “WP6: Dissemination and Exploitation”). “WP5: Proof of Concept and In-Vehicle Validation” is directly connected to the use case description of WP2. Furthermore, the user acceptance evaluation interconnects with the non-technical requirements of Task T2.3. The Figure 17 gives an overview of the work packages in the ESRIUM project and mirrors the core role of WP2.

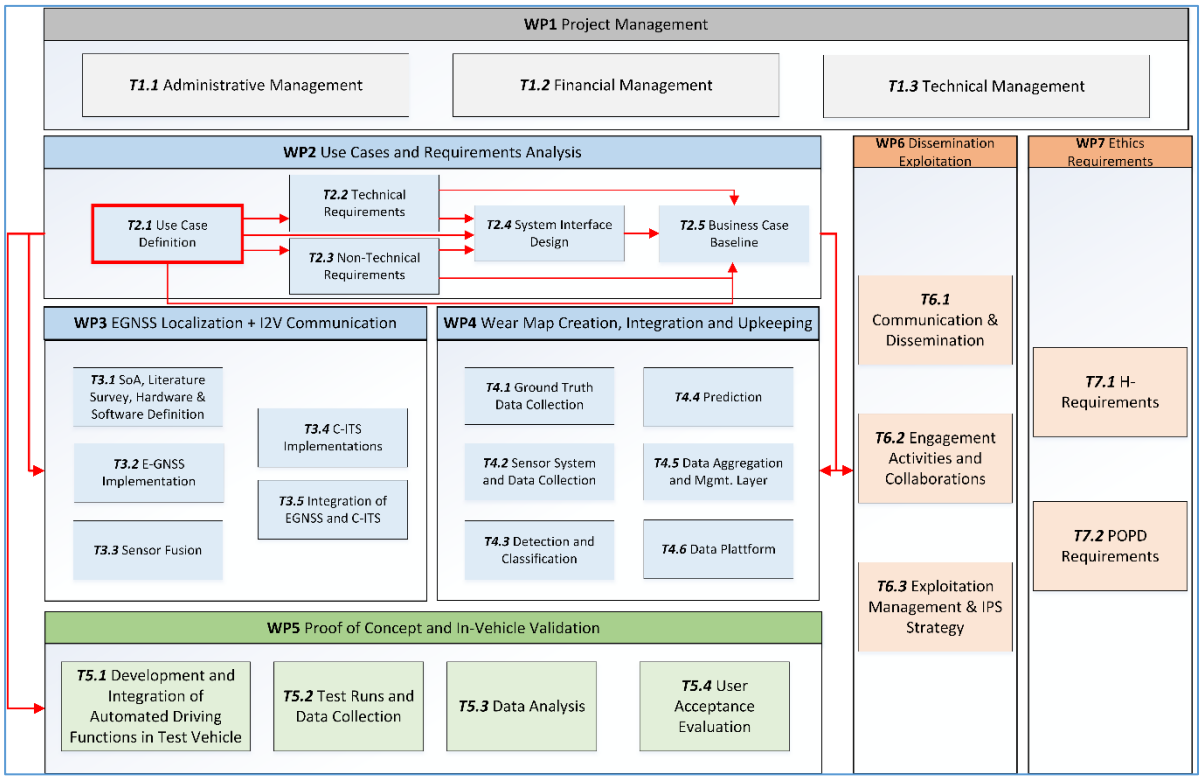

Figure 17: ESRIUM work packages.

SECTION 5: CONCLUSIONS

In this deliverable, we present the results of the work carried out under Task: "T2.1: Use Case Definition" of work package "WP2: Use Cases and Requirements Analysis". Due to the Covid-19 pandemic situation, we had to change the original validation approach within a stakeholder workshop (as stated in the DoW) and instead move to a step-by-step approach for elaborating the use cases and validating them from multiple perspectives. Based on the DoW, a use case analysis defined and developed four use scenarios of ESRIUM services, including their potential audiences and use requirements, as well as their respective challenges. The use cases were validated and adapted in a bilateral workshop with the key customer ASFINAG and subsequently tested in an internal validation process with all project partners. This was done in order to develop a consolidated consensus within the diverse and multidisciplinary team of the ESRIUM project and to benefit from the different perspectives along the value chain. In addition to a brief description, the resulting use cases also contain key assumptions for successful demonstration, the stakeholders and project partners involved, the realisation prerequisites, remaining challenges as well as barriers and open issues, evaluation metrics, expected benefits and the preliminary USP. Additionally, placeholders for later insertion of technical and non-technical requirements, system interface design aspects as well as business case aspects have also been included.

In addition to the formulation of the individual use cases, an analysis of their mutual dependencies and their relations to the stakeholders was also carried out. As a result, the individual dependencies of the use cases as well as their connection with the stakeholders and their respective roles (e.g. provider, user) in connection with the ESRIUM services could be identified. Road operators act both as users and providers by using the services from EUC-001 for the purpose of providing routing recommendations (EUC-002) via C-ITS. Likewise, road operators provide GNSS via C-ITS in order to make the service of routing recommendations possible at all, making the realisation of EUC-002 dependent on the existence of the service of EUC-003. The road wear map is subsequently used by

end users and OEMs, making it possible to be e.g. integrated in navigations systems as a means of convenient routing decisions.

Validation of the uses cases from different perspectives led to a better understanding of the needs and requirements as well as the features of the ESRIUM services. This understanding will be used as an input to the upcoming Tasks “T2.2: Technical requirements”, “T2.3: Non-technical requirements”, “T2.4: System interface design” and “T2.5: Business case baseline” to facilitate elicitation of the necessities for the implementation of ESRIUM services.