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Architecture for Scalable, Self-human-centric, Intelligent, Secure, and Tactile next generation IoT

D3.3 – Use Cases Manual & Requirements and Business Analysis – Final

Deliverable No.	D3.3	**Due Date**	30-Apr-2022
Type	Report	**Dissemination Level**	Public
Version	1.0	**WP**	WP3
Description	Final version of business scenarios, use cases and requirements. Defines dependencies, inter-relations and mapping of requirements onto business needs and technical solutions.		

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Executive Summary

This deliverable is written in the framework of WP3 – Requirements, Specification and Architecture of **ASSIST-IoT** project under Grant Agreement No. 957258.

This deliverable outlines the results of Tasks 3.2 and 3.3 activities during the period M7 up to M18 up of the ASSIST-IoT project, which were driven by the internal stakeholders, i.e., the industrial partners leading the project pilots. Beginning with the end in mind, i.e., the ASSIST-IoT application areas (container terminal automation, construction safety and vehicle condition diagnostics and monitoring), the Consortium finished formalising the pilot scenarios, which were briefly described in the Grant Agreement.

This deliverable includes business scenarios, use cases and requirements identified within ASSIST-IoT, which will support the design and the implementation of the three project's pilots.

- The aim of the port automation pilot is to prevent containers from being lost and to improve the operational efficiency of terminal operators. By smartly linking and using edge node IoT technology, the location of all Container Handling Equipment (CHE) within the port can be continuously monitored, container locations can be recorded, reported, and made available to authorized users. Improving operational performance is possible by supporting automated CHE collaboration. A further form of automation will be introduced and implemented, both between and between RTGs, trucks, and unmanned vehicles. To this end, use will be made of machine-to-machine communication and, in the case of manned vehicles, through guides on a mobile app.
- The aim of the Smart worker safety pilot is aimed at guaranteeing a safe working environment, the use of personal protective equipment and monitoring the physiological parameters of the construction workers. Unfortunately, most accidents are caused by human error and inattention in unsafe situations. The introduction of an active personal health and tracking system for employees can inform the employee but also the safety officer in real time. Such as falling or immobility of the construction worker, entering an unsafe or unauthorized workplace, exposure to UV radiation or overheating due to working conditions.
- The aim of the Cohesive vehicle monitoring and diagnostics is to monitor the vehicle diagnostics providing an cohesive evaluation of the vehicle condition both at an individual and a fleet scale. Diagnostic and damage detection methods are provided either on the vehicle embedded controller, or in specific inspection facilities performing advanced vision-based tests. The implementation of the ASSIST-IoT reference architecture in this pilot will enhance the capabilities of automotive OEMs to monitor the emission levels of vehicles which are already in operation. In addition, exterior condition inspection and documentation will be provided to OEMs-supply chains and stakeholders in order to provide insights into the required corrective maintenance tasks based on the integration of data streams coming from different sources.

To this end, the industrial and academic leaders of each pilot collaborated with all the Consortium partners to express, in the form of business scenarios, the business needs and solutions to business problems that need to be addressed. Based on the common understanding of the functionality of the systems under development, their functionality was documented in the form of use cases, which describe the interactions between actors (persons, devices, or digital entities), the assumptions and the expected outcomes after the execution of a flow of actions. Further functional and non-functional requirements were identified and finalised based on the expertise and experience of all partners. This final version of the manual includes 18 use cases, 43 functional and 48 non-functional requirements (90 in total; 29 of them common to all pilots).

The information included in this deliverable corresponds to all the identified requirements and use-cases associated to tasks T3.2 and T3.3, which finalise with the submission of this document. Different methods and criteria have been considered to extract requirements. The most important inputs are the needs expressed by the stakeholders in diverse internal meetings and workshops performed in this period, as they are the final users of the project outcome. Additionally, the most important (common functional and technical) requirements for the ASSIST-IoT solution as a whole, IoT technological proposition have been investigated and documented. Finally, the wide experience of the partners was considered.

The analysis of each business domain allowed for the definition and refinement of the project's scope. It also led to better understanding and agreement between partners on how business needs fit existing IoT architectures

and will also help define what process improvements, organisational changes and policy developments will be required. The project's key value indicators and the pilot's key performance indicators were further decomposed by defining acceptance criteria to the identified use cases and requirements in order to be able to measure the outcome of the pilots and provide input for the technical evaluation of the project results.

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List of acronyms

Acronym	Explanation
AI	Artificial Intelligence
AIOTI	Alliance for Internet of Things Innovation
AR	Augmented Reality
BIM	Building Information Modelling
BLE	Bluetooth Low Energy
CAN	Controller Area Network
CHE	Container Handling Equipment
CCP	CAN Calibration Protocol
DLT	Distributed Ledger Technology
EDPB	European Data Protection Board
ETA	Estimated Time of Arrival
EU-OSHA	European Agency for Safety and Health at Work
GDPR	General Data Protection Regulation
HiFi	High Fidelity
HW	Hardware
ICT	Information and Communications Technology
IoT	Internet of Things
ISC	In-Service Conformity
MFT	Malta Freeport Terminal
NO_x	Nitrogen Oxides
NGI	Next Generation Internet
OCR	Optical Character Recognition
OBD	On-Board Diagnostic
OEM	Original Equipment Manufacturer
OGC	Open Geospatial Consortium
OSH	Occupational Safety and Health
OTA	Over-The-Air
PPE	Personal Protective Equipment

RDE	Real Driving Emissions
RFID	Radio-Frequency Identification
RTG	Rubber-Tired Gantry
STS	Ship-To-Shore
SW	Software
TEU	Twenty-foot Equivalent Unit
UV	Ultraviolet

1. About this document

The aim of the use case, requirements and business analysis - final report is to provide document an analyse context and subjects needed for the design and implementation of the solutions proposed within the ASSIST-IoT project. This document is the successor of D3.2.

Deliverable context

Item	Description
Objectives	**O6**: D3.3 clearly contributes to meet this objective, as it brings the project one step closer to the implementation of the pilots, by finalising the definition of the use cases and requirements that will be pursued in WP7 and evaluated in WP8. **O1-5**: D3.3 includes the final version of non-functional (technical) requirements, setting the bare minimum ground that the enablers associated to technical objectives will need to cover.
Work plan	WP3 (Requirements, Specifications and Architecture) as a whole, and especially tasks T3.2 (Formalization of use cases) and T3.3 (Requirements Definition and Business Analysis), are following an agile approach to define business scenarios, use cases and requirements. Volere[1] methodology and MosCoW[2] technique was used to ensure general coherence and to maximize usefulness for all the technical stages
Milestones	This deliverable does not mark any specific milestone; still, it hugely contributes to *MS4 – Pilots initially deployed*, that means a formal specification of the pilots, which is shared between D7.2 and, arguably, this document (D3.3).
Deliverables	This deliverable is the result of the activity carried out in T3.2 and T3.3 and D3.2 has been used as input for this deliverable. The results of this deliverable will provide information to WP4 and WP5 with respect to the identification of devices and HW/SW enablers; for WP7, it provides more details and a better structure to the pilot-scenarios; for WP8 it initialises the evaluation framework through requirements definition; for WP1 and WP2 it provides more detail with respect to data (management and ethic/protection).

1.1. The rationale behind the structure

The document is divided into seven sections. The first is an introduction that covers the purpose of the ASSIST-IoT project and the description of this document. The methodology for defining the requirements and their maintenance is described in deliverable D3.2. The requirement tables have been changed. The changed version is given in Appendix 2, the customer satisfaction and customer dissatisfaction parameters have been added to the requirements which is in line with the Volere methodology. In sections 3, 4, 5, business scenarios, use cases and requirements, grouped by the pilots defined in the project, are described, and analysed. Afterwards, section 6 relates about common functional and non-functional requirements associated with the ASSIST-IoT solution. In section 7 summary, an overall conclusion and future work are provided.

1.2. Outcomes of the deliverable

The need identification is an iterative process that takes place over the life of the project, therefore existing business scenarios, use case and requirements have been improved or new ones have been added. This document contains the latest requirements that must be met. In terms of their priority, about three quarters are mandatory. This happens because the primary focus is on identifying the essential features and functionalities that the different products should have.

Currently the project describes: 9 business scenarios, 18 Use cases and 91 requirements. 43 of these requirements are functional and 48 non-functional, of which 29 are common to all pilots.

[1] https://www.volere.org/
[2] https://www.agilebusiness.org/page/ProjectFramework_10_MoSCoWPrioritisation

Compared to D3.2, the non-functional requirement has increased by 22. Four of the functional requirements have been cancelled and 5 new ones have been added.

1.3. Deviations and corrections

During the evolution from document D3.2 to D3.3, insightful changes have taken place within the Business scenarios as well as within the Use cases. Comparison with D3.2, of both the UCs and BSs show the following significant deviation.

BS-PS2-2 "Fall Arrest Monitoring" as originally defined. Has been adapted to "Fall related incidents identification" The fall monitoring function appears to be much easier to perform on closer inspection. Namely by using and reading the motion and acceleration sensor of the positioning tag, which every construction worker carries. As a result, use case UC-P2-4 has also changed.

UC-P2-2 (Geofencing boundaries enforcement) and UC-P2-3 (Danger zone restrictions enforcement) were found to have so much overlap that they were combined into a use case (UC-P2-2). As a result, UC-P2-3 has been dropped.

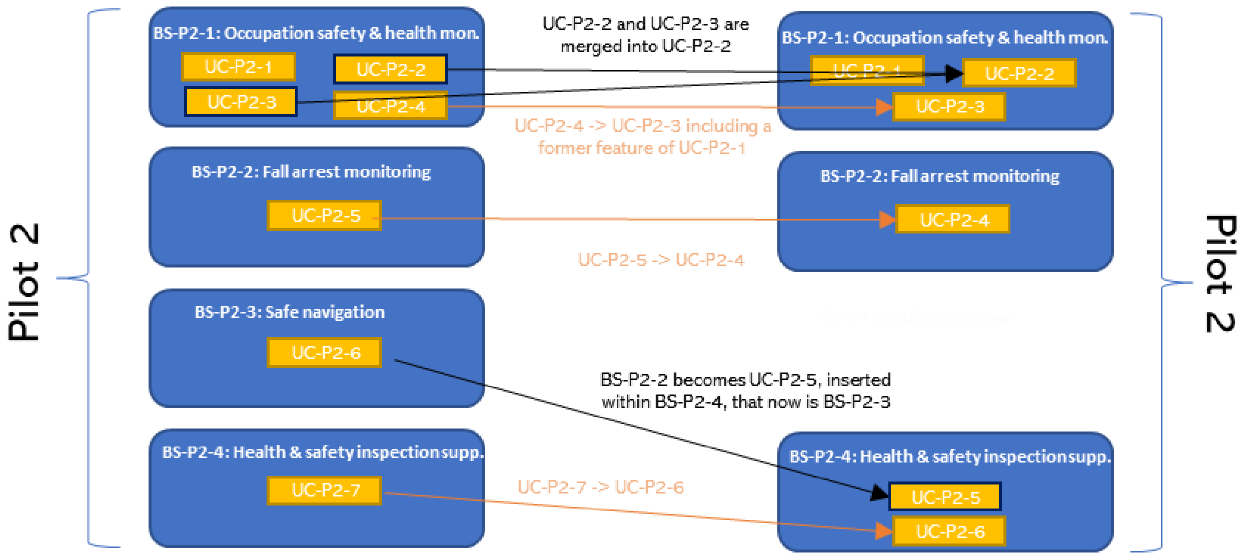


Figure 1. Modifications in UCs and BSs – Pilot 2

2. Introduction

The ASSIST-IoT project aims at designing, implementing, and validating an open, decentralized, reference Next Generation IoT (NG-IoT) architecture, with its corresponding enablers, services, and tools for assisting human-centric applications within multiple verticals. This objective is fully aligned with Next Generation Internet (NGI) vision, in which an Internet that responds to people's fundamental needs, including trust, security, and inclusion, while reflecting the values and the norms all citizens enjoy in Europe is envisioned. To accomplish ASSIST-IoT and NGI visions, several key enablers are required for guaranteeing the successful deployment of the architecture in the three human-centric pilots embraced in the project, i.e., port automation, smart safety of workers, and cohesive vehicle monitoring. Furthermore, ASSIST-IoT forms its human-centric leitmotif adding fundamental NGI pillars such as resilience, sustainability, privacy, and trust with the help of e.g., Distributed Ledger Technologies (DLTs), seen as instrumental to the digital transition and Europe's industrial future[3].

ASSIST-IoT follows the AIOTI[4] guidelines. AIOTI (Alliance for Internet of Things Innovation) was initiated in 2016 to contribute to the creation of a dynamic European IoT ecosystem and speed up the take up of IoT. AIOTI was a response to public consultation on European Partnership for the successful development of Smart Networks and Services under the Horizon Europe Program, in which AI-based control systems (distributed intelligence) in critical areas (edge computing, tactile-internet) will depend on data (interoperability) provided by billions of IoT nodes (hyperconnectivity), communicating over smart networks.

To finalize the fundamental requirements for the project, business scenarios have been updated, as well as use cases and requirements for each pilot. For every business scenario, use cases were formulated against which requirements fulfilment will be verified and interactions with ASSIST-IoT components will be tested. The KPIs for each use case have been formulated in a way that these can be tested and evaluated as part of the WP7 and WP8 activities. In-depth analysis of legal requirements is provided in D3.4.

The requirements definition is an important step in any project, due to the several benefits that they can provide to the project. The scope is defined, and the requirements are updated. Compared to D3.2 the customer satisfaction and customer dissatisfaction have been added to the requirements. The requirements have clear evaluation and validation criteria to obtain a quality product.

[3] European Commission, "Next Generation Internet – The Internet of Humans", August 2019, https://ec.europa.eu/futurium/en/blog/next-generation-internet-internet-humans
[4] https://aioti.eu/

3. Pilot 1: Port automation

Pilot 1 will be driven by the industrial partner and port terminal operator Terminal Link Group (TL) and will be deployed on its premises – in the Malta Freeport Terminal (MFT). MFT is one of the largest ports of transhipment in the Mediterranean region with more than 2,000,000 containers/year. However, MFT has almost reached its maximum capacity, leading tpermanent congestion in the yard, as depicted in Figure 2. This congestion results in an increase in waiting and turn-around times of landside trucks, causing inefficiency of the logistics chain, as longer vessel stay times are required, and even some vessels must be diverted to other ports.

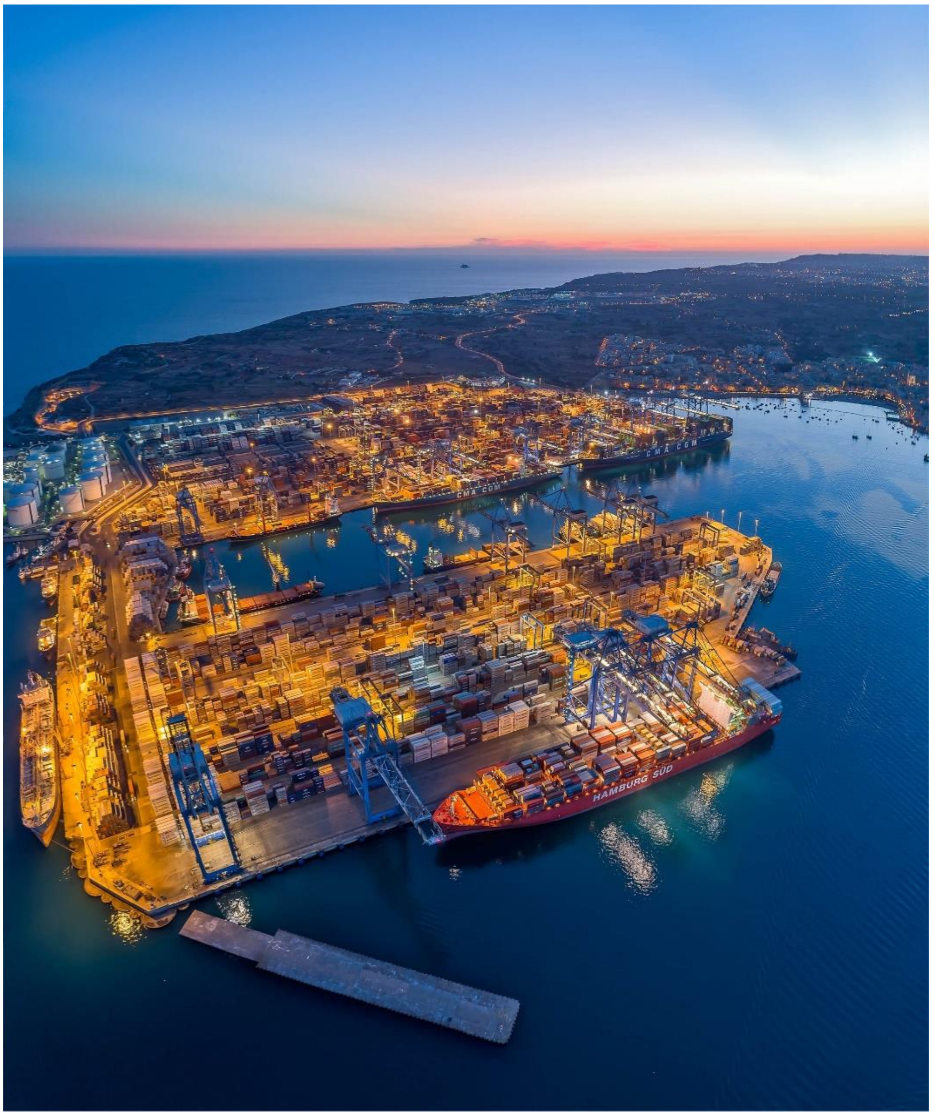


Figure 2. Malta Freeport Container Terminal

The containers are managed by heavy Container Handling Equipment (CHE) like Rubber-Tyred Gantry cranes (RTGs), Ship-To-Shore Cranes (STSs), or Terminal Tractors (TTs). However, even though digital information is used in diverse stages of terminal and shipping lines processes, the CHE-involved processes always require on-board operators, who interact with each other by exchanging information required to handle freight. In particular, while data acquisition is mostly solved for current container terminals, decentralised combinations of multi-source heterogeneous data, trusted data sharing for supply chain inter-business integration, or low-latency network capabilities are still pending. The ASSIST-IoT Port Automation pilot aims to demonstrate the benefits of ASSIST-IoT, easing the use of complex industrial processes and equipment in the maritime industry and tackling the aforementioned limitations.

3.1.BS-P1-1: Tracking assets in terminal yard

Several containers are lost every year in port terminals like MFT, leading to customers' dissatisfaction. However, the solution to tackle this loss is not as straightforward as installing GPS modules on the containers. Terminals to alleviate the issue of location capabilities approximately locate every container by means of CHE (specifically RTG/STS cranes and TTs) movement registries on the Terminal Operating System (TOS). Hence, they only notify the bay number in which the containers have to be loaded/unloaded by truck drivers, and with the help of which RTGs. In addition, the registries can only be performed by terminal staff. Therefore, truck drivers who do not belong to the terminal company are only informed of their job order when accessing the port gates with some printed papers, leaving them outside the workflow. This lack of additional contextual information in an overcrowded container terminal (Figure 3) leads to **lower operational efficiencies**

Figure 3. Malta Freeport Terminal Eye view.

To increase these operational efficiencies, this business scenario is focused on providing higher CHE visibility to all users involved in the daily container management process. To do so, they should be able to have access to the GPS coordinates and TOS data in real-time.

Business scenario BS-P1-1, Tracking assets in terminal yard	
The main problem to solve is to avoid losing containers and enhance the operational efficiency of terminal operators (including internal-external drivers). The reduction of the number of containers lost mandates the positions of all CHEs to be tracked. Additionally, CHEs must register all container handling operations (picking up and placing down a container by an RTG or being loaded or unloaded by a TT). All this information is registered in the TOS. ASSIST-IoT's edge-oriented and scalable architecture will allow the reuse of the gathered information on the edge, so that those actors requiring this type of data from specific assets can obtain them in a fast and secure manner.	
User/users:	• Terminal management • CHE drivers
Setting / context	Port terminal
Interacting system	Terminal Operating System (TOS), GPS installed on CHEs, Frontend adapted to mobile screens for truck drivers, Security access for external truck drivers
Users' goals	Terminal managers – control over container movements, to reduce the number of lost containers. CHE drivers – clear, reliable, and efficient system for identifying and locating containers and, container handling operation reporting to reduce idling times.
Initial status	For internal driver – they start their working daily routine, running the app on the mounted device. For external driver – they arrive to the terminal and run the app on their mobile devices with a temporary authorised identity.
Interaction	Terminal managers – application showing the general overview of the position of all CHEs in the yard with GPS installed, which coordinates are collected by ASSIST-IoT Gateways and SW enablers, as well as containers bay area by means of TOS historical data collected. Truck drivers – application aiding in reporting operations. For external truck drivers, this app is installed on a mobile device, internal CHE drivers will have a mounted device in their cabin.
Data	Produced: route recording of every CHE with time and position of communication / identification by other devices within the terminal yard, information about containers handled by CHEs. Timestamp and location where the container is picked up and placed.
Motivation	Improve container traceability and minimize the number of containers lost. Gain real-time insight into the operational status of the port on the edge, limiting idling periods. Create a secure system that enables outsiders to interact with terminal assets.
Time	Ongoing operation of the terminal yard.
System functionalities	CHE location capabilities, Yard intelligent routing, Authentication and authorization roles management

Figure 4 shows the diagram of relationship between actors in this Business Scenario of Tracking assets in terminal yard. The figure is enhanced from the one used in D3.2. The "Position Detection System" actor has now an explicit connection with the CHE location tracking, in alignment with the changes recently exposed in the previous table.

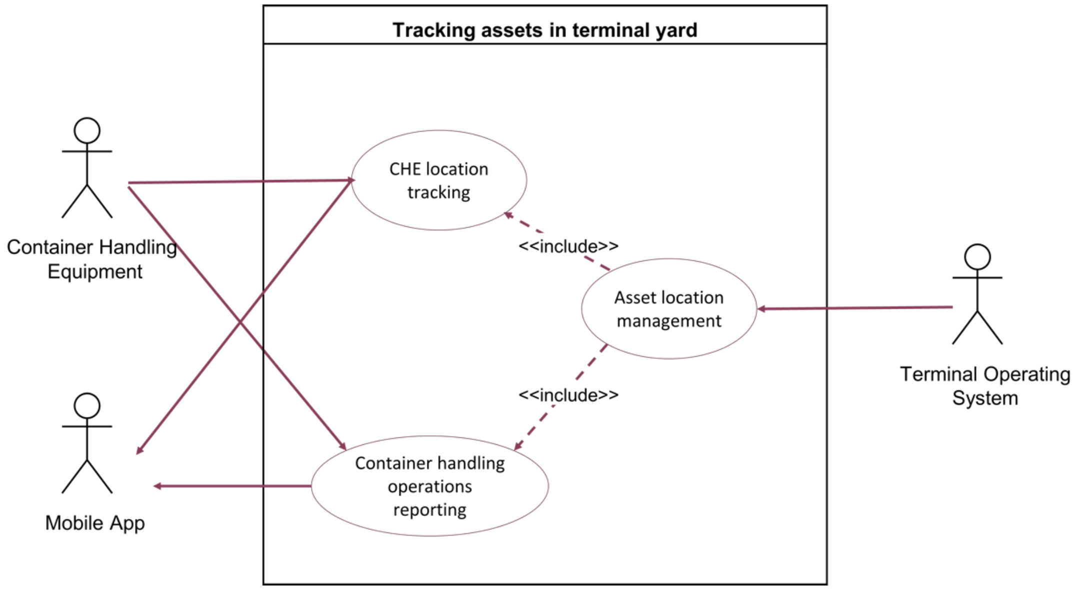


Figure 4. Use case diagram for the "Tracking assets in terminal yard" business scenario

3.1.1. UC-P1-1: CHE location tracking

This use case is about exposing different telemetry data that is handled by the PLCs of an RTG crane, as well as their GPS coordinates obtained from the GPS module installed on top of the crane, which can be observed in Figure 5. All this information is collected into the PLC gateway, which, in turn, by means of an edge data broker also installed on the PLC gateway that forwards the collected information via JSON messages to the CHE location management use case (UC-P1-3). Among others, the exposed data include (*che.coordinate.gps* – GPS coordinates of the position of the machine from the device installed on them; *che.on.feedback.status* - set to true when the machine is on; etc.).

Figure 5. RTG crane (left), and GPS antenna (right)

An infrastructure diagram of this use case is illustrated in Figure 6.

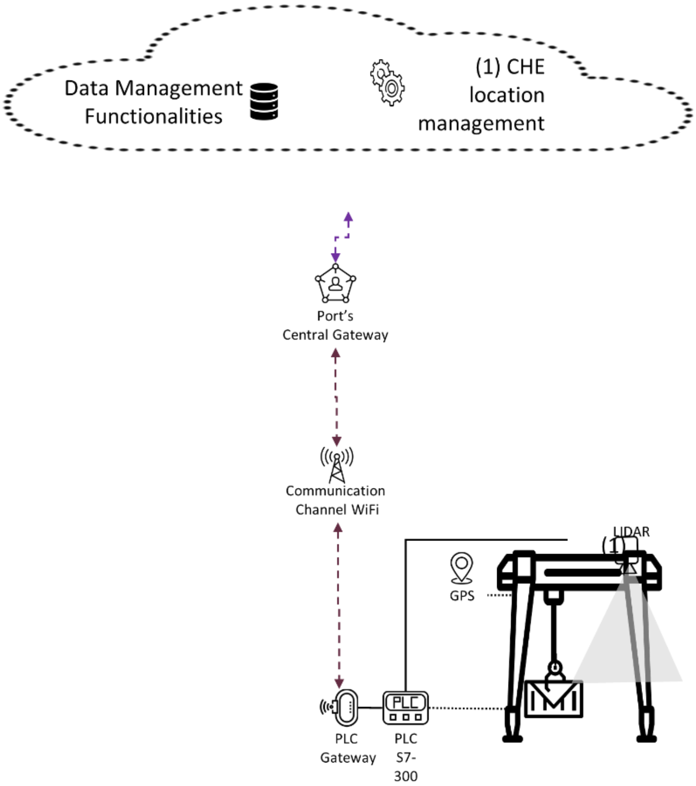


Figure 6. UC-P1-1 Infrastructure diagram

Use Case: UC-P1-1, CHE location tracking	
Description	The location of all CHEs within the port is recorded and reported
Reference Scenario	Tracking assets in terminal yard
Plane(s)	Device and Edge, Smart Network and Control, Data Management, Application and Services
Vertical Capabilities	Manageability and control
Functionalities within vertical capabilities	Management of devices
Objectives	ASSIST-IoT is constantly aware of the position of every CHE with accuracy of ±0.5 m.
Actors (system actor or natural persons)	• CHE PLC • CHE GPS • PLC Gateway
Pre-conditions	• CHE is on OFF status
Trigger	• CHE is turned on
Expected results	CHE position is reported to the ASSIST-IoT.
Design preferences	Either commercial off-the-shelf or industrial-grade RTG GPS will be used on the cranes in order to provide accurate positioning by means of permanent Line of Sight with satellite transponders.

Extends the use case (if applicable)	N/A
Includes the use case	N/A
Notes and issues	N/A
Main execution flow	1. CHE attempts to determine its location using GPS 2. CHE retrieves its absolute location from GPS 3. CHE reports its coordinates to ASSIST-IoT
Alternative execution (if applicable)	N/A
Exceptions (if applicable)	In the case there is no network connectivity temporarily, the information will be buffered locally and retransmitted later.
Requirements involved	R-P1-7, R-P1-8, R-P1-9
KPI	CHE location with accuracy of 0.5 m
Identified by:	TL, PRODEVELOP

3.1.2. UC-P1-2: Container handling operations reporting

This use case forms the second reporting leg of the BS-P1-1. In particular, this use case focuses on tracking the location of the container thanks to the telemetry data obtained from the spreader part of the RTG crane. When the job order received is finished the GPS coordinates of the RTG are compared to the expected GPS coordinates derived from the work order's assigned block area in the TOS (see Figure 7. If those two data fields do not match, an alarm is triggered in the form of a graphical interface presented both to the crane operator and to the truck driver.

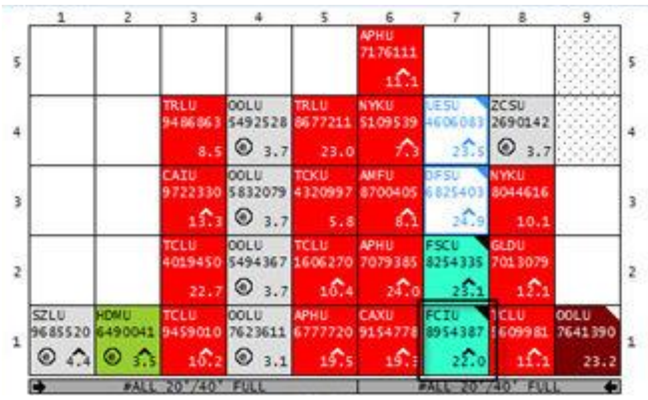


Figure 7. Container stack schema of a terminal block

Due to operational and security limitations of Malta Freeport, this use case will only have read-only access rights to the TOS. Therefore, instead of reporting the location of all the containers in the TOS to the whole terminal as envisioned in D3.2, a graphical user interface alerting about potential containers misplaced errors will be shown only to the involved terminal operators.

An infrastructure diagram of this use case is illustrated in Figure 8.

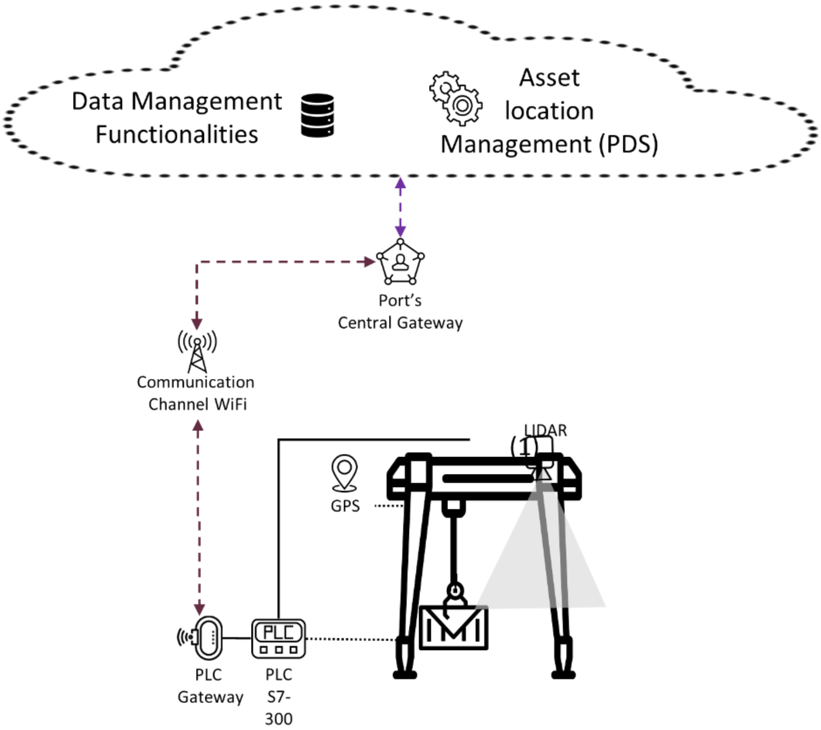


Figure 8. UC-P1-2 Infrastructure diagram

Some telemetry and TOS data that is envisioned to be reported from this use case as JSON documents include the following list:

- *che.spreader.unLock.action.status* – will take the value true when the machine is open twistlock
- *che.spreader.lock.action.status* - will be true when the machine is closing twistlock
- *che.spreader.end.geo_point* - GPS coordinates of the position where the spreader finished moving the container
- *che.coordinate.spreader.end* - GPS coordinates of the machine spreader at the end of the movement
- *tos.move_kind* – Kind of work order (e.g., DSCH – Discharge, YARD – Yard to Yard, LOAD – Load, etc.)
- *tos. from_pos_ID* - the starting work order yard position
- *tos.to_pos_ID* – the final work order yard position
- *tos.last_work_instruction_reference* – Reference to Last Work Instruction
- etc.

Use Case: UC-P1-2, Container handling operations reporting	
Description	CHE matches the location of a container being handled with the expected position of the assigned TOS work order
Reference Scenario	Tracking assets in terminal yard
Plane(s)	Device and Edge, Smart Network and Control, Data Management, Application and Services
Vertical Capabilities	Cybersecurity components, Manageability and control
Functionalities within vertical capabilities	Authentication, Authorization, Management of devices
Objectives	To track containers within the terminal by monitoring work order status

Actors (system actor or natural persons)	• CHE • TOS • PDS
Pre-conditions	CHE is carrying out a work order.
Trigger	CHE handles a container.
Expected results	The location of the finished operation is compared with the expected Terminal Operating System assigned position. If wrong, a graphical alert is triggered.
Design preferences	Reporting methods: • CHEs equipped with telemetry capabilities should report this automatically. • Otherwise, the machine's operator should report the operation using a mobile device (smartphone, tablet). Container identification: • Some RTGs can be equipped with an external container identification system based on OCR (reading container ID), and it is matched with the TOS work order. • Otherwise, the container has to be identified manually by the driver.
Extends the use case (if applicable)	N/A
Includes the use case (if applicable)	N/A
Notes and issues	N/A
Main execution flow	1. CHE is to handle a work order 2. CHE identifies the container assigned to the specific work order 3. CHE reports to ASSIST-IoT the operation being performed, and the container being handled 4. CHE proceeds with its work order 5. CHE reports to ASSIST-IoT that the container movement operation has been successfully performed to the CHE coordinates 6. TOS compares both values and trigger an alert to operators if the container is place in a wrong position.
Alternative execution (if applicable)	N/A
Exceptions (if applicable)	In the case there is no network connectivity at the time of the operation being performed, the information should be buffered locally and retransmitted later.
Requirements involved	R-P1-1, R-P1-2, R-P1-5, R-P1-10
KPI	The two CHEs involved in the real-time demo will report origin and destination coordinates of the container being handled
Identified by:	TL, PRODEVELOP

3.1.3. UC-P1-3: Asset location management

UC-P1-3 is about the provisioning of a human-friendly graphical user interface for both CHE operators as well as terminal managers. There will be three level of access rights depending on the user role that will be managed via the cybersecurity functionalities of ASSIST-IoT:

1. Terminal managers (highest-level credentials): They will have real-time location information of all the CHEs involved in the daily terminal operation routine, collected in UC-P1-1. This would help them permanently identify potential issues or operational bottlenecks in the operations of the terminal (e.g., one crane is stopped, there are several cranes waiting in the same block, etc.), as well as historical data statistical collection.
2. Internal TT operators (medium-level credentials): By making use of the TT equipment, they will be able to observe the location of the CHEs with whom they have to cooperate based on their assigned TOS work instructions. As internal truck drivers have several work instructions per day, they will be able to prioritize the work instructions based on the information exposed to the involved cranes.
3. External truck drivers (low-level credentials): By making use of the mobile application downloaded and installed on their own smartphones, and with the appropriate credentials provided by the terminal, they will be able to know exactly the location of the univocally crane assigned to his/hers work instruction, providing additionally, the most optimum route to their destination, avoiding those terminal lanes suffering traffic jams.

The following figure illustrates how the overall UC-P1-3 system would work.

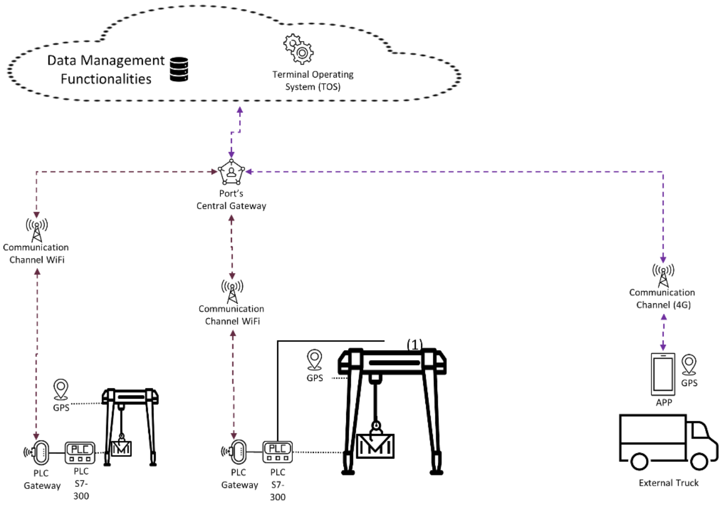


Figure 9. UC-P1-3 Infrastructure diagram

Additionally, a couple of the mobile app mock ups are illustrated below:

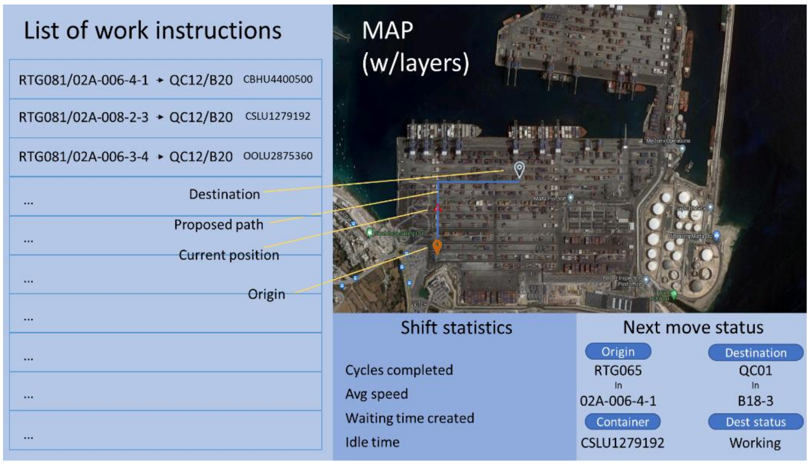


Figure 10. UC-P1-3 mobile app mock-ups (login page – top, main page – bottom).

Use Case: UC-P1-3, Asset location management	
Description	The information of all assets (CHEs) within the terminal yard that are continuously tracked is made available to authorized actors.
Reference Scenario	Tracking assets in terminal yard
Plane(s)	Device and Edge, Smart Networking and Control, Data Management, Applications and Services
Vertical Capabilities	Cybersecurity components, Manageability and control
Functionalities within vertical capabilities	Authentication, Authorization, Management of devices
Objectives	Authorised actors in the system are able to obtain information about the positions of the assets within the yard.
Actors (system actor or natural persons)	• TOS • CHE GPS • CHE PLC • Mobile app
Pre-conditions	CHEs are equipped with GPS and PLCs for reporting their operational status.
Trigger	N/A
Expected results	End-user is presented with information about the assigned asset's location at a given moment.
Design preferences	Location management shall be done in an edge-oriented, distributed, and scalable manner.
Extends the use case	N/A
Includes the use case	• **UC-P1-1** (CHE location tracking) • **UC-P1-2** (Container handling operations reporting)
Notes and issues	Access control to the CHE geo-localization data
Main execution flow	1. CHEs report their location (UC-P1-1) and container handling operations (UC-P1-2) to ASSIST-IoT 2. ASSIST-IoT aggregates and buffers the retrieved information 3. ASSIST-IoT forwards the information to the TOS for real-time tracking and historical data collection 4. ASSIST-IoT exposes the info to other actors with necessary authorization
Alternative execution (if applicable)	N/A
Exceptions (if applicable)	N/A
Requirements involved	R-P1-1, R-P1-2, R-P1-4, R-P1-9
KPI	All CHEs involved in the real-time demo will be located
Identified by:	TL, PRODEVELOP

3.2. BS-P1-2: Automated CHE cooperation

During the last decades, technological innovations have allowed the automation of certain processes in container terminals. However, automated cooperation of CHEs (e.g., ship/STS crane, STS/Truck, Truck/RTG, etc.) is still either done manually or driven by CHE proprietary and non-integrated solutions. ASSIST-IoT will tackle the automated CHE cooperation in the terminal yard between RTG cranes and trucks. In particular, due to the RTG-spreader's low mobility constraints (about 40 cm at most), the truck involved in the work order must be strictly aligned between two lines on the assigned yard-street. As this process is performed frequently every day, there is a necessity to improve the cooperation process between CHEs in general and the longitudinal alignment in particular. This new technology will allow the future unmanned or remote-control trucks to align with the remote RTGs.

Business scenario BS-P1-2, Automated CHE cooperation	
This business scenario aims at enhancing the operational performance by supporting automated CHE cooperation. The CHEs (RTG and truck) should be able to identify and authenticate each other before starting the operation. Then, the RTG guides the truck (internal or external) to the correct position. The guidance can be provided in a variety of ways, depending on the automation level of the truck. For unmanned vehicles, this can be achieved using machine-to-machine communication. Manned vehicles will receive guidance signals using positioning guidance traffic lights, as well as through movement recommendations on a mobile app available in the truck driver's cabin.	
User/users:	• RTG operator • Truck operator
Setting / context	Port Terminal
Interacting system	TOS, LIDAR, Traffic lights, Crane PLCs, Mobile app
Users' goals	Align the truck (external or internal) with RTG in an efficient and safe manner.
Initial status	The RTG and the truck have received a work order.
Interaction	N/A
Data	Location of the truck, Geofence area of the RTG, work order information, LIDAR information, Movement recommendations
Motivation	Improve the efficiency and safety of the RTG-truck alignment process.
Time	Ongoing operation of the terminal yard.
System functionalities	Machine-to-machine communication, CHE mutual authentication and identification, machine-to-human communication

Figure 11 shows the diagram of relationship between actors in this Business Scenario: Automated CHE cooperation. The figure is modified from the one used in D3.2, adding a new actor "Mobile App or Traffic Lights", that was not initially considered. In addition, "CHE" equipment as "actor" has been simplified to the RTG (relevant element in the BS) as the other interacting CHE as the trucks, that have their own actor in the diagram. In addition, now all actors pass through the Identification and Authentication system directly except for the Traffic Lights (or mobile app), that relates straightforward to the truck alignment.

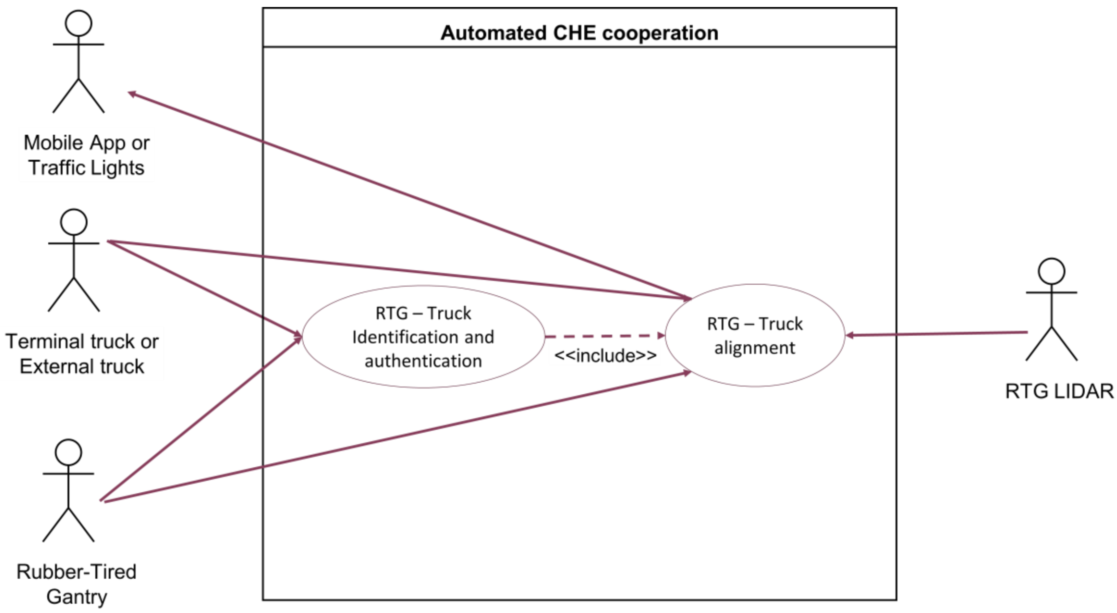


Figure 11. Use case diagram for the "Automated CHE cooperation" business scenario

3.2.1. UC-P1-4: RTG-Truck identification and authentication

Currently the communication between cranes and internal TTs is managed centrally through the TOS, which assigns and sends the job instructions to each other, while the RTG communication with external trucks is not possible.

The main goal of BS-P1-2 is to enable communication between internal and external trucks with the RTG crane. However, before opening a working data channel between the RTG crane and a truck (either internal TT or external truck) a proximity process of identification and authentication must be done. Consequently, there are two main problems to address in this use case: (i) get a reliable communication channel between both CHEs, in order to (ii) authenticate and secure the communication.

On the one hand, the reliable communication channel that should provide enough bandwidth and low latency to interconnect the truck with the RTG will be addressed by providing two access networks: (i) indirect communication through the internet by means of e.g., 4G/5G coverage (although it might be very limited in the transfer zone close to the RTGs due to containers walls blockages and the faraday cage effect of the RTG), or (ii) direct communication machine-to-machine by making use of low-range network or visual recognition solutions, such as QR, UWB, or BLE. This is the agreed option, in which a high-level illustration is shown below.

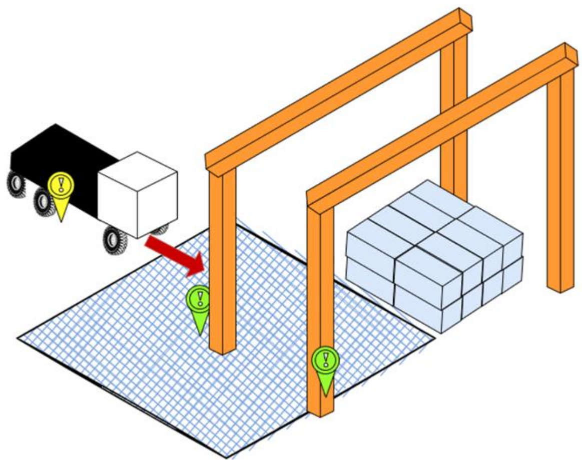


Figure 12. Truck entering into RTG geofenced area.

On the other hand, since an RTG is a paramount but critical machine in the terminal container handling operations, it demands top-level cybersecurity requirements. For this reason, ASSIST-IoT will resolve this issue by providing enhanced security authentication and authorization functionalities that are only executed on the edge when the CHEs are closed to each other. Prior to the execution of any work instruction, the truck must have the key "token" to authenticate its identity with the RTG, which in turn must also have the private token linked with each one of its work instructions (cargo visit and carrier visit) within its job list.

Next, if the exchanged tokens match, the alignment process associated with the UC-P1-5 is triggered.

Figure 13 depicts the infrastructure sketch of the UC-P1-4 use case.

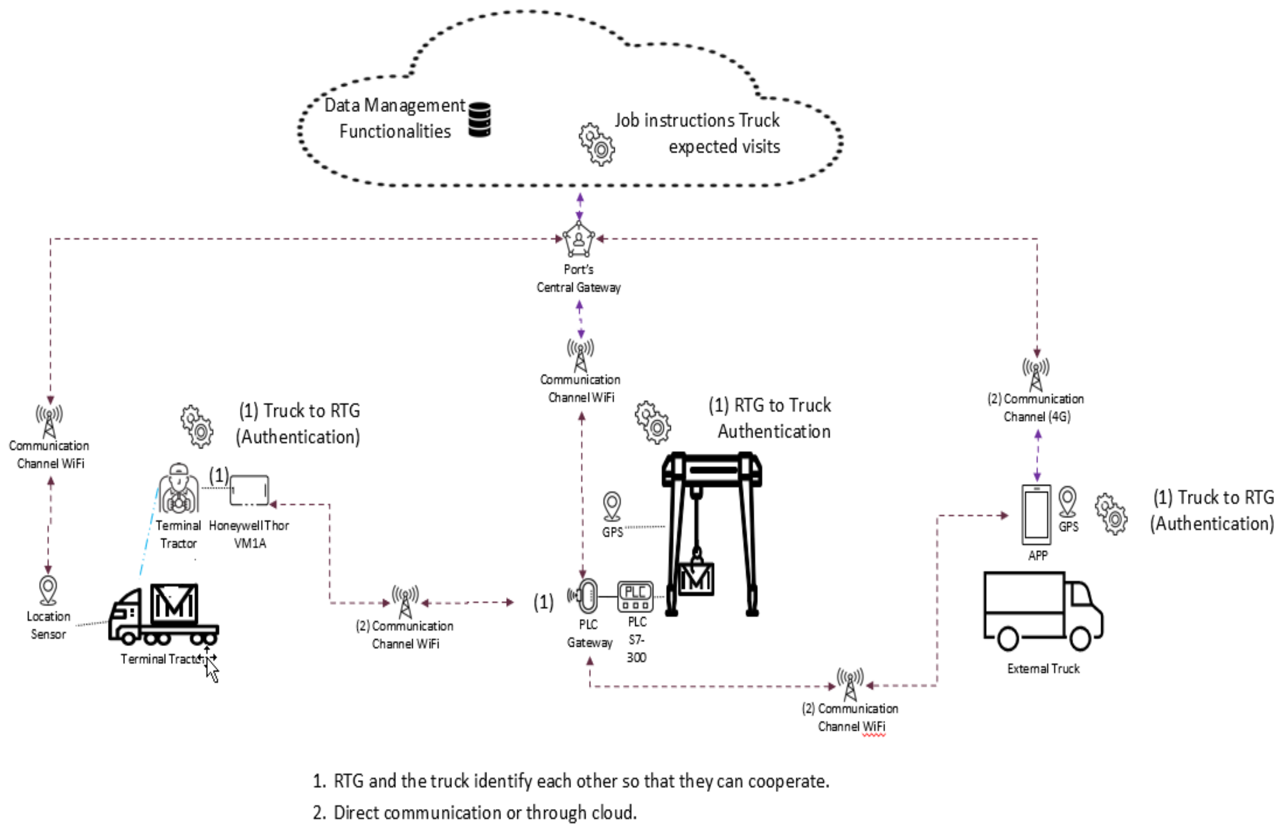


Figure 13. UC-P1-4 Infrastructure diagram

It is expected that the information model to be used for the authentication exchange between the truck and the crane will be the same and based on TIC 4.0 standard. A TIC 4.0 JSON message extract is printed in the following Figure 14.

```
{
    "che": [{
            "id": "",
            "name": "",
            "number": 0,
            "type": "",
            "location": {
            "on": {
            "off": {
            "standby": {
            "notstandby": {
            "working": {
            "idle": {
            "onlydriving": {
            "notonlydriving": {
            "working_and_notdriving": {
            "drive": [{
            "spreader": [{
            "hoist": [{
            "trolley": [{
            "cycle": [{
                    "id": "",
                    "loading": false,
                    "unloading": false,
                    "usefull": false,
                    "unusefull": false,
                    "paid": false,
                    "unpaid": false,
                    "handlingreason": "",
                    "move": {
                    "weight": {
                    "start": {
                    "end": {
                    "laden": {
                    "cargo": [{
                    "cargovisit": [{
                    "carrier": [{
                    "carriervisit": [{
                }
            ]
        }
    ]
}
```


Figure 14. TIC 4.0 standard data model for the UC-P1-4 use case

Use Case: UC-P1-4, RTG-truck identification and authentication	
Description	RTG and the truck identify each other upon the arrival of the tuck to close proximity of the RTG.
Reference Scenario	Automated CHE cooperation
Plane(s)	Device and Edge, Smart Networking and Control, Data Management
Vertical Capabilities	Cybersecurity component
Functionalities within vertical capabilities	Authentication and authorization
Objectives	RTG and the truck identify each other so that they can cooperate.
Actors (system actor or natural persons)	• RTG • Terminal tractor or external truck
Pre-conditions	• The truck is assigned a work order to perform with the RTG • The RTG is assigned a work order to perform with the truck
Trigger	The truck comes into proximity with the RTG (<15m)
Expected results	The truck and the RTG have identified and authenticated each other.

Design preferences	• Truck proximity in relation to the RTG is detected using M2M communications, geofencing (UWB anchors), and positioning sensors (UWB tags) on the truck • The communication should be performed directly between the machines, without any third party involved. • If manned operations are needed, both CHEs should make use of a smartphone/tablet to handle the identification and authentication exchange.
Notes and issues	N/A
Main execution flow	1. The truck approaches the RTG. 2. By means of ASSIST-IoT geofencing capabilities, the RTG detects the truck is in proximity. 3. Using ASSIST-IoT, the truck sends its ID to the RTG. The RTG sends its ID to the truck. 4. Using ASSIST-IoT, RTG verifies the truck's ID, and confirms if it is the one that it was expected. The truck verifies the RTG's ID, and determines it is the one that it was assigned to its work order. 5. RTG and truck can commence the cooperation
Alternative execution (if applicable)	3. Using ASSIST-IoT, the mobile app sends truck ID to the RTG. The RTG sends its ID to the mobile app. Proceeds with 4.
Exceptions (if applicable)	If either the RTG cannot verify the truck's identity or the truck cannot verify RTG's identity, the operation must not proceed. The exception must be handled manually.
Requirements involved	R-P1-10, R-P1-11, R-P1-12, R-P1-13
KPI	Two RTGs equipped with UWB geofencing services, and at least one TT and one external truck involved in the real-time demo will be identified and authenticated.
Identified by:	TL, PRODEVELOP, KONECRANES

3.2.2. UC-P1-5: RTG-Truck alignment

Following UC-P1-4, once the truck and RTG are in proximity and mutually authenticated, the operational information to do the alignment and all the activity of the RTG crane will be reported to a mobile app installed on the truck embedded device. This information includes the spreader, hoist and trolley movement data obtained from crane's PLC, as well as the LIDAR sensor messages (see Figure 15) that are sent both to the traffic lights as well as to the mobile app.

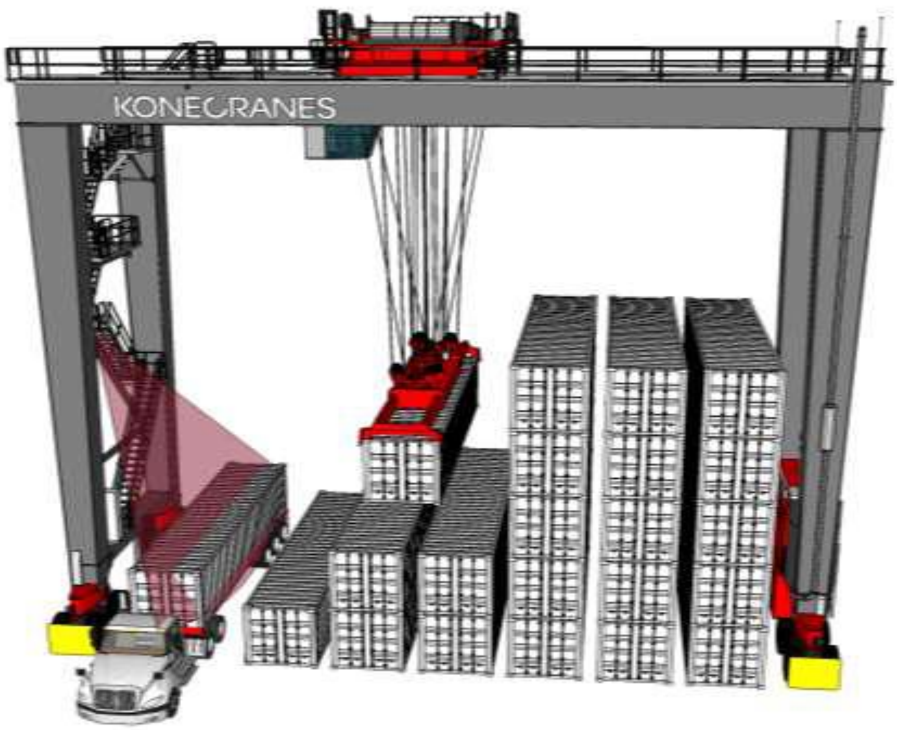


Figure 15. Truck-lane laser scanning.

A schematic of the use case is depicted in Figure 16.

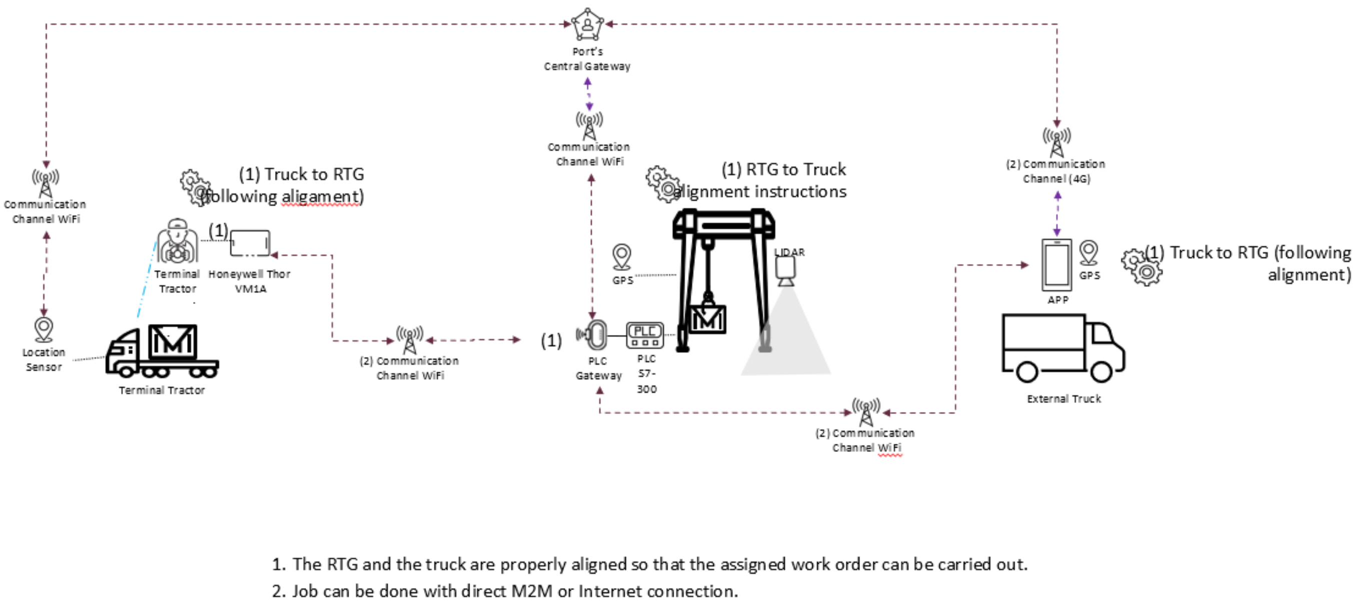


Figure 16. UC-P1-5 Infrastructure diagram.

Again, as in UC-P1-4, it is expected that the information model to be exchanged for the alignment between the truck and the crane will be based on TIC 4.0 standard. A TIC 4.0 JSON message extract is printed in the following figure, which can be observed the *che.id.spreader*, *che.id.hoist*, *che.id.trolley* data fields.

```
{
    "che": [{
            "id": "",
            "name": "",
            "number": 0,
            "type": "",
            "location": {
            "on": {
            "off": {
            "standby": {
            "notstandby": {
            "working": {
            "idle": {
            "onlydriving": {
            "notonlydriving": {
            "working_and_notdriving": {
            "drive": [{
            "spreader": [{
                    "id": "",
                    "name": "",
                    "number": 0,
                    "location": {
                    "size": {
                    "size20foot": {
                    "size30foot": {
                    "size40foot": {
                    "size45foot": {
                    "sizeISOwidth": {
                    "sizeWTP": {
                    "locking": {
                    "unlocking": {
                    "locked": {
                    "unlocked": {
                    "extending": {
                    "retracting": {
                    "landed": {
                    "weight": {
                }
            ],
            "hoist": [{
            "trolley": [{
            "cycle": [{
        }
    ]
}
```


Figure 17. TIC 4.0 standard data model for the UC-P1-5 use case

Use Case: UC-P1-5, RTG-Truck alignment	
Description	The RTG and the truck cooperate through bi-directional communication to align themselves for a container transfer operation.
Reference Scenario	Automated CHE cooperation
Plane(s)	Device and Edge, Smart Networking and Control, Application and Services
Vertical Capabilities	Self-*, Manageability and control
Functionalities within vertical capabilities	TBD
Objectives	The RTG and the truck are properly aligned so that the assigned work order can be carried out.
Actors (system actor or natural persons)	• RTG • RTG LIDAR • Terminal truck or External truck • Traffic lights / Mobile app.
Pre-conditions	• The TT is assigned a work order to perform with the RTG

	• The external truck driver was given a mobile device and is assigned a work order to perform with the RTG • The RTG is assigned a work order to perform with the truck (TT or external)
Trigger	The truck and the RTG are mutually identified and authenticated (UC-P1-4).
Expected results	The RTG and the truck are correctly aligned to perform their work order.

Design preferences	• The measurement of the truck's location in relation to the RTG can be carried out by a LIDAR or a camera system with computer vision capabilities. LIDAR is the preferred option, as it is the most advance and accurate solution in this field.
	• RTG-to-truck signalling can take many forms depending on the truck type and the hardware present on it:
	    o Device (e.g., traffic lights) installed on the RTG legs (visible by the TT and external truck drivers).
	    o Mobile device present in the external truck driver's cabin.
	    o Mounted device in the TT driver's cabin.
	    o Machine-to-machine communication for fully autonomous TTs.

Includes the use case	**UC-P1-4** (RTG-Truck identification and authentication)
Notes and issues	N/A

Main execution flow	• The RTG and the truck are mutually identified and authenticated (UC-P1-4).
	1. Repeat until aligned:
	    a. ASSIST-IoT receives a request from the RTG LIDAR for the truck to move in some direction
	    b. ASSIST-IoT forwards the request to the truck
	    c. The truck moves according to the ASSIST-IoT request
	    d. RTG LIDAR checks if the truck is aligned
	2. The truck stops
	3. Using ASSIST-IoT, the truck signals to the RTG that it is ready for the container loading/unloading operation.
	4. RTG loads/unloads the container on/from the truck
	5. Using ASSIST-IoT, the truck sends a confirmation to the RTG that it was properly loaded/unloaded

Alternative execution (if applicable)	N/A
Exceptions (if applicable)	N/A
Requirements involved	R-P1-10, R-P1-11, R-P1-12, R-P1-13
KPI	10% decrease of time elapsed between manual and automatic alignment
Identified by:	TL, PRODEVELOP, KONECRANES

3.3. BS-P1-3: RTG remote control with AR support

In a traditional container terminal layout, the yard cranes can be manned-RTGs. They can be working in a typical two crane per-stack configuration with various possibilities: end-feed-RMG, side-feed-RMG and RTG. The productivity per crane naturally depends upon the skills and attitude of the crane driver, and many other factors related to the processes involved in the terminal. In a traditional not remote yard crane operation with an average performance, the crane and crane driver's time usage can be broken down as follows (Figure 18): 11% for gantrying, 20% of the time is devoted to stacking, 10% of the time devoted to truck handling, and idling time is as high as 60%.

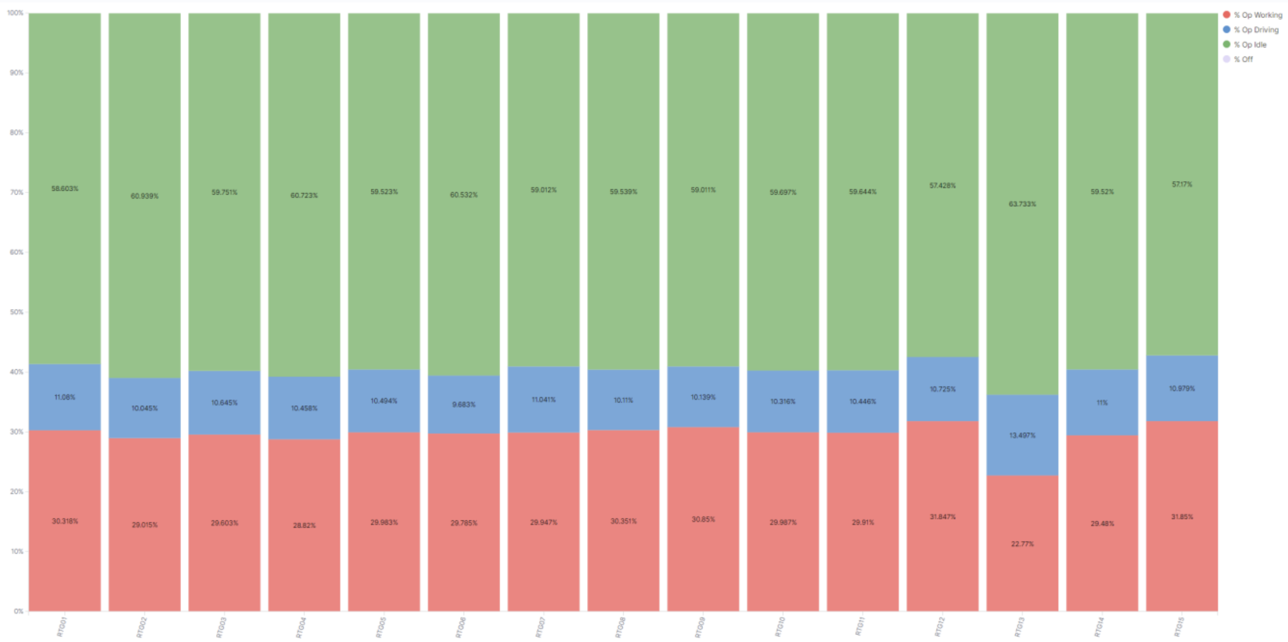


Figure 18. Average MFT RTG time breakdown during 60 days (working - red, gantrying – blue, idle - green)

This latter figure might seem high at first glance, but idling times can be even higher in typical manned-yard operations. Furthermore, when one looks at a fleet of manned-yard cranes, they are dispersed across the container's stacks. The logistics are even more complicated in order to transport the operators to and from the cranes, climbing into the cabins, toilet breaks, lunch breaks, and so on. Finally, supervision across the container stacks can be challenging at times, and communication could be complicated between the supervisors and the crane operators and between the crane operators themselves.

Remote operation allows for the control of several cranes by one driver who can virtually jump from one location to another by means of a remote desktop emulating a fully operational RTG crane cabin (see Figure 19). This allows to optimise the efficiency of the driver to a completely different breakdown about 15% for gantrying, 40% of the time is devoted to stacking, 20% of time devoted to truck handling, and idling time is as high as 25%. This means that the idling time is reduced from 60% up to 25% (35% of the driver cost savings).

Figure 19. Remote RTG crane desktop

Business scenario BS-P1-3, RTG remote control with AR support	
This scenario includes the completely remote operation of RTG cranes. Relying on the architecture of the ASSIST-IoT project, this scenario will empower the crane operators with all the extended capabilities developed in the pilot to effectively control and drive a crane from a control room. Remote operation of the equipment will be performed in a controlled environment, without interacting with other workers in the yard, with all due security measures. The success of implementing this pilot testbed will ultimately unleash two main impacts: improvement of the working conditions of thousands of workers with a clear RoI (Return of Investment) for the terminal.	
User/users:	Operator, Terminal management
Setting / context	Port terminal
Interacting system	TOS, RTG geolocation system, Crane Management Systems (CMS), container identification system, remote RTG system (ROS), Multilink wireless gateway
Users' goals	Terminal management – to reduce RTG idling periods.
Initial status	There is a stable connection between the RTG and RTG remote operator terminal.
Interaction	Remote operator – receiving guidance for work orders performed in the terminal yard. Remote operation of the RTG over a stable wired and/or wireless network connection.
Data	Video feed from RTG camera system, information about the location of containers within the terminal yard, TOS work orders, data from and commands for moving crane parts (hoist, gantry, straddle).
Motivation	Improve the efficiency of operator's and RTG's time use.
Time	Ongoing operation of the terminal yard.
System functionalities	Smart Network, AR visualization for remote RTG operator

Figure 20 shows the diagram of relationship between actors in this Business Scenario: RTG remote control with AR support. The figure is simplified from the one used in D3.2. The element coming from BS-P1-1 ("Asset location management") has been now removed as this connection was already explained. In addition, it has been described that the RTG Camera System can now directly connect to the Wireless remote RTG operation.

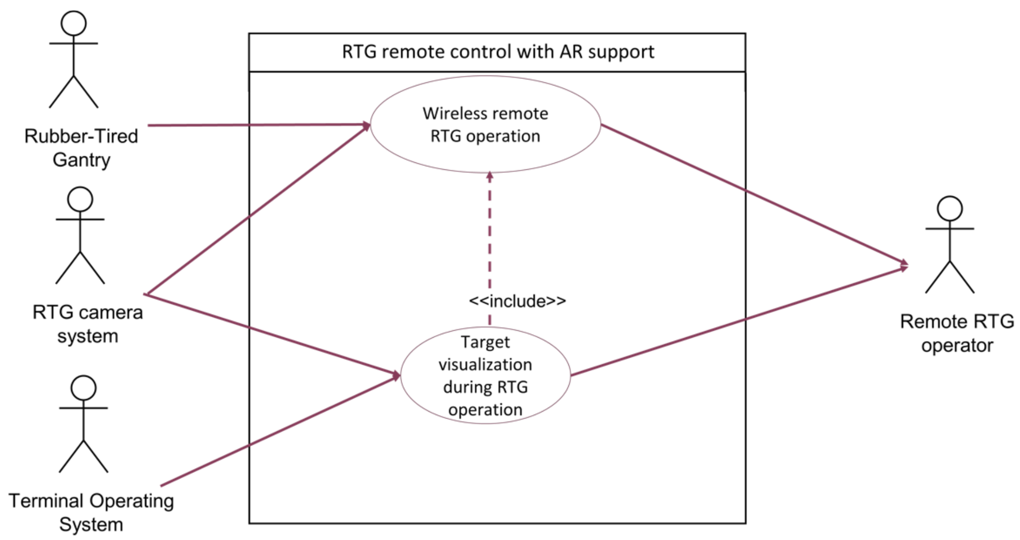


Figure 20. Use case diagram for the "RTG remote control with AR support" business scenario

3.3.1. UC-P1-6: Wireless remote RTG operation

This use case is about enabling a redundant and sufficiently capable wireless network to the remote RTG operation. For this use case, the bandwidth (60 Mbps for sending all the AV streams captured by the cameras installed on each remote crane) and latency (<150 ms glass-to-glass, i.e., from the glass of the camera capturing the environment up to the glass of the screen showing what is captured + 20 ms of layer-2 network) requirements should also be met, either with the primary connection or in case of this failing, by some of the secondary access networks. In principle, the three main wireless communication channels considered are FluidMesh (as primary network), 4G and WiFi. To do so, the ASSIST-IoT multilink software will be deployed on the network routers/switches installed both at cranes IT rooms, as well as at Remote server rooms. A screenshot of the first multilink advancements is shown in Figure 21.

Figure 21. Fluid-mesh transceiver (left), zero IP packets loss when switching between ethernet-WIFIi-Ethernet

An infrastructure diagram is illustrated in Figure 22.

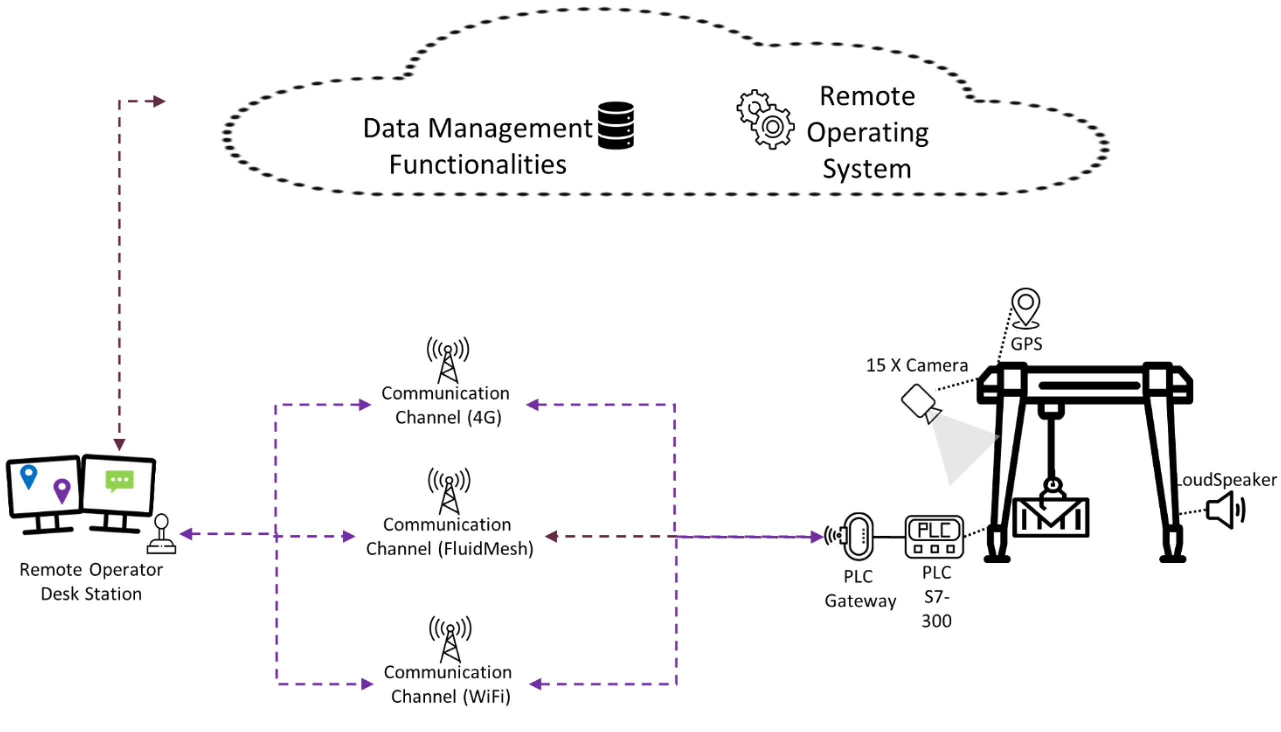


Figure 22: *UC-P1-6 Infrastructure diagram*

Use Case: UC-P1-6, Remote RTG operation	
Description	The operator controls the RTG wirelessly using a console with built-in enhanced visuals to aid them in performing the work order.
Reference Scenario	RTG Remote Control with AR Support
Plane(s)	Device and Edge, Smart Networking and Control, Data Management, Application and Services
Vertical Capabilities	Self-*, Manageability and control
Functionalities within vertical capabilities	Self-provisioning
Objectives	Allow for wireless remote operation of RTGs.
Actors (system actor or natural persons)	• Remote RTG operator • RTG ROS PLCs • RTG AV cameras
Pre-conditions	• The operator is set to execute a work order • The RTG is ready for remote operation • There is a stable wireless network connection between the operator and the RTG
Trigger	The operator starts executing the work order
Expected results	The work order is executed.
Design preferences	The capability for remotely controlling an RTG is already available in the market (although not deployed in MFT premises). The connection between the operator and the RTG should be wireless to reduce deployment costs and with multiple redundant links to ensure sufficient network stability.
Extends the use case (if applicable)	N/A
Includes the use case	**UC-P1-7** (Target visualization during RTG operation)
Notes and issues	N/A
Main execution flow	1. The operator receives work orders on their ROS terminal 2. The operator selects the work order to perform 3. The operator selects the RTG to be controlled 4. The operator starts carrying out the assigned work order 5. ASSIST-IoT provides a network connection between the operator and the RTG 6. The operator finishes the work order 7. The operator is ready to select the next work order
Alternative execution (if applicable)	N/A
Exceptions (if applicable)	N/A

Requirements involved	R-P1-18, R-P1-19, R-P1-20, R-P1-21, R-P1-22, R-P1-23, R-P1-24
KPI	Two RTGs are smoothly working without network interruptions (lower than 1 minute per day)
Identified by:	TL, PRODEVELOP, KONECRANES

3.3.2. UC-P1-7: Target visualization during RTG operation

Right now, remote operation of cranes does not provide the same immersive experience as local on-site cabin use due to the lack of line-of-sight, limiting the contextual information. However, thanks to the huge amount of data handled by the crane telemetry and Terminal Operating System (TOS), extra information is presented in sided small monitors/screens. The objective of this use case is that data and actions obtained from the PLCs of the crane as well as from the TOS can be provided more immersive by means of Computer Vision technologies. In particular, the guiding visuals of this use case will help remote RTG operators with the identification of the specific container to be handled for the job instruction under work. Hence, in addition to the previous wireless remote use case UC-P1-6, a Machine Learning video recognition module should be applied over the streams captured by the crane's cameras, which are received on the ROS A/V servers (as shown in the screenshots below). In order to fulfil this, additional data sets that emulate a similar remote operating scenario should be firstly collected, annotated, and trained appropriately.

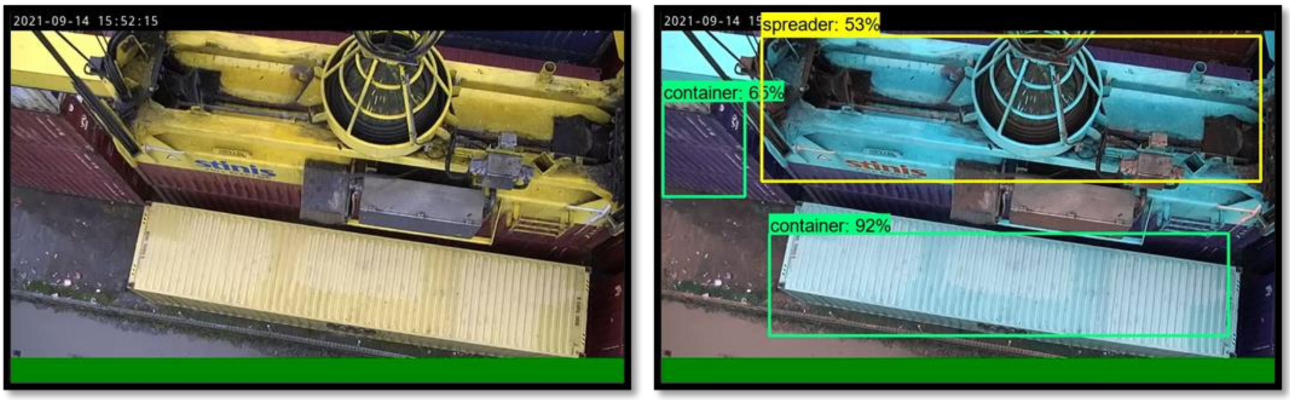


Figure 23. Containers highlighted thanks to computer vision features

Figure 24 illustrates the actors involved in this use case. In particular, the guiding visuals of this use case will help remote RTG operators with the identification of the specific container to be handled for the job instruction under work.

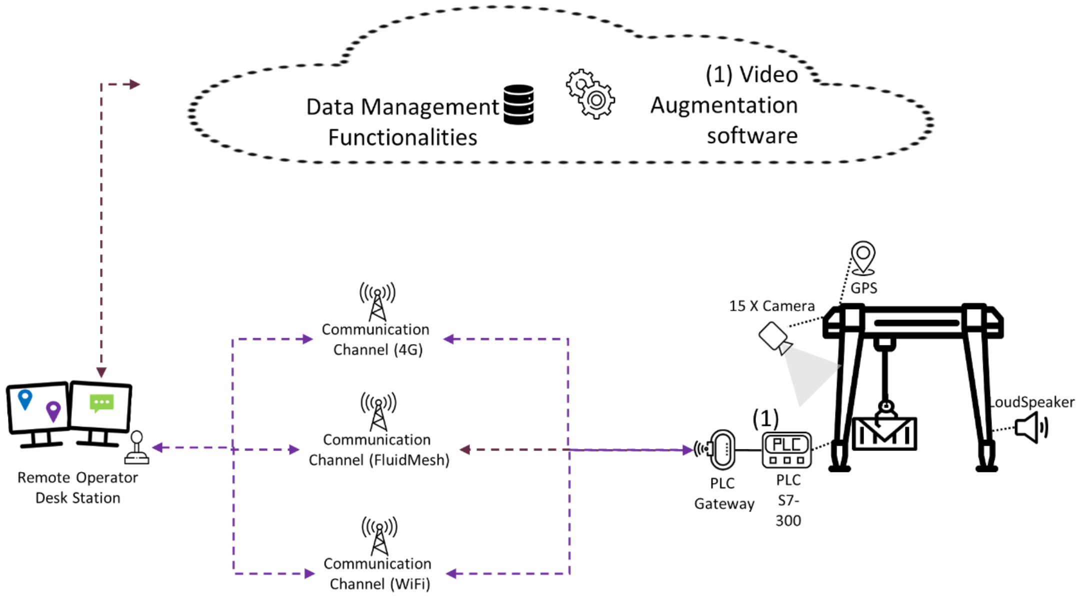


Figure 24: UC-P1-7 Infrastructure diagram

Use Case: UC-P1-7, Target visualization during RTG operation	
Description	Remote RTG operator is provided with AR guides for which container to pick up and where to place it.
Reference Scenario	RTG Remote Control with AR Support
Plane(s)	Device and Edge, Data Management Plane, Application and Services
Vertical Capabilities	Manageability and control
Functionalities within vertical capabilities	TBD
Objectives	Provide the operator with visuals indicating which container is to be handled
Actors (system actor or natural persons)	• Remote RTG operator • RTG camera system • TOS
Pre-conditions	The operator is executing a work order remotely.
Trigger	The operator is going to move a given container.
Expected results	The operator completes the work order.
Design preferences	TBD
Extends the use case (if applicable)	N/A
Includes the use case (if applicable)	**UC-P1-3** (Asset location management)
Notes and issues	This UC extends UC-P1-6

Main execution flow	1. The operator starts performing a work order 2. ASSIST-IoT obtains the information about the work order from the TOS 3. ASSIST-IoT is aware of the position of the RTG and the location of the container in the yard is obtained (UC-P1-1) 4. The RTG camera system provides the video feed from the RTG 5. ASSIST-IoT uses trained ML models and based on information from the TOS, identifies the containers to be retrieved and displays them in the video feed. 6. ASSIST-IoT identifies the container to be picked up with visual guidelines displayed over the video stream from the RTG camera system. 7. The operator orders the RTG to pick up the container.
Alternative execution (if applicable)	N/A
Exceptions (if applicable)	N/A
Requirements involved	R-P1-18, R-P1-19, R-P1-20, R-P1-21, R-P1-22, R-P1-23, R-P1-24
KPI	Container detection Mean Average Error (MAE) < 15%
Identified by:	TL, PRODEVELOP, KONECRANES

3.4. Pilot 1 system's requirements

Requirement: R-P1-1 CHE location services	
Category	Functional
Priority	Must
Use case IDs	UC-P1-2, UC-P1-3, UC-P1-4
Rationale	To enhance operational efficiency of yard workers and external drivers.
Description	CHEs are equipped with devices for reporting their operational status and location. External trucks receive Job instruction location.
Acceptance criteria	2 cranes, 1 TT, and 1 external truck involved in the real-time demo will be located in real-time. External driver **receives visual directions** about where to go and by whom is expected to be attended.
Customer satisfaction	4
Customer dissatisfaction	5
Identified by	**Source**
TL, PRO, KONECRANES	Partner's expertise

Requirement: R-P1-2, CHE location availability	
Category	Non-Functional
Priority	Should
Use case IDs	UC-P1-3, UC-P1-5
Rationale	The location information can be available during all working times
Description	The location of all CHEs within the terminal yard should be available as long as possible
Acceptance criteria	More than 95% of location data should be guaranteed. If communication is interrupted the data must be buffered to send it when reconnect.
Customer satisfaction	4
Customer dissatisfaction	2
Identified by	**Source**
TL, PRO, KONECRANES	Partner's expertise

Requirement: R-P1-3, CHE positioning accuracy	
Category	Non-Functional
Priority	Should
Use case IDs	UC-P1-3, UC-P1-1, UC-P1-2
Rationale	CHEs are continuously moving within a terminal yard
Description	The CHEs should be accurately positioned in the terminal yard by means of GPS or relative positioning technology
Acceptance criteria	The user range error (URE) should be ≤ 2 m
Customer satisfaction	3
Customer dissatisfaction	2
Identified by	**Source**
TL, PRO, KONECRANES	Partner's expertise

Requirement: R-P1-5, Container ID tracking system	
Category	Non-Functional
Priority	Could
Use case IDs	UC-P1-3, UC-P1-2
Rationale	The containers/cargo shall be always identified and tracked
Description	Once the truck is identified and the cargo verified, the job instruction will be activated by the RTGs. ASSIST-IoT will track the activity and verify that the job instruction is done successfully. If it does not, it will give an alarm to the driver or TOS.
Acceptance criteria	The crane involved in the real-time demo will report to the mobile app the origin and destination GPS coordinates of the container being handled
Customer satisfaction	3
Customer dissatisfaction	2
Identified by	**Source**
TL, PRO	Partner's expertise

Requirement: R-P1-10, CHE Identification	
Category	Functional
Priority	Must
Use case IDs	UC-P1-4
Rationale	For efficient reporting o CHE and container status
Description	The CHEs have to be uniquely identified before starting the cooperation process
Acceptance criteria	2 cranes, 1 TT, and 1 external truck involved in the real-time demo will be univocally identified.
Customer satisfaction	5
Customer dissatisfaction	4
Identified by	**Source**
TL, PRO, KONECRANES	Partner's expertise

Requirement: R-P1-11, CHE machine-to-machine communication	
Category	Functional

Priority	Optional
Use case IDs	UC-P1-4, UC-P1-5
Rationale	CHE-to-CHE/truck communication possibility will decrease the time of operations fulfilment (container manipulations), reduce latency, and allow communication even if the centralised data network is unavailable.
Description	The CHEs have to be able to communicate with each other without the need for a third entity in the process. Identification must be done in advance.
Acceptance criteria	One M2M low-range communication system shall be available when a truck is in proximity of 10 meters around a crane.
Customer satisfaction	4
Customer dissatisfaction	4
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement: R-P1-12, CHE authentication	
Category	Functional
Priority	Must
Scenario / Use case IDs	UC-P1-4
Rationale	The CHEs must carry out an authentication process before starting the fulfilment of the work order
Description	The CHEs must carry out an authentication exchange process before enabling direct communication.
Acceptance criteria	One crane and one truck are mutually authenticated by exchanging their credentials. Next, it will open the crane's telemetry information transmission to the authenticated truck without an external server or in the cloud.
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
TL, PRO, KONECRANES	Partner's expertise

Requirement: R-P1-13, CHEs authentication range	
Category	Non-Functional
Priority	Should
Use case IDs	UC-P1-4
Rationale	To perform the authentication process in a limited area.
Description	The CHEs have to perform only the authentication process within a limited coverage range in order to avoid unauthorised accesses
Acceptance criteria	Optimum: The CHEs are in a proximity range < 15m Minimum acceptance criteria: within the Terminal
Customer satisfaction	5
Customer dissatisfaction	4
Identified by	**Source**
TL, PRO, S21SEC	Partner's expertise

Requirement: R-P1-15, Alignment exposure	
Category	Non-Functional
Priority	Should
Use case IDs	UC-P1-5
Rationale	The CHEs have to perform the alignment process accurately
Description	The backwards/forwards movement extracted from the LIDAR system must be exposed to Human-to-Machine interfaces
Acceptance criteria	Two HMIs will present the alignment recommendations (traffic lights, app with user interface, app voice assistant)
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
TL, PRO, KONECRANES	Partner's expertise

Requirement: R-P1-16, Open/Accessible Remote capabilities	
Category	Functional
Priority	Must
Use case IDs	UC-P1-6
Rationale	A terminal operator (crane driver) can control an RTG crane remotely
Description	The remote operation system should be sufficiently open to enable the integration of ASSIST-IoT features for enabling RTG movements (drive, trolley, hoist, spreader, and twistlocks) remotely.
Acceptance criteria	One RTG shall be equipped with remote operation capabilities compatible with the ASSIST-IoT framework.
Customer satisfaction	4
Customer dissatisfaction	4
Identified by	**Source**
TL, PRO, UPV, KONECRANES	Partner's expertise

Requirement: R-P1-17, Customizable remote desktop	
Category	Functional
Priority	Must
Use case IDs	UC-P1-6, UC-P1-7
Rationale	A terminal operator (crane driver) can control an RTG crane remotely
Description	The remote console/desktop available in the market should be able to be customised to allow the integration of built-in enhanced visuals.
Acceptance criteria	One remote desktop shall be installed in terminal offices
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement: R-P1-18, Industrial and safety protocols support	
Category	Functional
Priority	Must
Use case IDs	UC-P1-6, UC-P1-7
Rationale	A remote RTG crane is nowadays using PROFINET and PROFISAFE network and security protocols
Description	ASSIST-IoT network plane should be interoperable with PROFINET and PROFISAFE protocols
Acceptance criteria	ASSIST-IoT support L2 level PROFINET network protocol
Customer satisfaction	4
Customer dissatisfaction	5
Identified by	**Source**
TL, PRO, UPV, KONECRANES	Partner’s expertise

Requirement: R-P1-19, Remote bandwidth capabilities	
Category	Non-Functional
Priority	Must
Use case IDs	UC-P1-6, UC-P1-7
Rationale	Several video streams are sent to the remote desktop
Description	The systems shall be able to provide enough throughput to ensure that the video streams are received correctly
Acceptance criteria	Throughput greater than 60 Mbps per remote crane shall be guaranteed
Customer satisfaction	4
Customer dissatisfaction	5
Identified by	**Source**
TL, KONECRANES	Partner’s expertise

Requirement: R-P1-20, Remote latency capabilities	
Category	Non-Functional
Priority	Must
Use case IDs	UC-P1-6, UC-P1-7
Rationale	The RTG engine/movements will be managed remotely
Description	The ROS network shall be able to provide end-to-end latencies that guarantee the proper use of the RTG from the remote desktop
Acceptance criteria	ASSIST-IoT glass-to-glass latencies (i.e., from the glass of the camera to the glass of the screen) shall be below 170ms. ASSIST-IoT network latency shall be below 20ms.
Customer satisfaction	5
Customer dissatisfaction	4
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement: R-P1-21, Remote reliability capabilities	
Category	Non-Functional
Priority	Must
Use case IDs	UC-P1-6, UC-P1-7
Rationale	The RTG engine/movements will be managed remotely, and several video streams are sent to the remote desktop
Description	The ROS network shall be sufficiently reliable to guarantee the proper use of the RTG from the remote desktop
Acceptance criteria	The ROS shall be working more than 99% of working time. The swap between networks must not interrupt operations.
Customer satisfaction	3
Customer dissatisfaction	3
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement: R-P1-22, Multilink wireless network capabilities	
Category	Non-Functional
Priority	Should
Use case IDs	UC-P1-1, UC-P1-2, UC-P1-6, UC-P1-7
Rationale	Wireless connectivity is not as reliable as wired connection
Description	To guarantee connectivity requirements when remote operation is performed wirelessly
Acceptance criteria	At least 2/3 wireless technology must be integrated in the ROS Minimum: fluid-mesh and WiFi Optimum: fluid-mesh, WiFi and 4G
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
TL, UPV, KONECRANES	Partner's expertise

Requirement: R-P1-23, AR support	
Category	Functional
Priority	Must
Use case IDs	UC-P1-7
Rationale	Additional visual enhancements to aid the work for remote operators is demanded
Description	Remote RTG operator shall be provided with AR guides (digital recommendations over the video streams) that indicate the container that he/she has to pick up and where has to place it.
Acceptance criteria	Digital recommendations over which container should be picked up based on the assigned TOS work instruction shall be overlapped in real-time with the video streams of the ROS
Customer satisfaction	3
Customer dissatisfaction	3
Identified by	**Source**
TL, PRO, KONECRANES	Partner's expertise

Requirement: R-P1-24, Wireless remote capabilities	
Category	Functional
Priority	Must
Use case IDs	UC-P1-6, UC-P1-7
Rationale	A terminal operator (crane driver) can control an RTG crane remotely
Description	The RTG shall be connected to the remote desktop with a redundant wireless network technology
Acceptance criteria	A stable and redundant wireless connectivity must be integrated in the Remote Operating System (ROS). The swap between networks must not interrupt operations.
Identified by	**Source**
TL, PRO, UPV, KONECRANES	Partner's expertise

4. Pilot 2: Smart safety of workers

A construction site is one of the most challenging environments in terms of ensuring safe and health work conditions due to its changeability and unpredictability. Moreover, within any construction site, a large number of people with various levels of training and experience, are occupied by several subcontracted companies, interact with each other, operate equipment or interface with heavy machinery. Both factors result in the highest injury and fatal accident statistics in Europe for this sector. Accidents may happen in a matter of seconds without providing any early warnings. In addition, a potentially life-saving timely response to an accident may also not be possible unless adequate monitoring mechanisms are in place. Collecting reliable and relevant information in order to generate intelligent insights for the protection of all individuals present anywhere within a large construction site is one of the aims of ASSIST-IoT. Such information and insights, along with the consistent application of data protection rules, will advance knowledge and raise awareness about occupational safety and also contribute to the digitalisation transformation of occupational safety and health management in the construction sector that keeps humans at the forefront.

The main objective of ASSIST-IoT in this application area is the prevention and near real-time detection of common Occupation Safety and Health (OSH) hazards such as stress, fatigue, overexposure to heat and UV radiation, slips, trips, falls from height, suspension trauma, immobility due to unconsciousness, collision (forceful impact) with heavy equipment, entrapment (unable to evacuate the worksite during an emergency) and improper use of PPE.

A table with the actors in the “smart safety of workers” pilot is given in Appendix 3. This exercise was performed in the previous period and early documented in deliverable D3.2, having now been properly updated.

The construction site is located in the centre of Warsaw, on the campus of the University of Warsaw. The construction site consists of two parts: the office part and the construction part.

Figure 25: Office and construction part

To enter the office part, stakeholders should have a special RFID card or call the reception and wait for someone to come and open the gate. There is no need to use personal protective equipment in the office part. Before entering the construction site, the worker passes a mirror that reminds him that they must wear personal protective equipment.

4.1. BS-P2-1: Occupation safety and health monitoring

The construction industry around the globe has been demonstrating an unsatisfactory health and safety track record. This is primarily attributed to high physical demands and hazardous working environments. Construction works often involve long working hours without sufficient breaks under unfavourable weather conditions. ASSIST-IoT will provide a safety net to each individual present at a construction site; the solutions may also apply to infrastructure works, but the focus is on building sites, including their surrounding area. The solutions that will be developed in the context of this scenario are focused on human-centric safety aspects and involve connected wearables and near real-time monitoring of relevant health and safety information while emphasising personal data protection and user-friendliness. Minimising intrusiveness that could distract from normal activities will be a priority to gain user acceptance.

Figure 26: Workers within the construction area

To improve the clarity of this business scenario, some changes have been introduced in comparison to the initial assumptions (see D3.2). Firstly, falls, slips and trips on the ground are separated from this BS and combined with falls from a height in BS-P2-2. It was also decided to resign from tags implemented to the personal protective equipment (PPE) for the purpose of verification of their use and provide visual monitoring system that will be able to ensure two functionalities at the same time: monitoring of entrances to the construction site where PPE are required and verification of required set of PPEs. Moreover, the two use cases (i.e., UC-P2-2 and UC-P2-3) related to workers location and prevention of accidents due to entering to the dangerous zone or collision are merged considering that both use cases apply the same smart devices (i.e., localisation tag) and principles. Consequently, UC-P2-3 is removed from this document. UC-P2-4 focused on the construction workers' entries in a combination with proper use of PPE.

Below business scenario BS-P2-1 is an unchanged description from D3.2

Business scenario BS-P2-1, Occupation safety and health monitoring
Proper use of personal protective equipment for each activity at a construction site is a requirement and should be ensured. The physiological parameters of the construction workers are being monitored in real-time using wearable sensors to ensure that their health and safety are protected at all times while at the construction site. Mobile processing units are used to locally assess the worker's fatigue and stress level, without transmitting sensitive information to a central location unless a serious incident occurs. The health assessment is based on combining measurements and information related to their identity, validity of trainings and medical tests; environmental conditions are also considered, such as ambient temperature and UV radiation. The construction workers' location within the construction site is monitored so that first responders can be sent in case of an emergency. Geofencing services are also supported to ensure that construction workers move around areas within which they are authorised and trained to be.

<table>
<tr><td colspan="2">The authorisation of construction workers to enter the construction site is verified.
Interfaces between construction workers and the construction plant (red zones) are also monitored as the system can detect when a construction worker operates in the construction plant.
Construction workers and the project's OSH manager are provided with relevant information about incidents and potential hazards. The OSH manager combines, only a relevant subset of real-time data with information that is manually provided by the entire workforce via existing management and collaboration platforms in order to assess and report the overall risk status for the construction site.</td></tr>
<tr><td>User/users:</td><td>• Construction worker
• OSH manager
• Construction plant operator</td></tr>
<tr><td>Setting / context</td><td>Any worksite within a larger construction site where one or more construction activities are taking place. Construction workers could be working at, below (in an excavation) or above (on one of the floors of an under-construction building, on a ladder or a telescopic boom lift) ground level; they may also be in close proximity to operating Mobile Construction Equipment.</td></tr>
<tr><td>Interacting system</td><td>Wearable sensors and actuators (e.g., thermometer, cooling system etc.), BIM system, weather station, visual monitoring system.</td></tr>
<tr><td>Users' goals</td><td>• Ensure the construction workers' health and safety at the worksite.
• Ensure that the construction workers do not exceed acceptable fatigue and stress limits
• Ensure proper use of PPE
• Ensure that the construction workers are protected from overexposure to heat and UV radiation
• Prevent unauthorised access to restricted areas
• Construction workers can raise the alarm if they identify a danger
• Update the construction site's incident log
• Update the construction site health and safety performance metrics
• Ensure that the construction plant operator is aware of construction workers in the vicinity.</td></tr>
<tr><td>Initial status</td><td>All the construction workers wear their personal protective equipment and smart wearables. A construction worker may be operating a construction plant or working at height. All Access Points are securely locked, and the construction workers and Plant have been registered with the main contractor.</td></tr>
<tr><td>Interaction</td><td>Smart devices and wearables are paired together to monitor the construction worker's status, e.g., wearing all PPE or operating construction plant. Construction workers and Plant are granted access through a controlled-access entry point. The construction worker can adjust the operation of the cooling system according to their preferences. Sensitive information is transmitted to a central database only in case of an identified incident or as a frequent status report summary. The construction worker is provided with an interface to send a notification in case of an emergency.</td></tr>
<tr><td>Data</td><td>Location and proximity data, physiological parameter measurements, weather conditions measurements, personal identification information, the validity of training and medical test, building information, users' thermal comfort preferences, alerts, and notifications.</td></tr>
</table>

Motivation	• Protect the construction workers, and everyone present at a worksite, at all times and promptly respond to any emergencies • The construction workers feel confident while at work as the common worksite hazards are monitored • Acquire a clear view of a construction site's operational health and safety performance around the clock • Prevent unauthorised access to certain worksites which may lead to avoidable exposure to hazards • Construction sites are busy and noisy places; separation between moving equipment and humans is not always possible and the field of view of construction plant operators is limited. Construction workers are focused on their work and may be unaware of hazards in the vicinity
Time	Continuous monitoring in the vicinity of the construction site
System functionalities	Parameter monitoring and analysis; Actuation; Notification and Alerting

Figure 27 shows the use case relationship of Occupation safety and health monitoring. The figure is simplified from the one used in D3.2. The "Geofencing Boundary Enforcement" (UC-P2-2) and "Danger Zone Restriction Enforcement" (UC-P2-3) use cases have been merged due to the use of the same location tracking device (localization tag).

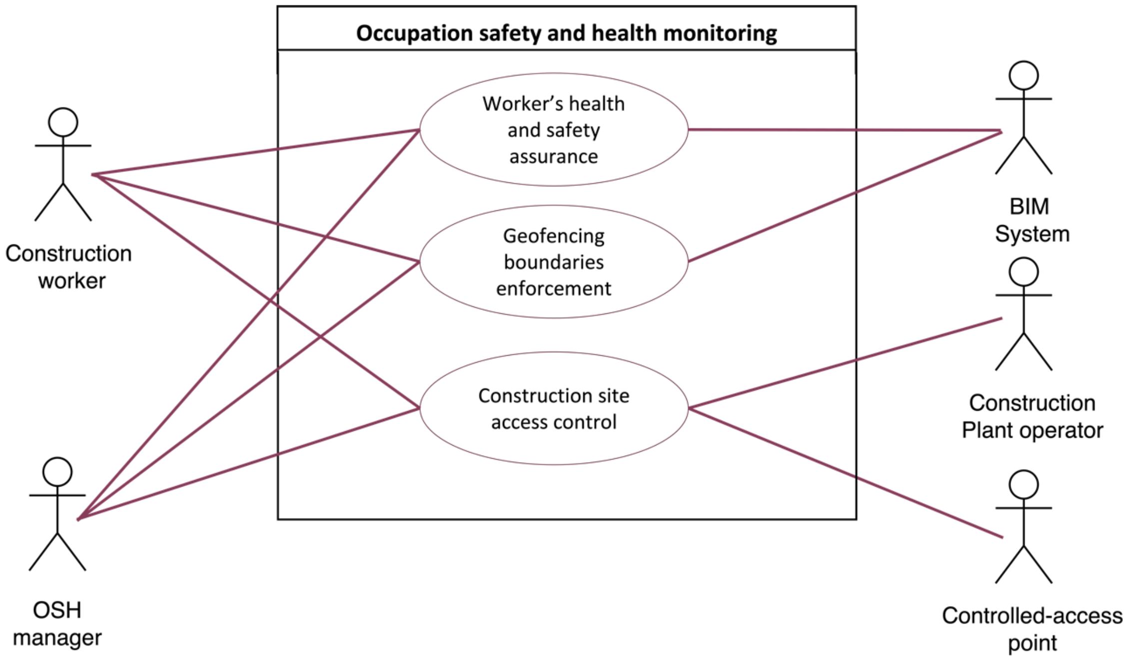
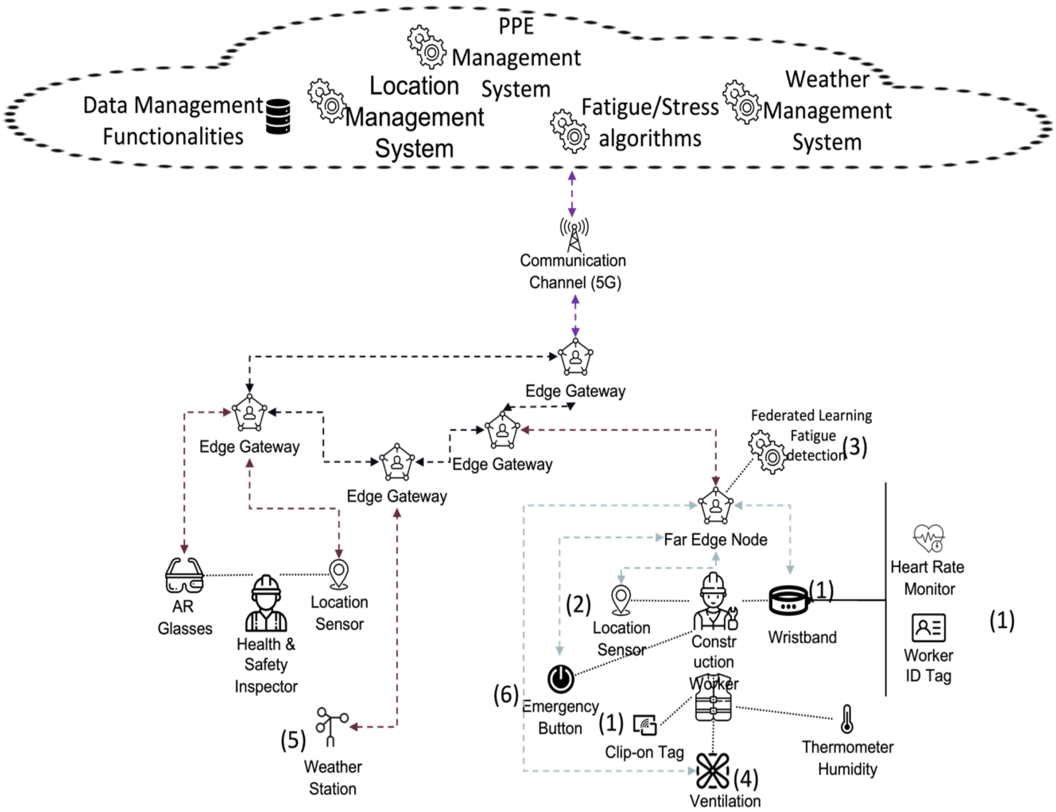


Figure 27. Use case diagram for the "Occupation safety and health monitoring" business scenario

4.1.1. UC-P2-1: Workers' health and safety assurance

Occupational safety and health could be improved by creating systems that can detect and report dangerous working conditions. Certain unnecessary and preventable risks might be avoided by using a monitoring system able to track a worker's exposure to the elements as well as their basic physiological state. Such a system would equip workers with trackers and sensors which would selectively report incidents and anomalies to an OSH manager, allowing them to prepare for and react to dangerous situations.



Objectives:

1. Monitor the physiological parameters of each construction worker and detect abnormalities that are potentially threatening to their health and safety
2. Track construction worker's location and motion patterns
3. Protect the construction worker from suffering extreme stress or fatigue
4. Reduce thermal discomfort of construction workers at the construction site
5. Prevent overexposure of construction worker to UV radiation
6. Notify the OSH manager about incidents and life-threatening events

Figure 28: Graphic representation of the Workers' health and safety assurance use-case.

Detection of abnormalities that are potentially threatening to the workers' health and safety will be based on measurements from the wristbands (PineTime smartwatch) and other smart devices. PineTime smartwatch's main advantages are (1) good documentation and the ability to use custom software, (2) long battery life, (3) dustproof and water resistant (IP67), (4) relatively low cost, (5) vibrations and colour display for communicating with the worker. It enables measuring the heart rate as the basic health-related parameter for fatigue and stress monitoring. In this use case, particular attention will be paid to meeting GDPR requirements and following the rules from the Ethics and Privacy Protection Manual (D2.4).

Figure 29. PineTime smartwatch used for monitoring worker's heart rate [source: www.pine64.org]

To reduce thermal discomfort during a work in high ambient temperature and with high metabolic rate, workers will be equipped with a personal cooling system – PCS (see BIP-15 in D9.6). The proposed PCS is based on the thermoelectric coolers (Peltier modules) integrated with high visibility protective clothing (Figure 30). The PCS can adjust the cooling power to the individual needs of the user based on the desired temperature in the undergarment microclimate to ensure thermal comfort.

Figure 30. A scheme of high visibility vest with integrated thermoelectric modules

Prevention from overexposure of construction worker to UV radiation will be possible due to the use of a weather station. The weather station selected for use in the trial is Davis Instruments Vantage Pro2 Plus with a USB data logger (). The weather station collects the following parameters:

- Barometric pressure,
- Relative humidity,
- Wind speed and direction,
- Rainfall,
- Solar radiation,
- Air temperature,
- Ultraviolet (UV) radiation.

Figure 31. Selected weather station Davis Instruments Vantage Pro2 Plus [source: www.davisinstruments.com]

A location tag (for example) on the helmet (Figure 32) can inform the employee to prevent dangerous situations in real-time and additionally inform an employee about a restricted area.

Figure 32. Tag for monitoring the location of hazardous worker situations.

The difference in the use of smart IoT devices, i.e., tags, weather station, etc., will be connected to the ASSIST Next Generation IoT Gateway/Edge node (Figure 33), the so-called GWEN.

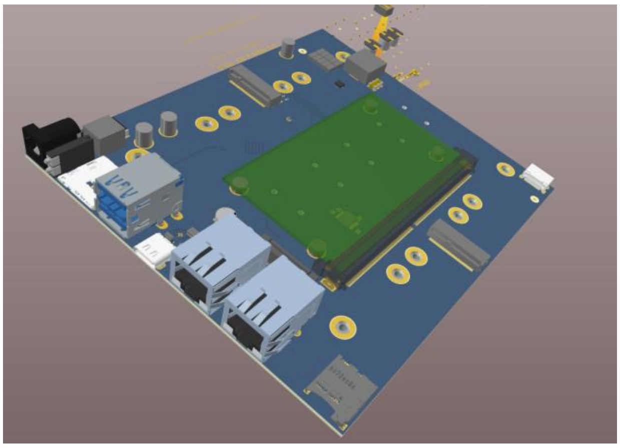


Figure 33. Impression of the 5G ASSIST Gateway Edge Node (GWEN).

Within the use case two interfaces are planned: one for the OSH manager (Figure 34) that will include a view of the current state of environmental conditions as well as the selected notifications; and one for the worker through the wristband (Figure 35) that will provide some first-level notifications in order to prevent the worker from a health issue (e.g. dehydration).

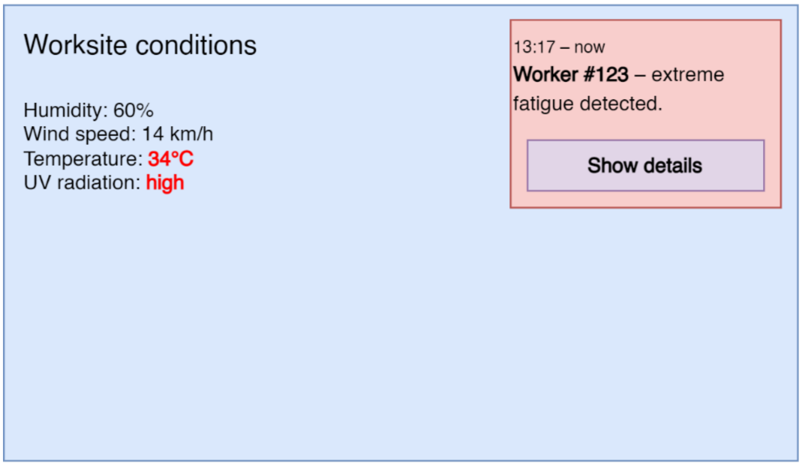


Figure 34. Mockup of the OSH manager's interface

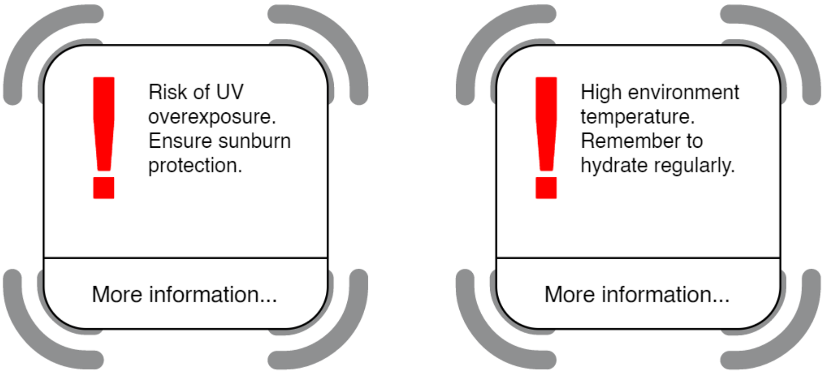


Figure 35. Mockup of the worker's wristband interface

Some changes have been introduced in this use case in comparison to D3.2. The update includes resignation from the GPS technology for the purpose of workers' localisation and a decision on the use of localisation tags for both indoor and outdoor localisation. Therefore, the wristband will be used only for the identification of worker's health issues based on the monitoring of physiological parameters. Localisation tag will also be used for the generation of alarms by the worker in the case of dangerous situations.

Use Case: UC-P2-1, Workers' health safety assurance	
Description	Monitor and protect the construction workers' personal health and safety. Notify the OSH manager about incidents or undesirable behaviour in the construction site.
Reference Scenario	BS-P2-1
Plane(s)	Device and Edge, Data Management, Smart Network and Control, Application and Services
Vertical Capabilities	Manageability, Security, Privacy and Trust, Interoperability, Self-*
Functionalities within vertical capabilities	Self-diagnosis, federated learning, self-awareness
Objectives	• Monitor the physiological parameters of each construction worker and detect abnormalities that are potentially threatening to their health and safety • Track construction worker's location and motion patterns • Protect the construction worker from suffering extreme stress or fatigue • Reduce thermal discomfort of construction workers at the construction site • Prevent overexposure of construction worker to UV radiation • Notify the OSH manager about incidents and life-threatening events
Actors (system actor or natural persons)	• Construction worker • OSH manager • BIM system
Pre-conditions	The construction worker is at the construction site wearing their Personal Protective Equipment.
Trigger	Time-based, continuous monitoring
Expected results	• The first responders are promptly notified about the occurrence, nature and location of an emergency and rescue the construction worker who is in danger • The construction worker can instantly notify the OSH manager in case of an emergency • The construction site's incident log is updated
Design preferences	• Wristbands for physiological parameters. • Weather conditions and air quality monitoring station • Personal cooling system, with a user interface, integrated with the vest • Camera for verification of use of PPE and monitoring the entrance of the construction site.
Extends the use case	N/A
Includes the use case	UC-P2-2
Notes and issues	N/A

Main execution flow	1. ASSIST-IoT is aware of the construction worker's identity and pairs them with their smart PPE. 2. ASSIST-IoT tracks the location of the construction worker. ASSIST-IoT is aware of the construction worker's authorisation to access specific areas within the construction site. 3. ASSIST-IoT verifies that the construction worker is not near a geofenced area (UC-P2-2) 4. ASSIST-IoT monitors the weather conditions at the construction site, the exposure of the construction worker to UV radiation, the physiological parameters of the construction worker. 5. ASSIST-IoT analyses all the collected data from the construction workers who are present at the construction site and identifies no increased risk of exposure to OSH-related hazards for the construction worker 6. ASSIST-IoT has not detected any increased risk to the construction workers health and safety, but they notify the OSH manager by raising an alarm through ASSIST-IoT
Alternative execution	3a. The construction worker attempts to enter an area through a camera-controlled gate 3a.1. ASSIST-IoT proceeds to UC-P2-4 5a. ASSIST-IoT detects increased risk of overexposure to heat 5a.1. ASSIST-IoT actuates the protection from overexposure to heat process 5a.2. The construction worker is adjusting the overexposure-to-heat protection process and ASSIST-IoT records the construction worker's preferences 5a.3. ASSIST-IoT verifies that the risk has been reduced and stops the overexposure-to-heat protection process 5b. ASSIST detects an increased risk of extreme fatigue or overexposure to UV radiation 5b.1. ASSIST-IoT notifies the construction worker and alerts the OSH manager
Exceptions	1a. ASSIST-IoT detects that the construction worker is not paired with all the required smart PPE 1a.1. ASSIST-IoT notifies the construction worker and alerts the OSH manager
Requirements involved	R-P2-1, R-P2-3, R-P2-4, R-P2-7, R-P2-8, R-P2-9, R-P2-10, R-P2-11, R-P2-12, R-P2-17, R-P2-18
KPI	KPI.2.2.1 Workers alerts KPI.2.2.2 OSH hazards detected KPI.2.2.3 Hazard detection time KPI.2.2.4 User acceptance KPI.2.2.5 Notification and alerting KPI.2.2.10 OSH manager notification latency
Identified by	MOW, CIOP-PIB

4.1.2. UC-P2-2: Geofencing boundaries enforcement

Knowing a worker's location on a construction site allows faster identification of unsafe activities and movements. An up-to-date BIM model coordinated by an OSH manager can track needed information to identify dangerous locations and provide alerts to the OSH manager as well as to the worker themselves. The system will be able to use a worker's location to identify (the same location tag will be used with the UC-P2-1) if they are entering a hazardous area or are in proximity to potentially dangerous construction plants.

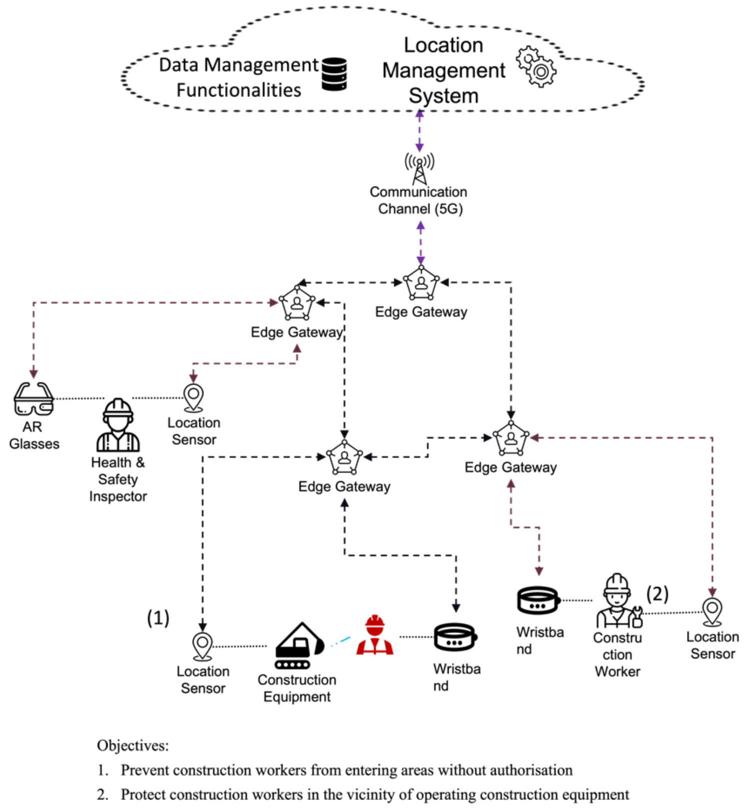


Figure 36. Graphic representation of the Geofencing boundaries enforcement use-case.

For the localisation purpose, the previously described localisation tag will be used. The dangerous zones will be predefined in the BIM model (Figure 37). Prevention from the collision will be based on both the worker's and the construction plant's localization tag.

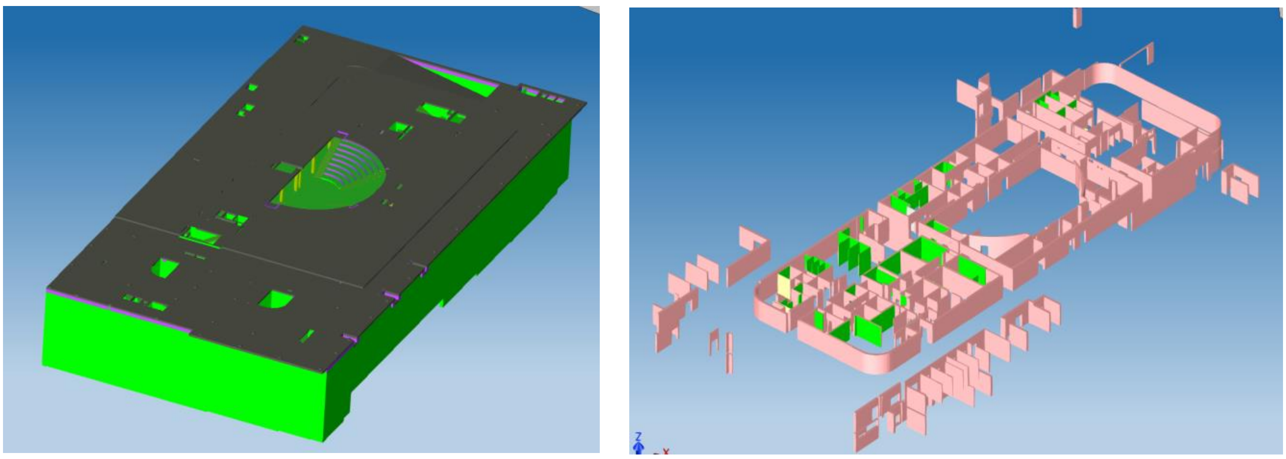


Figure 37. BIM model for dangerous zone definition

Therefore, the following data will be used for the purpose of this use case:

- Location data from the worker/construction plant
- Notification to the OSH
- Restricted zones

Figure 38. Mockup of the OSH manager's interface

UC-P2-2 and UC-P2-3 are combined into one and continue as UC-P2-2 "Geofencing Boundary Enforcement" because of the large common overlap. As a result, UC-P2-3 has been dropped.

Use Case: UC-P2-2, Geofencing boundaries enforcement	
Description	Enforce area-based access restrictions within the construction site
Reference Scenario	BS-P2-1
Plane(s)	Device and Edge, Application and Services
Vertical Capabilities	Manageability, Interoperability
Functionalities within vertical capabilities	Self-awareness, devices interoperability
Objectives	• Prevent construction workers from entering areas without authorisation • Protect construction workers in the vicinity of operating construction equipment
Actors (system actor or natural persons)	• Construction worker • BIM system • OSH manager

Pre-conditions	Restricted areas are defined in the system, within the BIM System, by the OSH manager.
Trigger	Time-based, continuous monitoring while the construction worker is on the construction site
Expected results	• Construction workers are alerted when entering restricted or dangerous areas • The OSH manager is notified about any unsafe behaviour or incidents • The construction site's incident log is updated
Design preferences	The construction worker's location is being tracked, indoors and outdoors. The permission to access a specific area of the construction site is indicated on the BIM system for each construction worker
Extends the use case	UC-P2-1
Includes the use case	N/A
Notes and issues	N/A
Main execution flow	1. ASSIST-IoT is tracking the location of the construction worker 2. ASSIST-IoT verifies that the construction worker is authorised to be at their current location 3. ASSIST-IoT determines whether the worker is in or is approaching a dangerous zone 4. ASSIST-IoT is tracking the location and orientation of a construction plant.
Alternative execution	2a. ASSIST-IoT detects that a construction worker is approaching a location at which they are not authorised to be 2a.1. ASSIST-IoT alerts the construction worker and notifies the OSH manager 3a. ASSIST-IoT detects that the worker is in or is approaching a dangerous zone. 3a.1. ASSIST-IoT alerts the construction worker and notifies the OSH manager 4a. ASSIST-IoT detects that the worker is in the plant's dangerous zone 2a.1. ASSIST-IoT alerts the construction plant operator if the worker is in the plant's dangerous zone
Exceptions	N/A
Requirements involved	R-P2-2, R-P2-3, R-P2-11, R-P2-12, R-P2-15
KPI	KPI.2.2.1 Workers alerts KPI.2.2.2 OSH hazards detected KPI.2.2.4 User acceptance KPI.2.2.5 Notification and alerting KPI.2.2.9 Worker alert latency KPI.2.2.10 OSH manager notification latency
Identified by	MOW, CIOP-PIB

4.1.3. UC-P2-4: Construction site access control

Construction site safety may be further improved by incorporating automated access controls to the site as well as to individual construction plants by incorporating this function into a tracking system. Only having authorised individuals at the construction site or near certain equipment and machinery will decrease the risk for an untrained or uncertified person to cause harm to themselves or others.

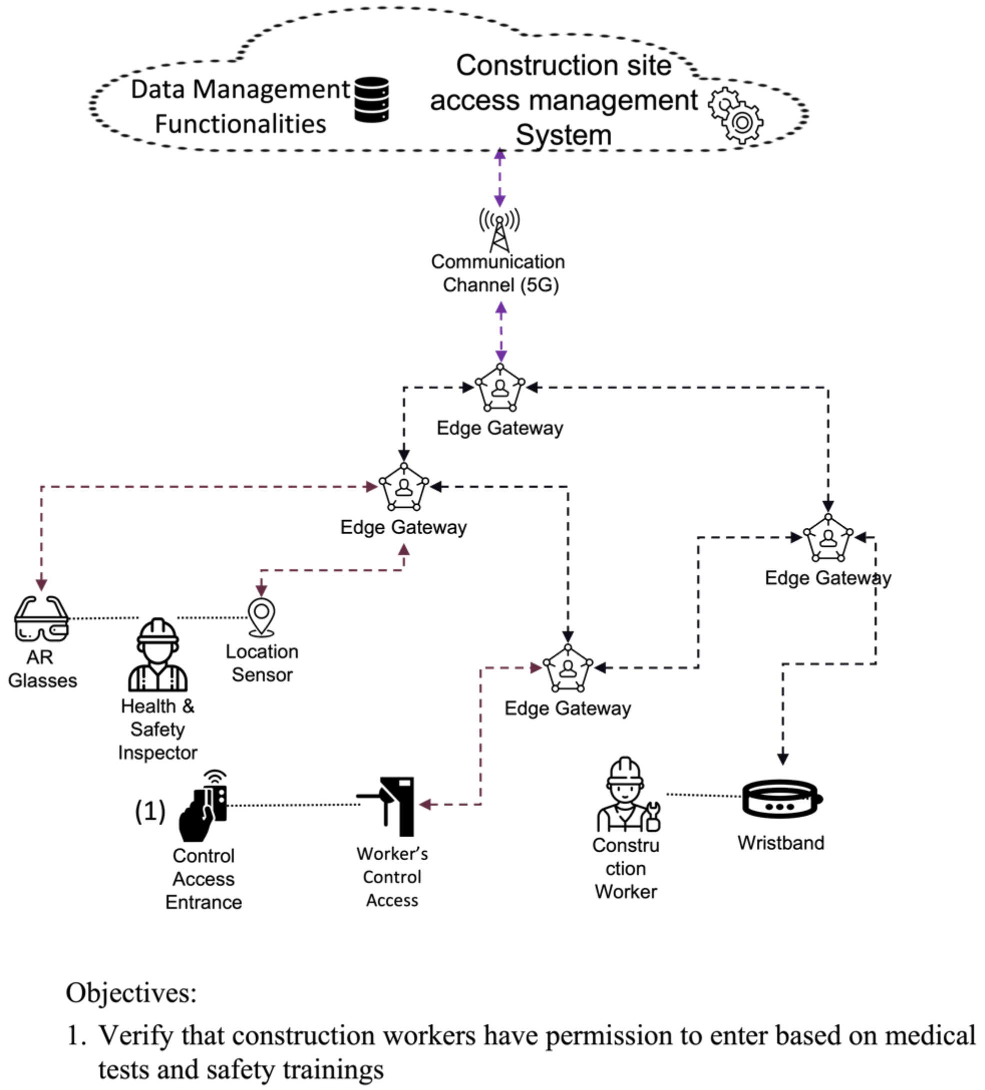


Figure 39. Graphic representation of the Construction site access control use-case.

Figure 40. The entrance gates to the office area and the path to the entrance to the construction part.

A high-quality video camera is located at the entrance to the construction part to identify persons within a video stream, along with their PPE.

A list of the data that will be used in the use case:

- Data about the worker's authority
- Identities
- Identification
- Location of the worker

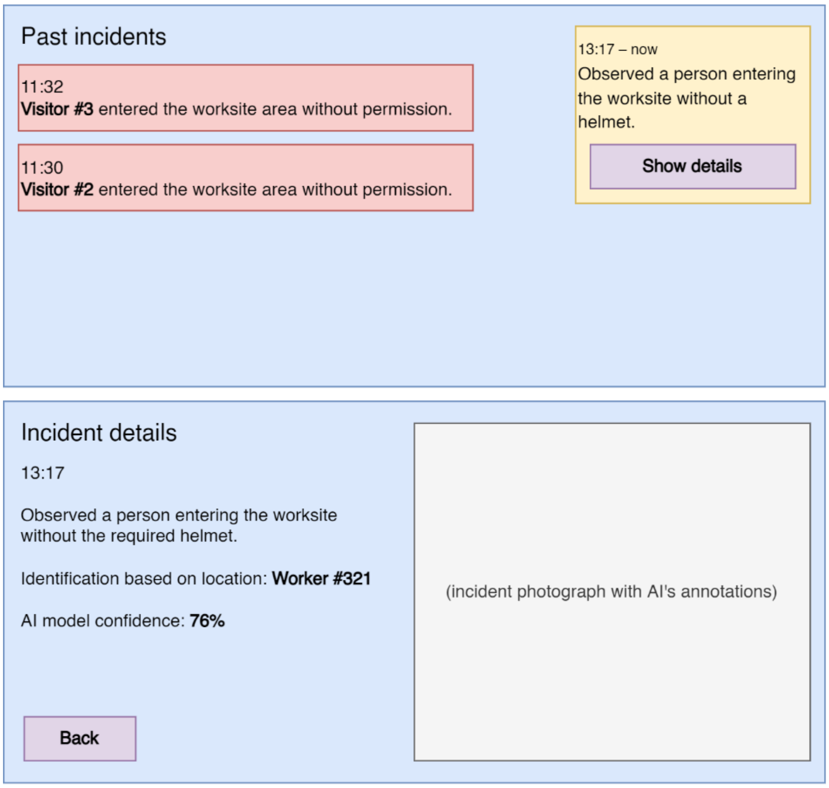


Figure 41. Mockup of the OSH manager's interface

In the final version of the use case, the verification of entry to the construction site is made based on the camera image. It concerns construction workers together with a verification of the use of proper PPE.

Use Case: UC-P2-4, Construction site access control	
Description	Control access to the construction site.
Reference Scenario	BS-P2-1
Plane(s)	Device and Edge, Application and Services
Vertical Capabilities	Security, Privacy and Trust, Interoperability
Functionalities within vertical capabilities	Self-awareness, Devices interoperability
Objectives	• Verify that construction workers have their PPE and the necessary qualifications and medical examinations to enter the worksite.
Actors (system actor or natural persons)	• Construction worker • Controlled-access point • OSH manager
Pre-conditions	The OSH manager provides ASSIST-IoT with an updated list of the authorised construction workers
Trigger	A construction worker without PPE approaches a controlled-access point for entry.
Expected results	• Only authorised construction workers with PPE are granted entry
Design preferences	• Identification device for worker's identification. • Device to handle the recognition of persons and their PPE at the controlled-access point.
Extends the use case	UC-P2-1
Includes the use case	N/A
Notes and issues	N/A
Main execution flow	1. A construction worker approaches a controlled-access point 2. ASISST-IoT establishes a connection between the controlled-access point and the construction worker 3. The construction worker is identified via the location tags 4. ASSIST-IoT verifies if that the construction worker has PPE and the necessary qualifications and medical examinations to enter the worksite.
Alternative execution	4a. The construction worker enters the worksite without PPE 4a.1. ASSIST-IoT identifies the construction worker 4a.2. ASSIST-IoT alerts to the OSH manager about any irregularities
Exceptions	N/A

Requirements involved	R-P2-1, R-P2-2, R-P2-3, R-P2-12
KPI	KPI.2.2.1 Workers alerts KPI.2.2.2 OSH hazards detected KPI.2.2.9 Worker alert latency KPI.2.2.5 Notification and alerting KPI.2.2.10 OSH manager notification latency
Identified by	MOW, CIOP-PIB

4.2. BS-P2-2: Fall related incidents identification

A danger found on most construction sites is falling from a height. Such a scenario must be reported and responded to immediately. This use case envisions scenarios where a fall occurs, as well as when a fall was prevented by fall arrest equipment. Both scenarios warrant a response from the OSH manager to ensure the worker's safety.

The name of this business scenario has been changed in relation to D3.2 due to the change in the nature of the detected events (slips, trips, falls and immobility of the construction worker). In a current version of the BS-P2-2 identification of falls on the ground, fall arrest from a height and immobility (e.g., due to a loss of consciousness) are included while in D3.2 this BS included only work on a height and fall arrest.

Business scenario BS-P2-2, Fall related incidents identification	
If either a fall from a height is arrested by the protective equipment or construction worker is falling because of slipping or tripping, the incident should be detected and automatically reported, along with the location and the identity of the worker, in order to be further investigated. If the worker remains suspended from high, an alert should be raised, and help should be sent to the location of the incident immediately.	
User/users:	All construction workers including the ones working on a height.
Setting / context	• The construction worker is working at height, such as in an aerial lift, on a boom-type elevating work platform, on a scaffolding or a roof close to the edge, etc. • The construction worker is working at the construction site as usual.
Interacting system	A location tag with an accelerometer is placed on the worker
Users' goals	• Receive urgent help either if a construction worker is suspended from an anchor, after a fall, and unable to return to safety or falls due to a slip, trip or loss of consciousness and needs first aid • Inform the OSH manager about any incident in order to respond and investigate • Update the construction site's incident log • Update the construction site health and safety performance metrics
Initial status	• The construction worker is working at height and is attached to an anchor point • The construction worker is working at the construction site as usual
Interaction	The construction worker is equipped with the location tag. Location and acceleration measurements are gathered from worker's location tag by the localisation tracking enabler.
Data	• Identity of the user

	• Location of the incident • Acceleration
Motivation	Provide help to a construction worker suspended in the air by a fall arrest system and avoid suspension trauma as well as to a construction worker either injured due to slip/trip or having health issues.
Time	Continuous monitoring which is activated when the threshold value of acceleration is exceeded
System functionalities	Device-to-device communication, geolocation, alerting
Identified by	MOW, CIOP-PIB

Figure 42 Presents the use case relationship of Fall related incidents identification. In case of a construction worker falls and immobility, detected by its location tag, the tag gives an alarm, and the OSH manager is informed.

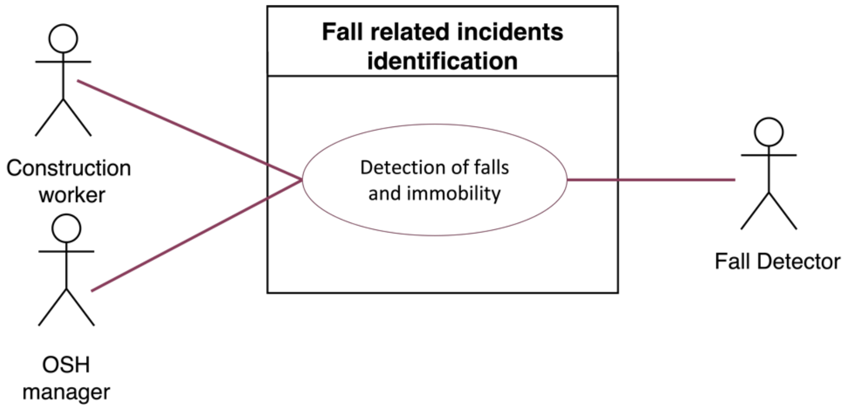
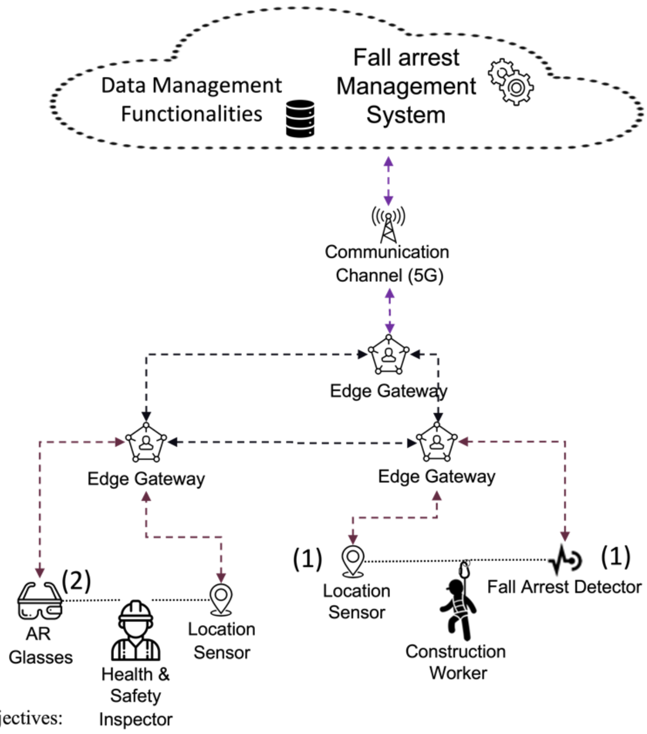


Figure 42. Use case diagram for the "Fall related incidents identification" business scenario

4.2.1. UC-P2-4: Detection of falls and immobility

This use case relates to the detection of falls and immobility based on the motion patterns analysis. The basic measurements performed in this use case relate to the location and acceleration of the worker by means of the worker's location tag. The location Tracking enabler gathers those measurements, and the readings are annotated semantically by the Semantic Annotation enabler. FL Local Operations enabler can perform inference on the gathered live data and re-train the machine learning model responsible for detecting worker's slips, trips, falls, and immobility. The notification about the fall/mobility, alerts, and incident logs are delivered to the OSH manager through the Tactile Dashboard enabler and the Business KPI Reporting enabler. The Integrity Verification enabler assures the integrity of the logs.



Objectives:

1. Detect fall or immobility based on the location and acceleration measurements
2. Notify the OSH manager when a construction worker is suspended in their fall arrest equipment, or first aid is needed due to the fall on the ground of immobility (loss of consciousness)

Figure 43. Graphic representation of the Detection of falls and immobility use-case.

For the localisation purpose, the localisation tag described in Figure 32 will be used. Therefore, the set of data used in the use case include location and acceleration of the worker.

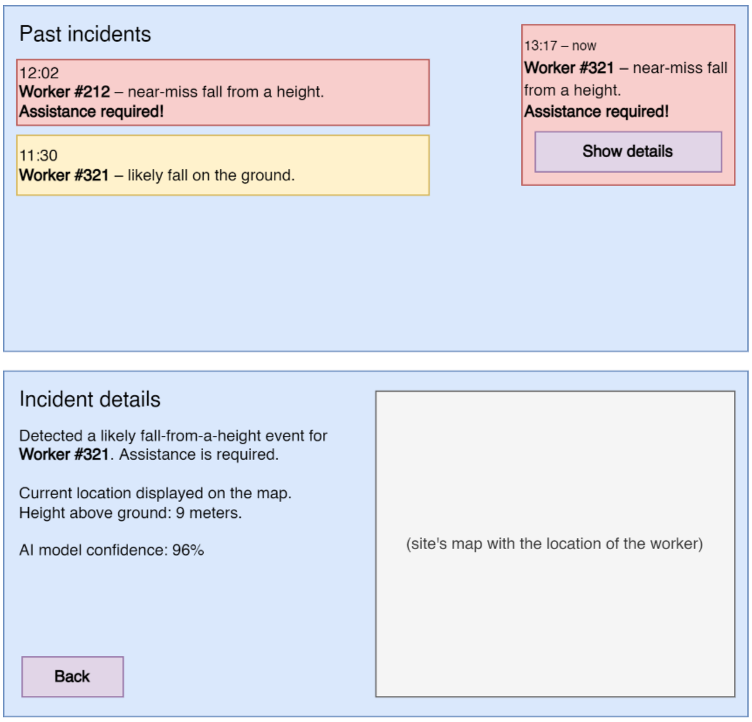


Figure 44. Mock-up of the OSH manager's interface

Within the deliverable D3.2, it was assumed that the monitoring of fall arrest incidents would be possible thanks to the fall arrest detector based on the force measurements. However, considering a possible application of the accelerometer into the localization tag, it has been decided to include a change of technology applied for the identification of fall arrest while keeping the assumed functionality. As a consequence, the same technology will be used to identify both falls on the ground (due to slip or trip), falls from a height and immobility. Therefore, monitoring of on-the-ground incidents has been moved from BS-P2-1 to BS-P2-2 and combined with on-the-height ones.

Use Case: UC-P2-4, Detection of falls and immobility	
Description	Identify with the use of a location tag worn by a worker any incident related to a fall or immobility of the construction worker, especially in the case of being suspended by their fall arrest equipment.
Reference Scenario	BS-P2-2
Plane(s)	Device and Edge, Application and Services
Vertical Capabilities	Interoperability, Self-*
Functionalities within vertical capabilities	Self-awareness, self-diagnosis, device interoperability
Objectives	• Detect fall or immobility based on the location and acceleration measurements • Notify the OSH manager when a construction worker is suspended in their fall arrest equipment, or first aid is needed due to the fall on the ground of immobility (loss of consciousness)
Actors (system actor or natural persons)	• Construction worker • Location tag • OSH manager
Pre-conditions	The worker is equipment with the location tag
Trigger	The acceleration and location measurement indicates an incident
Expected results	• The OSH manager is notified about the incident • The construction worker is rescued in case of an incident • The construction site's incident log is updated
Design preferences	A location tag is intended to be worn in the high visibility vest or on a special additional strap surrounding the human body.
Extends the use case	N/A
Includes the use case	N/A
Notes and issues	N/A
Main execution flow	1. ASSIST-IoT monitors the acceleration and location of the workers 2. ASSIST-IoT detects exceeding the threshold values and identifies the worker's location 3. ASSIST-IoT notifies the OSH manager about the incident 4. ASSIST-IoT records the incident

Alternative execution	N/A
Exceptions	N/A
Requirements involved	R-P2-1, R-P2-3, R-P2-4, R-P2-6, R-P2-10
KPI	KPI.2.2.3 Hazard detection time KPI.2.2.4 User acceptance KPI.2.2.8 Near-miss fall from a height KPI.2.2.5 Notification and alerting KPI.2.2.10 OSH manager notification latency
Identified by	MOW, CIOP-PIB

4.3. BS-P2-3: Health and safety inspection support

Given the ASSIST-IoT guidelines, at a large construction plant following the IoT ecosystem process, data and information are continuously generated and are collected, processed and visualised to relevant stakeholders. In such a plant, the construction workers are equipped with personal edge devices, while vehicles, such as trucks, are equipped with localisation devices. An access control unit is mounted at the entrance, controlling the authorised access to the construction plant. A weather monitoring station is also installed to monitor UV radiation. The various systems are interconnected through gateways where pods of the distributed Edge Data Broker Enabler are deployed. To demonstrate and validate our architecture, a construction plant located in Poland (Figure 1) will enable our performance and evaluate the proposed workflow.

Figure 45. An out-door area in the Pilot site, in which the HSO inspector will perform an on-site inspection using the MR device.

In the deliverable D3.2, the need to visualize the safety plans was described, indicating that it should be followed by the construction workers via the MR device. Upon detailed discussions with OSH managers and Mostostal personnel, it has been established that the safety plans are considered basic knowledge for the inspectors that will be the main end-users of the MR enabler. Thereafter, visualizing safety plans were considered obsolete and has not been included in the present scenario. The aim is not only to contribute to a better defined and more useful scenario but also deliver a user friendly and usable solution. BS-P2-3 (former BS-P2-4) has been enhanced with an interactive report module that allows media data attachment (photos, videos), giving the OSH the possibility to report dangerous situations linked to construction workers or environment. The inspectors will be informed about incidents through alerts and notifications. Furthermore, this project has the goal of testing innovative AR solutions to provide information regarding escape routes by utilising data provided by BIM models.

Business scenario BS-P2-3, Health, and safety inspection support	
An OSH manager, senior manager or external auditor may conduct an inspection in order to verify whether or not health and safety regulations are followed at all times at the construction site. The inspector should be able to confirm that the necessary procedures are followed; to this end, they should be able to retrieve information about status of the workers and report dangerous situations. Any observations should be securely logged, and the site's incident should be updated so that further action to mitigate potential hazards can be taken.	
User/users:	An OSH manager, senior manager or external auditor acting as OSH inspector
Setting / context	Any worksite within the construction site

Interacting system	The OSH inspector receives contextual visual information related to their location and the activities taking place at the location (such as, the workers in close proximity and their training records).
Users' goals	Conduct an inspection to ensure that they have checked all the necessary requirements for the inspected activities, and they have addressed and reported incidents.
Interaction	The OSH inspector is at the construction site office getting ready to conduct an inspection at different worksites
Initial status	The OSH inspector receives relevant information on a portable device
Data	BIM, dangerous zone, workers' training and medical records, worker's permissions and company name.
Motivation	Regular inspections are required in order to ensure compliance with health and safety regulations. Construction activities are performed at various worksites at different stages of development and have various requirements with respect to health and safety measures. Inspectors are informed about incidents and are able to report.
Time	On demand, initiated by the OSH inspector.
System functionalities	MR visualization, Data safety and security, Alerting and reporting.
Identified by	MOW, CIOP-PIB

Figure 46 present the use case relationship of Health and safety inspection support. Whereby the OSH manager carries out an inspection to check whether the health and safety regulations, evaluation routes and notifications for the workers on the construction site are always complied with.

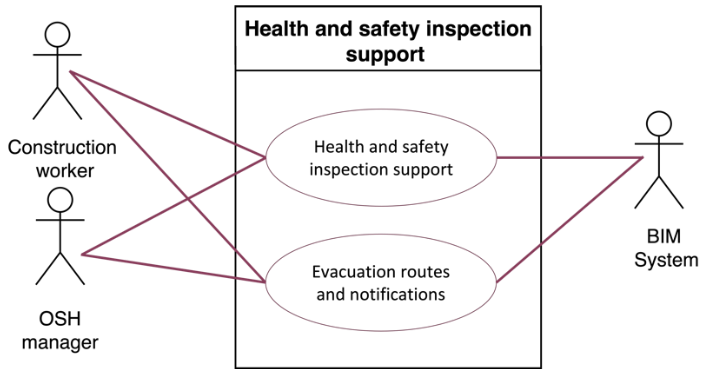


Figure 46. Use case diagram for the "Health and safety inspection support" business scenario.

4.3.1. UC-P2-5: Safe navigation instruction

For the localization purpose the localization tag visualised in Figure 32 and described in the previous use cases will be used.

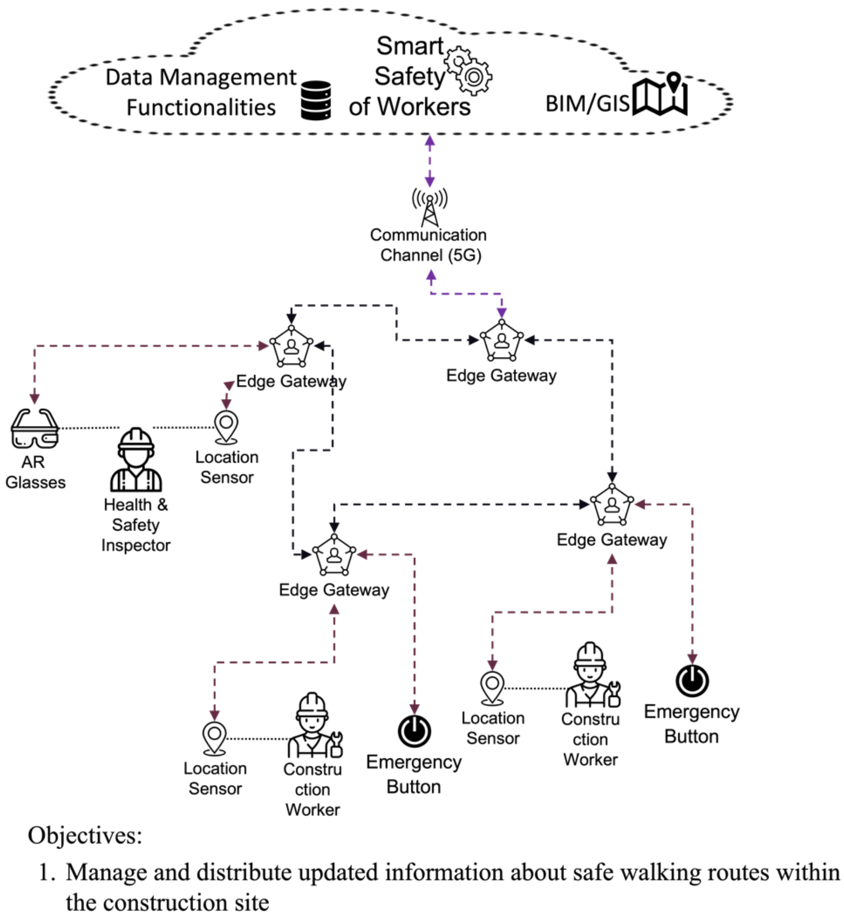


Figure 47: Graphic representation of the Evacuation routes and notifications use-case.

A list of the data that will be used in the use case is:

- worker’s location
- worker-triggered alarms
- information on escape routes and key evacuation infrastructure
- assignment of PPE and other equipment to workers
- worker identification

This use case relates to safe navigation instructions. The MR device will display 3D models of the construction site enhanced with information about escape routes and key evacuation infrastructure. The basic measurements performed in this use case relate to the location of the worker and “alarm” button presses by means of worker’s location tag. The Workplace safety controller will aggregate the location and alarm data and, using the Location Processing enabler, will establish whether there is a dangerous situation on the worksite. This may include, e.g., congestion along the escape routes, or a large number of alarms in one location. The Workplace safety controller will issue relevant notifications about dangerous situations to the MR device of the OSH manager.

Use Case: UC-P2-5, Safe navigation instructions	
Description	Providing construction workers with safe walking routes and hazardous locations.
Reference Scenario	BS-P2-3
Plane(s)	Device and Edge, Smart Network and Control, Data Management Plane, Application and Services
Vertical Capabilities	Interoperability, Self-*
Functionalities within vertical capabilities	Self-awareness, device interoperability
Objectives	Manage and distribute updated information about safe walking routes within the construction site
Actors (system actor or natural persons)	• Construction worker • BIM system • OSH manager
Pre-conditions	The Building Information Model includes: • as-is information about the construction site • approved walking paths • approved emergency evacuation paths • emergency assembly points • hazardous locations
Trigger	The construction worker is at the construction site and requests navigation instructions or receives an evacuation alert
Expected results	The construction worker arrives at the worksite or at an emergency assembly point
Design preferences	Mobile device that supports location-based services and has a display
Extends the use case	UC-P2-5
Includes the use case	N/A
Notes and issues	N/A
Main execution flow	1. ASSIST-IoT tracks the location of the construction worker 2. The construction worker requests from ASSIST-IoT navigation instructions to a destination within the construction site 3. ASSIST-IoT is updating information about the as-is state of the construction site and approved walking paths based on information from the Building Information Model. 4. ASSIST-IoT provides navigation instructions along approved routes to their mobile device. 5. The construction worker confirms safe arrival at their destination
Alternative execution	2a. ASSIST-IoT receives an emergency evacuation alert from the OSH manager

	2a.1. ASSIST-IoT alerts the construction worker and provides navigation instructions for safe evacuation from their current location based on approved evacuation routes 2a.2. ASSIST-IoT updates the evacuation navigation instructions based on real time information from the evacuation paths followed by all the construction workers 2a.3. The OSH manager indicates on the Building Information Model hazardous areas that must be avoided by construction workers during the evacuation process 2a.4. ASSIST-IoT updates the evacuation navigation instructions 2a.5. The construction worker confirms safe arrival at the emergency assembly point
Exceptions	N/A
Requirements involved	R-P2-1, R-P2-12, R-P2-14, R-P2-15
KPI	Establishment of connection with Edge Data broker: Latency <300 ms User acceptance (Safe arrival at the destination without passing through hazardous or inaccessible areas)
Identified by	MOW, CIOP-PIB

4.3.2. UC-P2-6: Health and safety inspection support

Figure 48. Microsoft HoloLens 2 is a pair of mixed reality smartglasses

Microsoft HoloLens 2 was selected to develop the MR solution to monitor and improve the health and safety of construction workers and minimise their exposure to risk factors. The Microsoft Hololens 2 is the most popular MR device, equipped with multiple sensors (such as head and eye tracking, depth sensors and gyroscope), advanced optics (with high resolution and holographic density), and a holographic operating system that melds seamlessly with its environment. Visual information will be overlayed on the physical surroundings of the OSH manager during the inspection. Given the hand and eye-tracking sensors, this device allows for direct manipulation, commanding and real-time tracking.

In the construction deployment, a standalone native application is being deployed on a head mounted device (Microsoft Hololens 2) to monitor and protect the construction workers' health and safety and notify the OSH inspector about incidents or undesirable behaviour on the construction site. At the same time, the application visualizes information from the BIM model, including construction components and dangerous zones. The MR enabler, which is the main enabler of the UC-P2-6 collects, curates, and then displays the required information regarding the construction site and the workers. More specifically:

- The physiological parameters of the construction workers are being monitored in real-time using wearable sensors.
- Edge processing units locally assess the worker's fatigue and stress levels through federated learning schemas.

- Measurements and information related to the worker's identity, training, and medical expiration dates.
- Environmental conditions are also considered, such as ambient temperature and UV radiation.
- The construction workers' location within the construction site is monitored so that first responders can be sent in case of an emergency.
- Geofencing services are also supported to ensure that construction workers move around areas where they are authorized and trained.
- Interactions between construction workers and construction plant are continuously monitored.
- The gate to the construction site, and other secondary access points (gates and doors), are controlled.
- A fall arrest detector is attached to the construction worker when they are working at height, such as at an aerial lift.

The most important and dynamic elements of a construction site are the workers. Those on the ground change daily, and so do the responsibilities they take on. The MR Enabler located in the application and service layer uses the Edge Data Broker (located in the data management layer) to receive real-time information and alerts Figure 49. Considering that the Edge Data Broker Enabler is the "common middle point" in which the IoT devices of the construction plant continuously publish their data, it allows the MR device to consume them based on their needs. In case of required communication with other ASSIST-IoT components and devices, this is enabled through the smart network and control layer.

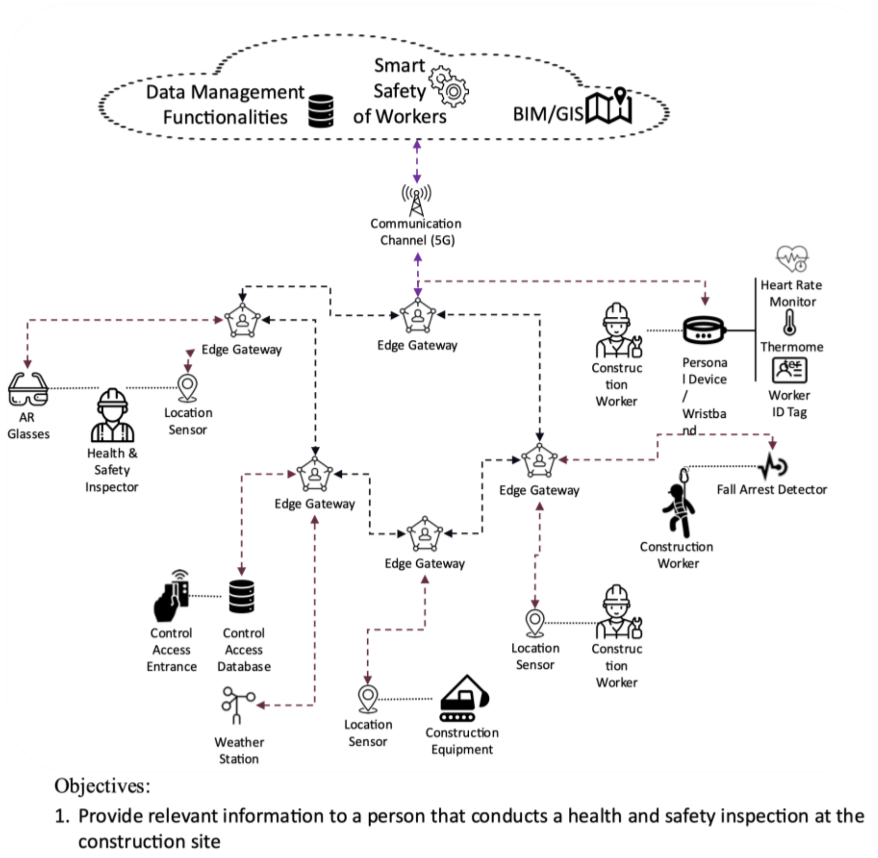
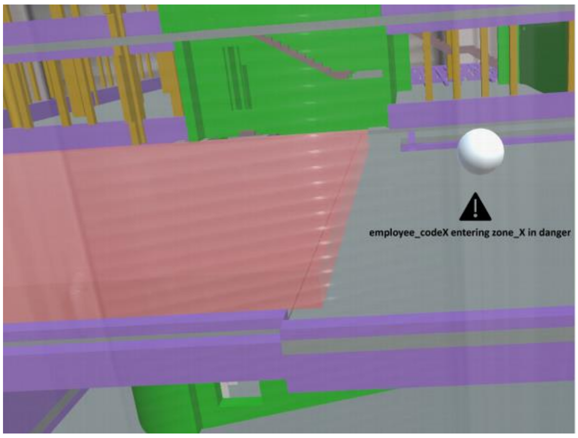


Figure 49. Graphic representation of the Health & Safety inspection support use-cases. The MR device consumes data from the Edge Data Broker. The data are either generated by IoT devices or transmitted from the cloud where other IoT intelligent functionalities.

Alerts and notifications are generated from various components of the Next-Generation ASSIST-IoT ecosystem. They are used to notify the OSH inspector of incidents such as falling and other accidents, exceedance of permitted physiological and environmental parameters, for unauthorized access, or when approaching dangerous zones. Through the MR interface (as shown in Figure 50**¡Error! No se encuentra el origen de la**

referencia.) the OSH inspector is notified not only about the type of incident, but also the location and the worker involved.



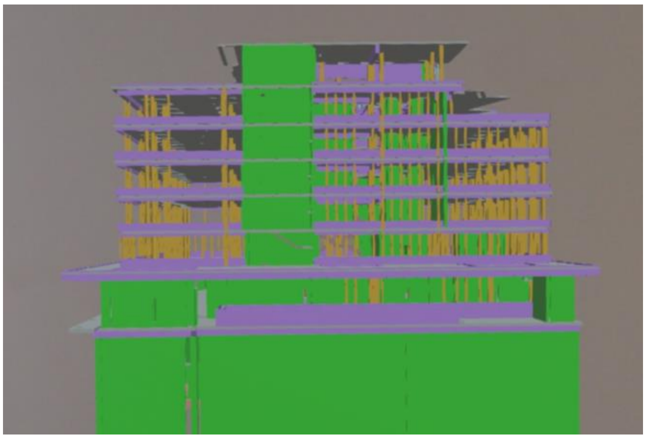


Figure 50. Example of the representation of a worker entering a danger zone.

Left figure: A worker (symbolized with a white ball) is about to enter the dangerous zone at the construction site (red rectangle), and the MR interface notifies the OSH inspector about the type of incident, the ID of the worker, and their location. Right figure: The BIM model visualized through the MR glasses upon conversion to the required format.

During the inspection, one of the primary responsibilities of the OSH inspector is to report unusual or dangerous situations to the stakeholders. For example, when a construction worker, who has been assigned to the construction plant, is not equipped with the appropriate personal protective equipment, it should be reported as an incident. Through the MR device, the inspector can create an interactive report that includes photos or videos Figure 50 and relevant information such as the worker's identity and location. Figure 51 shows an example of the reporting functionality of the interface.

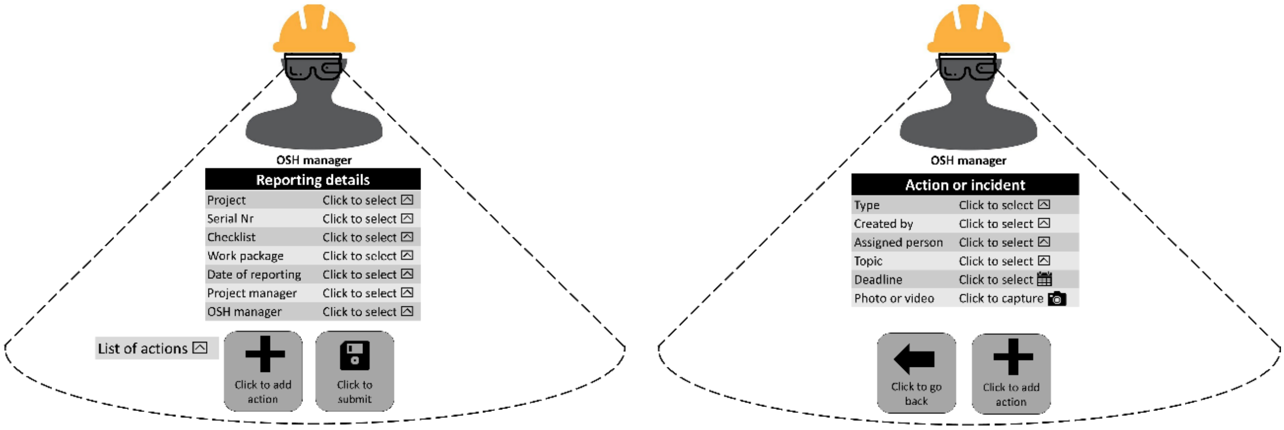


Figure 51: The template for the production of reports through the MR interface.

The image at the top shows the template for inserting the general reporting information, and the image at the bottom shows the template for enlisting an action or an incident.

The present report has a few changes compared to D3.2. Starting with the description section, a module has been now inserted aiming at informing the inspectors about undesirable behaviour. Furthermore, we have added an interactive report module that allows the inspector to report during incidents or other events.

The safety measures that must be followed for the type of activity were excluded from the objectives as there is no interest from the OSH inspector, who is also our main end-user. This obsolete functionality has been substituted by MR information that will be visualised by the inspector about the ID and other personal information of the workers at their location, the dangerous situations within the construction site and the worker's health and safety risks. Concerning the pre-conditions, the information about workers' medical and training records expiration dates, identity of the construction workers, authorized access, as well as location data from the worker's in real-time within the construction site should be provided (it is worth mentioning that an ethical analysis of this activity is being performed by the Consortium and all defined measures will be put in place to guarantee data privacy and to safeguard workers' rights and freedoms).

Use Case: UC-P2-6, Health and inspection support	
Description	Provide relevant information to a person that conducts a health and safety inspection at the construction site and inform them about incidents or undesirable behaviour. In addition, an interactive report module to report is provided to the inspector.
Reference Scenario	BS-P2-3
Plane(s)	Data Management, Application and Services
Vertical Capabilities	Manageability, Privacy and Trust, Interoperability
Functionalities within vertical capabilities	Device's interoperability
Objectives	Provide the OSH inspector with information about: • the ID and other personal information of the workers at their location • the type of activity that is being performed at their location • the training records expiration dates of the construction workers that participate in the construction's activities • the medical records expiration dates of the construction workers that participate in the construction's activities • the dangerous situations within the construction site • the worker's health and safety risks • Provide a report module to the inspector (input media through the MR interface)
Actors (system actor or natural persons)	• OSH inspector • Building Information Model
Pre-conditions	The Building Information Model includes information about the nature of activities performed at each location at, and the location of dangerous zones. Information about the construction workers' medical and training records expiration dates, their identity, as well as authorized access should be provided. Location data from the workers in real-time within the construction site is also provided. Alerts and notifications generated from the fall arrest monitoring system, weather station, fatigue monitoring, unauthorised access, and construction worker's emergency button, are also provided.
Trigger	The OSH inspector initiates the inspection process
Expected results	All the issues identified during the health and safety inspection are securely logged
Design preferences	Mixed Reality Glasses
Extends the use case	UC-P2-1

Includes the use case	N/A
Notes and issues	N/A
Main execution flow	1. The OSH inspector requests from ASSIST-IoT inspection support 2. ASSIST-IoT tracks the location of the OSH inspector 3. ASSIST-IoT provides the OSH inspector with relevant information 4. The OSH inspector records their observations about the condition of the construction site to ASSIST-IoT
Alternative execution	N/A
Exceptions	2a. ASSIST-IoT is not aware of the OSH manager's location 2a.1. The OSH manager requests from ASSIST-IoT for inspection-related information at their location
Requirements involved	R-P2-1, R-P2-3, R-P2-12, R-P2-15, R-P2-19, R-P2-20
KPI	Establishment of connection with Edge Data broker: • Latency <300ms • Reporting: >90% success rate • Notifications and alerting: >90% success rate • Users are able to manipulate the BIM models: The 3D object manipulation allows ≥6 degrees of freedom (6DOF)
Identified by	MOW, CIOP-PIB

4.4. Pilot 2 systems' requirements

Requirement R-P2-1: Personal location tracking	
Category	Functional
Priority	Must have
Use case IDs	UC-P2-1, UC-P2-2, UC-P2-4, UC-P2-5, UC-P2-6
Rationale	Provide location-based services.
Description	ASSIST-IoT shall track the location of workers within the construction site, indoors, with an accuracy of 1 m. The elevation context shall also be discerned using the Building Information Model to infer on which building floor a worker is. Information about the worker's location should be sent only in the case of risk situation/irregularity.
Acceptance criteria	Accuracy of the worker's location identification at the level of 1m.
Customer satisfaction	5
Customer dissatisfaction	5

Identified by	Source
MOW	Partner's expertise

Requirement R-P2-2, Construction plant location tracking	
Category	Functional
Priority	Should
Use case IDs	UC-P2-2
Rationale	vehicles inside the construction site should be tracked to increase safety of people working in their close vicinity.
Description	ASSIST-IoT shall track the location of construction via the drivers' localisation within the construction site with an accuracy of 1 m. The location of the construction plant shall be tracked directly or through the operator's location.
Acceptance criteria	Track the location of vehicles construction workers on the construction site
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
MOW	Partner's expertise

Requirement R-P2-3, Localisation tag for construction workers	
Category	Non-Functional
Priority	Must have
Use case IDs	UC-P2-1, UC-P2-2, UC-P2-4, UC-P2-6
Rationale	Each construction worker should be able to prove their identity, the necessary qualifications and medical examinations (via the tag) in order to enter the worksite. Moreover, the localisation tag should provide personal location monitoring, as well as body acceleration. The localisation tag should have an alarm button to inform the OSH manager about dangerous situations. It should also have the ability to inform the worker about dangerous situations.
Description	ASSIST-IoT shall be able to identify each construction worker and track their location via a wearable device. Personal details, the necessary qualifications and medical examinations shall be included. Moreover, the localisation shall be equipped with sensors for acceleration measurements. It will also provide an ability for the worker to send and receive alerts and notifications, respectively.

Acceptance criteria	At least grade '4' on technology acceptance from the majority of the construction workers
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
CIOP-PIB	Partner's expertise

Requirement R-P2-4, Continuous authentication for localisation tag	
Category	Functional
Priority	Should
Use case IDs	UC-P2-1, UC-P2-4
Rationale	Ensure that a construction worker is wearing their **localisation tag** and non-authorised and improper use of wearables is prevented.
Description	ASSIST-IoT shall ensure that wearables are used by the person they were assigned to. Authentication could be continuous and achieved via biometrics or through a third party, e.g., the OSH manager.
Acceptance criteria	Unauthorised use is detected and reported.
Customer satisfaction	5
Customer dissatisfaction	3
Identified by	**Source**
CERTH	Partner's expertise

Requirement R-P2-5 "Wristband pairing with other devices capability" has been dropped because the use of smartphones on the construction site is not allowed. This means that linking a wristband to smartphones no longer applies (so also not of different types).

Requirement R-P2-6, Device number minimisation	
Category	Non-Functional
Priority	Must have
Use case IDs	UC-P2-1, UC-P2-4

Rationale	Reduce the number of different wearable sensors or integrate them within the same devices in order to increase usability and limit the need for maintenance of separate devices (e.g., change of separate batteries).
Description	ASSIST-IoT shall use as few as possible distinct wearable sensors.
Acceptance criteria	At least grade '4' on to technology acceptance from the majority of the construction workers
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
CIOP-PIB	Partner's expertise

Requirement R-P2-7, Monitoring the weather conditions at the construction site	
Category	Functional
Priority	Must have
Use case IDs	UC-P2-1
Rationale	The personal thermal comfort of each construction worker depends on their environment. Exposure to UV radiation cannot exceed a predetermined threshold value during 8 hours of work.
Description	ASSIST-IoT shall monitor the weather conditions (e.g., ambient temperature, wind velocity, humidity, UV radiation, precipitation) at the construction site.
Acceptance criteria	Adequate information to assess the effect of ambient conditions on each construction worker's stress, fatigue thermal comfort, exposure to UV radiation.
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
MOW	Partner's expertise

Requirement R-P2-8, Personal cooling system	
Category	Functional
Priority	Must have
Use case IDs	UC-P2-1
Rationale	There are several technologies that can be used for the purpose of a personal cooling system (PCS), but either thermoelectric (Peltier modules) or air cooling (e.g., by fans) seem to be the most appropriate for construction workers. The cooling should be provided

	especially on the torso; therefore, the PCS should be integrated with clothing (either the high visibility vest or the underwear). Clothing needs to be subjected to washing so the PCS should be demountable or resistant to washing cycles. The higher the body cooling area, the better. When integrated with high-visibility protective clothing (e.g., vest), PCS should not influence its protective properties according to EN ISO 20471:2013+A1:2016.
Description	ASSIST-IoT shall actively reduce the thermal load of each construction worker performing physically demanding activities, especially in hot environments, according to their personal preferences.
Acceptance criteria	PCS should be able to cool local skin temperature of at least 1°C Cooling temperature not lower than 15°C. Weight of the PCS not higher than 2 kg.
Customer satisfaction	5
Customer dissatisfaction	4
Identified by	**Source**
MOW	Partner's expertise

Requirement R-P2-9, Assessment of Personal Exposure to UV Radiation	
Category	Functional
Priority	Should
Use case IDs	UC-P2-1
Rationale	Indirectly assess each worker's exposure to UV radiation as they may not carry specialised sensors on their person.
Description	ASSIST-IoT shall estimate the exposure of each worker to UV radiation based on combining the ambient UV radiation and their location and clothing.
Acceptance criteria	The total daily (8hours) exposure to UV radiation is estimated for every construction worker at the construction site
Customer satisfaction	5
Customer dissatisfaction	3
Identified by	**Source**
CIOP-PIB	Partner's expertise

Requirement R-P2-10, Fall and immobility detection	
Category	Functional
Priority	Must have

Use case IDs	UC-P2-1. UC-P2-4
Rationale	The worker's motion pattern will be monitored in order to identify hazards such as falls and immobility, using a triaxial accelerometer placed close to their centre of gravity. Providing help to the worker that fell (in both cases of arresting while working on a height and due to slip/trip on ground) and/or lost their consciousness.
Description	ASSIST-IoT shall be able to identify fall-related events and immobility by monitoring the workers' body acceleration and detecting prolonged immobility or suffering a forceful impact. Information about such an event shall be transmitted to the OSH manager. The detection should be based on the measurements performed by the location tag located in the high visibility vest. In order to ensure the proper functioning of this tag for the purpose of falls identification, its stable position on a human body should be provided
Acceptance criteria	Identification of fall or immobility events within the construction site
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
MOW	Partner's expertise

Requirement R-P2-11, Geofencing	
Category	Functional
Priority	Must have
Use case IDs	UC-P2-2
Rationale	Workers should be prevented from entering areas where they are not authorised to be. Workers should be prevented from entering dangerous zones.
Description	ASSIST-IoT shall monitor the location of workers and constantly assess whether or not they are authorised to be at that location, which depends on their training and role. They are also notified if they are within a hazardous area. Authorisation and hazards are indicated on the Building Information Model.
Acceptance criteria	The worker is notified in the case of unauthorized entrances
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
MOW	Partner's expertise

Requirement R-P2-12, Alerts and notifications minimization	
Category	Non-Functional
Priority	Should
Use case IDs	UC-P2-1, UC-P2-2, UC-P2-5¸ UC-P2-6
Rationale	Construction workers shall not be distracted while operating equipment unless it is necessary.
Description	ASSIST-IoT shall make sure that alerts and notifications are not unnecessarily intrusive and that they correspond to the risk level. The alert level of the notification received by the construction worker will be communicated to the OSH manager and the information will be recorded.
Acceptance criteria	At least grade '4' on to technology acceptance from most construction workers
Customer satisfaction	5
Customer dissatisfaction	3
Identified by	**Source**
MOW	Partner's expertise

Requirement R-P2-13 "Fall protection detection" has been discontinued because it has already been described in requirement R-P2-10 "Fall and immobility detection"

Requirement R-P2-14, Safe navigation instructions	
Category	Functional
Priority	Must have
Use case IDs	UC-P2-5
Rationale	Safe navigation for evacuation purpose of the construction workers in case of emergency (e.g., fire). Avoiding overcrowding along evacuation routes. Navigation instructions during an emergency should be adapted to reflect the current situation at the construction site. The route should follow approved walking paths through areas where the worker is authorised to access. In case of an emergency the workers receive evacuation instructions along predefined routes. The routes are updated from the OSH manager according to the evolving situation based on the routes followed by safely evacuated workers. Routes should be based on BIM models and take into account (i.e., avoid) eventual location of existing hazard that caused a need for evacuation.
Description	ASSIST-IoT shall provide navigation instructions according to pre-defined evacuation routes.
Acceptance criteria	The construction worker arrives at the desired location.

Customer satisfaction	5
Customer dissatisfaction	3
Identified by	**Source**
CIOP-PIB	Partner's expertise

Requirement R-P2-15, BIM data models and interoperability compliance	
Category	Non-Functional
Priority	Must have
Use case IDs	UC-P2-2, UC-P2-5, UC-P2-6
Rationale	Location-based services and navigation routes will be provided based on support from BIM authoring applications using industry-specific formats (building SMART, OGC)
Description	ASSIST-IoT shall be able to produce and consume BIM data in standard interoperable formats.
Acceptance criteria	Compliance to standardised formats for the exchange of BIM information.
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
MOW	Partner's expertise

Requirement R-P2-16, Device Reliability and Durability	
Category	Non-Functional
Priority	Should
Use case IDs	UC-P2-1
Rationale	The weather conditions and type of activities at a construction site are quite demanding and challenging.
Description	The ASSIST-IoT devices shall be reliable and durable
Acceptance criteria	A minimum IP rating of IP54.
Customer satisfaction	5

Customer dissatisfaction	3
Identified by	**Source**
MOW	Partner's expertise

Requirement R-P2-17, Wireless coverage	
Category	Non-Functional
Priority	Must have
Use case IDs	UC-P2-1
Rationale	Some construction areas include materials and assets that prevent the signal to travel among the devices.
Description	The ASSIST-IoT shall cover the indoor and outdoor construction area, ensuring the connectivity among the devices via central getaways without affecting by signal obstacles
Acceptance criteria	The wireless coverage shall cover the vast majority of the construction area.
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
MOW	Partner's expertise

Requirement R-P2-18, Temporary storage	
Category	Non-Functional
Priority	Must have
Use case IDs	UC-P2-1
Rationale	When the coverage of the network is not stable and the edge device cannot be connected, the edge device will store the processed information in a temporary storage.
Description	ASSIST-IoT shall have local temporary storage where critical information is stored. It shall be integrated in the worker's processing unit.
Acceptance criteria	At a minimum, it will be able to store sensor data produced within 30 minutes of operation
Customer satisfaction	5
Customer dissatisfaction	5

Identified by	Source
MOW	Partner's expertise

Requirement R-P2-19, Alerts and notification MR visualization	
Category	Functional
Priority	Must Have
Use case IDs	UC-P2-6
Rationale	The OSH shall be informed about hazardous events and other incidents within the construction area
Description	Alerts and notifications are used to notify the OSH inspector for incidents such as falling and other accidents, exceedance of permitted physiological and environmental parameters, unauthorized access, or when a worker is approaching dangerous zones. Alerts and notifications will be transmitted to the MR device through the EDBE (or other).
Acceptance criteria	The vast majority of the messages, that transmitted from the gateway to the MR device should be successfully delivered
Customer satisfaction	4
Customer dissatisfaction	*5*
Identified by	**Source**
ICCS	Partner's expertise

Requirement R-P2-20, Reports	
Category	Functional
Priority	Must Have
Use case IDs	UC-P2-6
Rationale	The OHS shall report context-based media reports (photo and info) through MR device
Description	During the inspection, one of the primary responsibilities of the OSH inspector is to report unusual or other situations to the stakeholders (for example, when a construction worker, is not equipped with their appropriate personal protective equipment, or when a construction element requires attention, should be reported as an incident). Through the reporting functionality, the inspector will generate different reports that include photo and relevant information, and the system will save it to the LTSE.
Acceptance criteria	To accept this requirement, reports should successfully be saved to the ASSIST-IoT databases.

Customer satisfaction	3
Customer dissatisfaction	3
Identified by	**Source**
ICCS	Partner's expertise

5. Pilot 3: Cohesive vehicle monitoring and diagnostics

Looking back at D3.2, it can be noted that the roadmap for the Use Cases and Business Scenarios painted during the writing of the previous deliverable is still sound and valid. Therefore, only minor corrections and updates were necessary, to reflect the progress being made in the project.

So far, ICT penetration in the automotive industry is fractional and mostly driven by vehicle manufacturers. The connectivity between the vehicle fleet and OEM is also limited mainly due to high costs and bandwidth issues. Most initiatives covering IoT deployment in vehicles fail to integrate information coming from different sources (e.g., business data, environmental data, data from within the vehicle, historical vehicle maintenance data) and in gaining access to vehicle data due to safety and security reasons. While real-time control of a moving vehicle raises safety concerns, and therefore precludes complete open access to the information and control firmware. There is no theoretical barrier to trusted third parties gaining access to the onboard sensor measurements for diagnostics and monitoring purposes. Moreover, there is no current application or deployment that integrates and presents vehicle information to a user in an interactive friendly environment depending on their role and relation to the vehicle and minimise recalls.

The implementation of the ASSIST-IoT reference architecture in this pilot will enhance the capabilities of automotive OEMs to monitor the emission levels of vehicles which are already in operation (ISE, in-service emissions). Monitoring the fleet emission levels will allow the implementation of timely corrective actions, if needed, in order to restore them to the accepted limits. Ensuring that fleet ISE meets the certification limits during their lifetime will imply a *de facto* fulfilment of the EU regulations, which are to be verified through the in-service conformity (ISC) mechanism.

In addition, a new approach to vehicle powertrain diagnostics, as well as, exterior condition inspection and documentation will be provided to OEMs-supply chains, workshops in the after-sales business automobile repair professionals, suppliers and operators of rental cars or vans or shared mobility services, fleet managers, and insurance service providers in order to provide insights into the required corrective maintenance tasks based on the integration of data streams coming from different sources.

Figure 52: Ford Kuga test vehicle in the vicinity of Valencia during a test drive for Pilot 3A

The main functionalities that will be provided by ASSIST-IoT in this application domain are the following:

- Interfacing a research grade automotive controller, for granting real-time access to a hybrid vehicle and for enabling the deployment of on-demand diagnostic methods for propulsion fault detection using machine learning methods that exploit available information, which may be combined with those provided by the OEM and third parties and for the dynamic generation of new diagnostic methods.
- Integrating computer vision-based exterior inspection facilities for providing extended information on vehicle condition.
- Developing human-centric interfaces for diagnostic reports; integrating information coming from end-users and service mechanics by tactile interaction with the vehicle.

- DLT and federated learning methods, implemented within the infrastructure, to ensure privacy, confidentiality, and protection of vehicle-condition information, so that no data can be tampered with and that authorised entities can be granted access to undisputed original information.

5.1. BS-P3A-1: Fleet in-service emission verification

The certification of vehicle emissions, before the adoption of the Euro 7 standards[5], is mostly based on a limited number of standardised tests which are performed during the development phase using dynamometers and rolling road test rigs under pre-defined driving conditions, such as given temperature and certain driving profiles, so that the tests are reproducible. While these tests are complemented with RDE (Real Driving Emission) tests for verifying that a vehicle meets the certification levels in a broader range of driving conditions, there is no factual verification of the vehicle and fleet emission levels during the service life. Thus, limited real-world driving is involved and only a few combinations of driving conditions are considered. ISC refers to tests of randomly selected vehicles in order to verify the compliance of the certification levels; however, these tests involve a limited number of vehicles and are restricted to a limited time of service and mileage (maximum 5 years in service and less than 100.000 km). The existence of some vehicles that exceed the accepted emission levels are to an extent accepted by the legislator. However, on-demand fleet-wide detection and handling of emission outliers is not possible; these vehicles can only be identified one by one during regular inspections, for example on behalf of a technical inspection agency, or due to obvious vehicle defects. Currently, only limited datasets from tested vehicles are available and no comprehensive database exists.

Emission regulations for propulsion systems are getting stricter globally; most of the aforementioned practices are expected to change with the introduction Euro 7 standards, which are currently under public consultation. Automotive OEMs will have to adapt to stricter ISC regulations and upgrade their fleets so that they are not forced to resort to costly recalls of vehicles. Under the new regulations, most probably, OEMs will need to prove the emission conformity while the fleet is in service, throughout the vehicles' lifetime and, possibly, under real driving scenarios.

The approach that will be implemented in ASSIST-IoT is based on the idea that instead of conducting discrete tests on a sample of individual vehicles, the focus should be on the emissions distribution of the entire fleet (ISE, in-service emissions). The rationale is that there will always exist extreme scenarios for which a single test may fail all the time; for example, a winter uphill full-throttle start with a cold after treatment, and the engine is very challenging, emissions-wise, but potentially irrelevant from a statistical point of view. The emissions footprint of each vehicle along its use phase will be monitored, and any particular vehicle that exhibits an abnormal emissions profile should be subsequently diagnosed and repaired. From a fleet perspective, the monitoring of ISE levels and ensuring the distribution is conforming to regulated limits will allow avoiding incertitude when tested through ISC procedure.

Business scenario BS-P3A-1, Fleet in-service conformity verification
The OEM software engineer has established a fleet monitoring scheme where each vehicle is able to locally process, and transmit to a central location, sensor measurements of emissions and driving conditions provided through the Powertrain Control Module. A fraction of the vehicle fleet is equipped with both standard and high-fidelity emissions sensors contributing to the generation of models for the sensor measurements drift. These models can be applied to the correct measurements from the entire fleet. When the OEM software engineer is asked to verify the fleet's in-service conformity, drift-compensated sensor measurements of emissions and driving conditions are used to calculate the emissions distribution of the entire fleet. The fleet's emissions distribution is compared to legal limits and, if the distribution is found not acceptable, the Powertrain Control Modules of the fleet are recalibrated until the fleet's in-service conformity is restored. The definition of the calibration updates is based on previously generated emissions models. The effect of the updates is verified on a limited number of vehicles before it is deployed to the entire fleet. Any vehicles with a non-conforming emissions profile are identified.

[5] European vehicle emissions standards – Euro 7 for cars, vans, lorries and buses (europa.eu)

User/users:	OEM software engineer, Powertrain Control Module
Setting / context	The fleet is in operation and comprises privately owned and commercial cars in Europe. The OEM has to make sure that the fleet complies with EU regulations as defined in the form of nominal statistical distributions. The PCM is parameterised based on development phase tests (both RDE and in engine and chassis test benches). Vehicles are equipped with standard NOx sensor with are prone to drift like most ageing sensors. In the framework of the ASSIST-IoT project, some vehicles are equipped with an additional HiFi NOx sensor which is handpicked from standard production to ensure high accuracy within the expected production spread and is frequently replaced to ensure minimal drift and allow the determination of the measurement bias for the entire fleet.
Interacting system	The vehicle's propulsion system performance and emissions are controlled by the PCM. The fleet communicates with the OEM's database and exchanges data and firmware updates.
Users' goals	• Verify the fleet's in-service emissions conformity • Identify non-conforming vehicles
Initial status	The fleet is in operation and some of the vehicles are equipped with two sets of sensors measuring their operational parameters. The second set is of high fidelity and is frequently replaced guaranteeing reliable measurements. The OEM software engineer identifies or supervises the automatic identification of statistically relevant vehicles for fleet surveillance and applies the results to the majority of vehicles operating without a HiFi sensor.
Interaction	The OEM software engineer monitors the fleet's in-service conformity and updates its parameterisation, if necessary.
Data	Sensor measurements, at very high sampling frequencies describe the vehicles' operation and drift correction model parameters. These datasets are to be kept in the far edge node, and only relevant data propagated to the cloud.
Motivation	The expected benefits from the implementation of the described approach are the following: • The pre-production testing focus is diverted away from fulfilling numerous synthetic tests to consider continuous acceptable fleet performance. This provides for tracking the in-service emission level (ISE) allowing for a statistical surveillance. This makes the ISC verification straightforward. • Flexibility towards changing environmental and legal conditions. • Total fleet recalls may be avoided; potentially defective vehicles are identified and diagnosed, and only those that exhibit non-conforming emissions are called in for service • The fleet's emission distribution is estimated from the statistically relevant number of vehicles during real-world driving conditions (varying ambient temperature, different geographic region, vehicle age, style of driving) based on reliable sensor data (compensated for sensor drift). • Best compromise between cost / effort and confidence. • Availability of open and transparent vehicle data throughout their lifetime
Time	The fleet's monitoring is continuous. ISE levels are checked against the regulation levels for ISC verification on demand.
System functionalities	Device-to-device communication, real-time monitoring and data analysis, federated learning, alerting

Figure 53 shows the diagram of relationship between actors in this Business Scenario: Fleet in-service emission verification, that has remained the same as explained in deliverable D3.2:

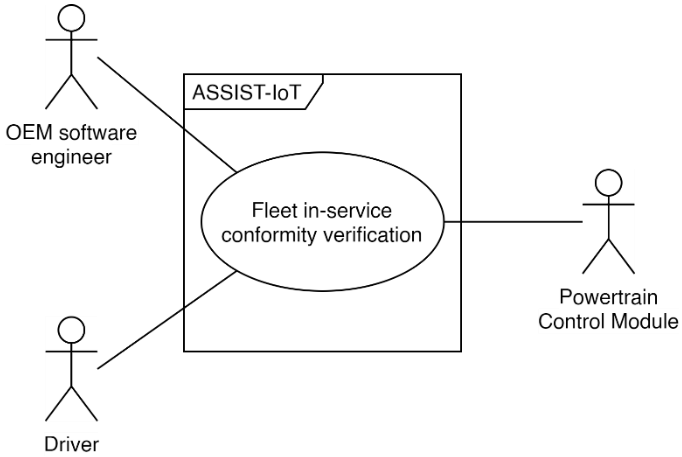


Figure 53. Use case diagram for the "Fleet in-service conformity verification" business scenario

5.1.1. UC-P3A-1 Fleet in-service emissions verification

UC-P3A-1 has been adapted after discussions with several PCM subject matter experts. Previously an automatic approach was envisioned to update the PCM calibration, but this was not deemed as feasible unanimously by all contacted experts, as the PCM's closed loop control is prone to unwanted, potentially critical side effects, if manipulated by an external control loop from the outside. Therefore, as both, the main goals of Pilot 3A and the showcasing of ASSIST-IoT capabilities are not affected by this change, it was decided to go to a manual calibration update approach instead.

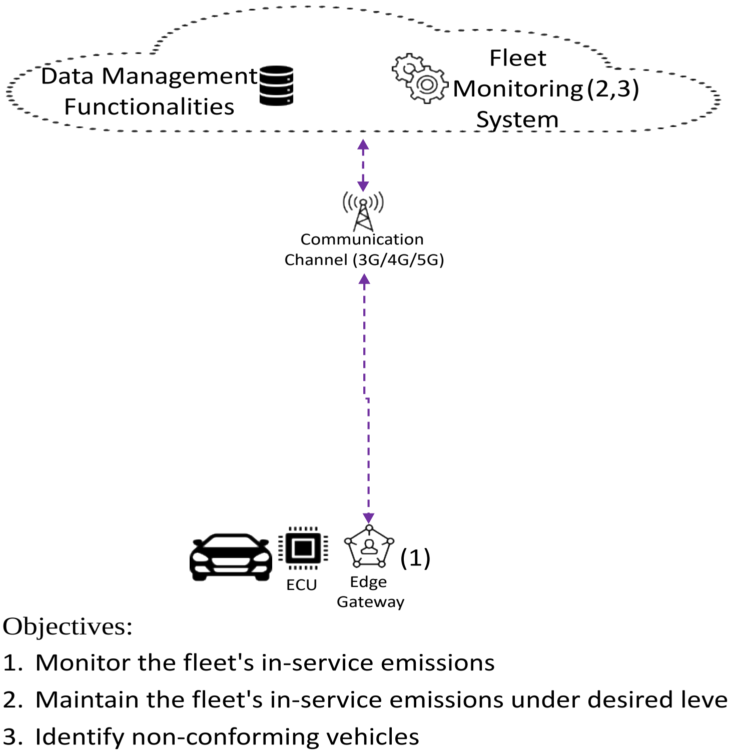


Figure 54. UC-P3A-1 "Fleet in-service emission verification" diagram

Figure 55. Photo of the research grade open PCM installed in the vehicle

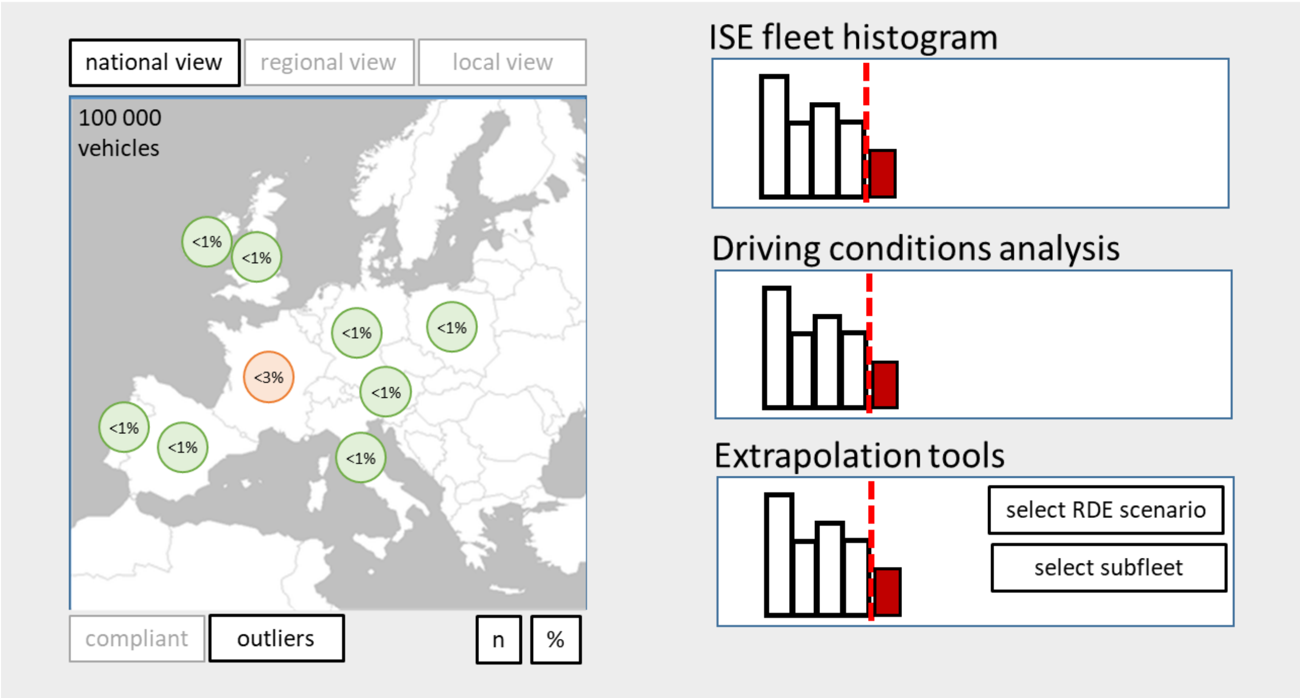


Figure 56. Example UI to display the emission distribution of a vehicle fleet

Table 1: Data used in BS-P3A-1 (Exemplary only)

Signal Group	**Exemplary Signals**	**Exemplary Usage**
Overall driving condition	Vehicle Speed, Vehicle Acceleration, Outside Temperature, Steering Angle, Engine Status	• Modelling the overall driving condition of the vehicle • Capturing climatic, environmental and driver related aspects
Emissions	Tailpipe NOx, Tailpipe O2, Airmass Flow, Soot load, Diesel Particulate Filter temperature	• Determine In-Service Emissions • Evaluate impact on calibration changes
Vehicle Position	GPS data, Vehicle Speed, Vehicle Acceleration	• Allow differentiation between urban and rural areas, e.g., for specific low emission urban calibrations

Use Case: UC-P3A-1, Fleet in-service emissions verification	
Description	Monitor the fleet and ensure that its emissions distribution conforms with corresponding regulations.
Reference Scenario	BS-P3A-1
Plane(s)	Device and Edge, Data Management, Application and Services
Vertical Capabilities	Manageability, Scalability, Security, Privacy and Trust
Functionalities within vertical capabilities	TBD
Objectives	• Monitor the fleet's in-service emissions • Maintain the fleet's in-service emissions under desired levels • Identify non-conforming vehicles
Actors (system actor or natural persons)	• OEM software engineer • Powertrain Control Module • Driver
Pre-conditions	The fleet comprises vehicles that are equipped with standard emission sensors and includes vehicles that are equipped with an additional high fidelity NO_x emissions sensor.
Trigger	Time-based continuous monitoring. On demand in-service conformity verification
Expected results	• The fleet complies with the emission regulations • Vehicles that exceed the emission thresholds are identified
Design preferences	Local resource processing unit integrated to the PCM, capable of supporting federated learning requirements and intelligent filtering methods in order to send only valuable information to the OEM via 5G infrastructure.
Extends the use case	NA
Includes the use case	UC-P3A-2
Notes and issues	A fraction (ex: 1% to 5%) of the annual vehicle production is monitored; A fraction (ex: 10%) of these vehicles are equipped with an additional HiFi NO_x sensor.
Main execution flow	1. ASSIST-IoT receives from the Powertrain Control Module all the sensor measurements via Drivelet data files and processes them locally 2. ASSIST-IoT transfers relevant in-vehicle data from the entire fleet to the OEM software engineer or cloud surveillance software on demand 3. The OEM software engineer or cloud surveillance software initiate the fleet's in-service conformity verification process 4. ASSIST-IoT estimates a drift model for the measurements of the standard emissions sensor using data from the vehicles that are equipped with both the standard and high-fidelity emissions sensor 5. ASSIST-IoT takes into account the emissions measurements drift models in order to estimates the fleet's in-service emissions (ISE) distribution and compares it to the ISC regulated limits (ex: the 95% fractional)

	6. ASSIST-IoT verifies that the fleet's emissions distribution conforms with the current regulations and no vehicle's emissions profile is outside the ISE distribution confidence interval 7. ASSIST-IoT notifies the OEM software engineer
Alternative execution	6a. ASSIST-IoT detects that the fleet's ISE is approaching the ISC regulated limits and notifies the OEM software engineer. The software engineer updates the calibration accordingly. 6a.1. ASSIST-IoT deploys the updated calibration to a selected number of vehicles (validation sub-fleet) 6a.2. ASSIST-IoT monitors the effect of the updates to the emissions profile of the validation sub-fleet 6a.3. ASSIST-IoT verifies that the Powertrain Control Module parametrisation update has the desired effect and distributes it to the entire fleet 6a.4. ASSIST-IoT identifies vehicles with an emissions profile that is outside the acceptable limits and notifies the OEM software engineer 6a.5. ASSIST-IoT proceeds to UC-P3A-2 6a.3a. ASSIST-IoT verifies that the Powertrain Control Module parametrisation update does not have the desired effect 6a.3a.1. ASSIST-IoT repeats steps 6a.1-6a.3 Steps 2-9 can be triggered or supervised by the OEM software engineer
Exceptions	N/A
Requirements involved	R-P3A-1, R-P3A-2, R-P3A-3, R-P3A-4, R-P3A-5, R-P3A-9, R-P3A-10, R-P3A-11, R-P3A-12
KPI	Cut of 50% in potential vehicle series recalls based on fleet emission distribution, by unit / fleet monitoring and addressing of outlier vehicles
Identified by	FORD-WERKE, UPV

5.2. BS-P3A-2: Vehicle diagnostics

Modern vehicles have dedicated onboard diagnostics (OBD) algorithms, which are distributed between the different controllers of the vehicle network; the PCM integrates those dedicated to propulsion system diagnostics. OBD algorithms are decided during the production phase and cannot be easily updated on demand; in many cases, the existence of a fault is detected, but the system is not able to properly identify the source of the default, rendering the troubleshooting difficult. A limited number of diagnostic methods are also available for technical inspections while servicing the vehicle; these are triggered by the service technician which means that detailed information related to a problem while the vehicle is in operation and exhibits fault symptoms may not be available. As a result, even if a problem is detected, its source may not always be identified. Because of the lack of specificity in isolating the fault source, many times an entire subsystem may be replaced in a trial-and-error approach.

ASSIST-IoT will implement diagnostic methods on demand. Those methods can be deployed on the vehicle when a failure is suspected or for routine diagnostic operations. The advantage of this approach over the current OBD system is twofold: on the one hand, the methods can be evolved along with the vehicle service life, using for that the information available from the complete fleet in real driving operation and allowing federated learning; on the other hand, the methods are implemented while the vehicle is in operation, thus gathering information of the faulty system while driving. Both aspects will allow the development of advanced diagnostics with expected higher failure identification capabilities.

<table>
<tr><th colspan="2">Business scenario BS-P3A-2, Vehicle diagnostics</th></tr>
<tr><td colspan="2">The OEM software engineer has established a fleet monitoring scheme where each vehicle in the fleet is able to locally process, and transmit to a central location, sensor measurements of emissions and driving conditions provided through the Powertrain Control Module. A fraction of the vehicle fleet is equipped with both standard and high-fidelity emissions sensors contributes to the generation of models for the sensor measurements drift. These models can be applied to the correct measurements from the entire fleet. When the OEM software engineer is asked to verify the fleet's in-service conformity, drift-compensated sensor measurements of emissions and driving conditions are used to calculate the emissions distribution of the entire fleet. The fleet’s emissions distribution is compared to legal limits and, if the distribution is found not acceptable, the Powertrain Control Modules of the fleet are recalibrated until the fleet’s in-service conformity is restored. The definition of the calibration updates is based on previously generated emissions models. The effect of the updates is verified on a limited number of vehicles before it is deployed to the entire fleet. Any vehicles with a non-conforming emissions profile are identified.</td></tr>
<tr><td>User/users:</td><td>OEM software engineer, Driver, OEM aftersales services manager, Aftersales service technician</td></tr>
<tr><td>Setting / context</td><td>The vehicle potentially has a defect that is affecting its performance or emissions profile</td></tr>
<tr><td>Interacting system</td><td>Powertrain Control Module</td></tr>
<tr><td>Users’ goals</td><td>To update the pool of methods able to identify faulty parts causing the vehicle to increase its emission levels and reduce the vehicle down-time.</td></tr>
<tr><td>Initial status</td><td>A potentially defective vehicle has been identified.</td></tr>
<tr><td>Interaction</td><td>The OEM software engineer updates the vehicle’s diagnostics capabilities if needed. The vehicle diagnoses itself and informs the OEM aftersales services manager and the aftersales service technician so that they can initiate the necessary actions. The OEM software engineer or the driver is able to put the vehicle under active monitoring, if needed. The OEM aftersales manager is informed about the detected failure so spare parts can be pre-actively sent to the garage in order to reduce vehicle down-time. The driver receives notifications on the dashboard about the vehicle’s condition</td></tr>
<tr><td>Data</td><td>Sensor measurements at very high sampling frequencies and thousands of parameters describing the vehicles’ operation.</td></tr>
<tr><td>Motivation</td><td>The expected benefits from the implementation of the described approach are the following:
• Increased customer trust and satisfaction.
• Better management of aftersales services.</td></tr>
<tr><td>Time</td><td>The vehicle’s on-board monitoring is continuous; high-frequency active monitoring is enabled and disabled on demand. ISE verification against ISC levels for a particular vehicle is happening on demand.</td></tr>
<tr><td>System functionalities</td><td>Device-to-device communication, data safety, security and provenance (communication and storage)</td></tr>
</table>

Figure 57 shows the diagram of relationship between actors in this Business Scenario: Vehicle diagnostics, that has remained the same as explained in deliverable D3.2:

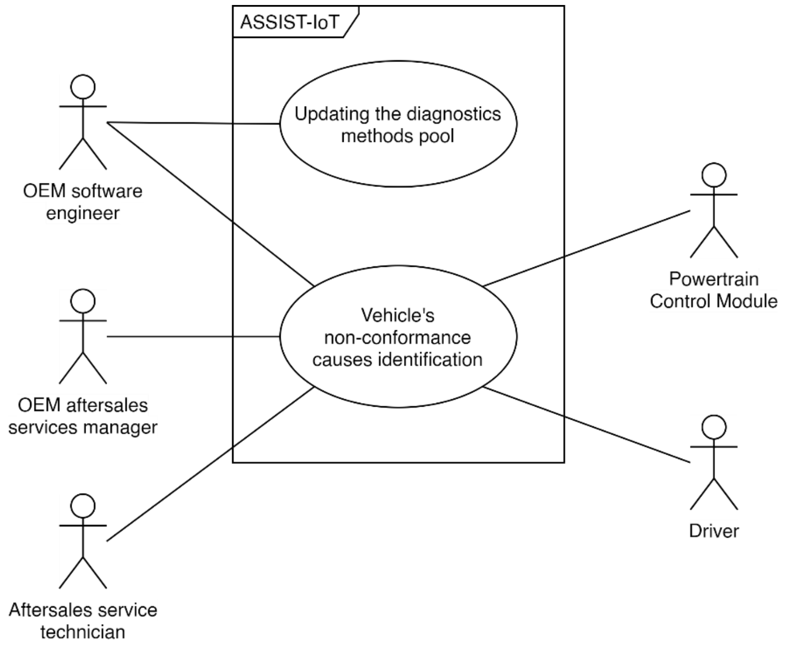


Figure 57. Use case diagram for the "Vehicle diagnostics" business scenario

5.3.UC-P3A-2: Vehicle's non-conformance causes identification

UC-P3A-2 is still reflecting the previously defined goals, and therefore only a minor structural update was necessary. In the previous version of this document a sub-task was missing, that the driver should be informed, if the vehicle needs to be fixed in the garage. This was added in this version of the document.

UC-P3A-2 addresses the desire to simplify the analysis process once a previously unknown fault was reported, meaning the driver of a vehicle reports an unusual and unwanted behaviour, but the root cause is not understood yet. The OEM engineer now consequently starts a time- and resource-consuming process to identify the underlying cause for the fault:

- Reproduction of the fault. As most previously unknown faults are seldom, the reproduction of the fault, either in the vehicle or on a test bench, is a very challenging task.
- Measurement of data channels in the vicinity of the suspected module.
- Analysis of previously measured data.
- Update of affected module to remove root cause of fault.

With the help of ASSIST-IoT and the ideas being developed in Pilot 3A, this process can be simplified significantly

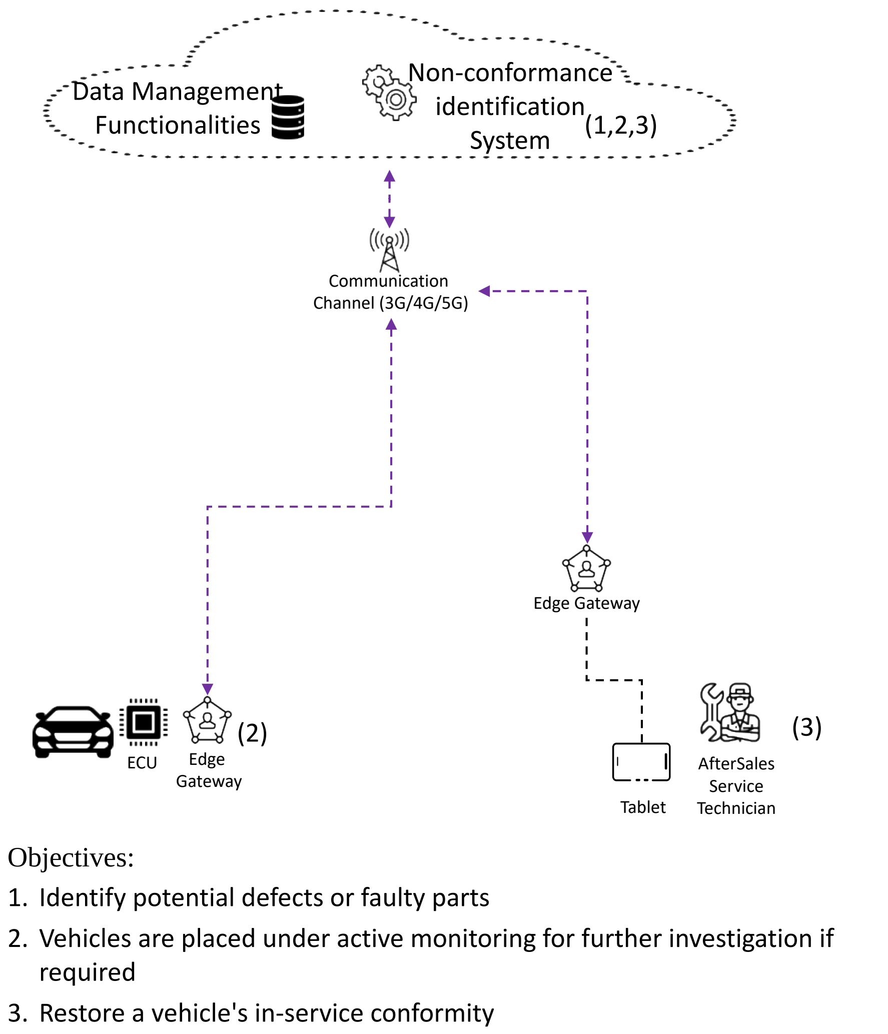


Figure 58. UC-P3A-2 « Vehicle non-conformance causes identification » diagram

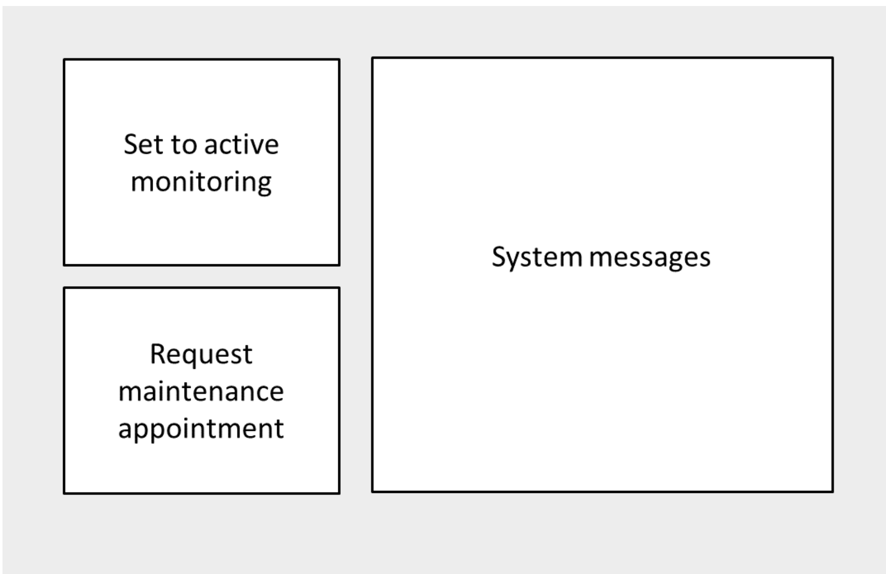


Figure 59. Example of a simple in-vehicle menu structure with input options and feedback

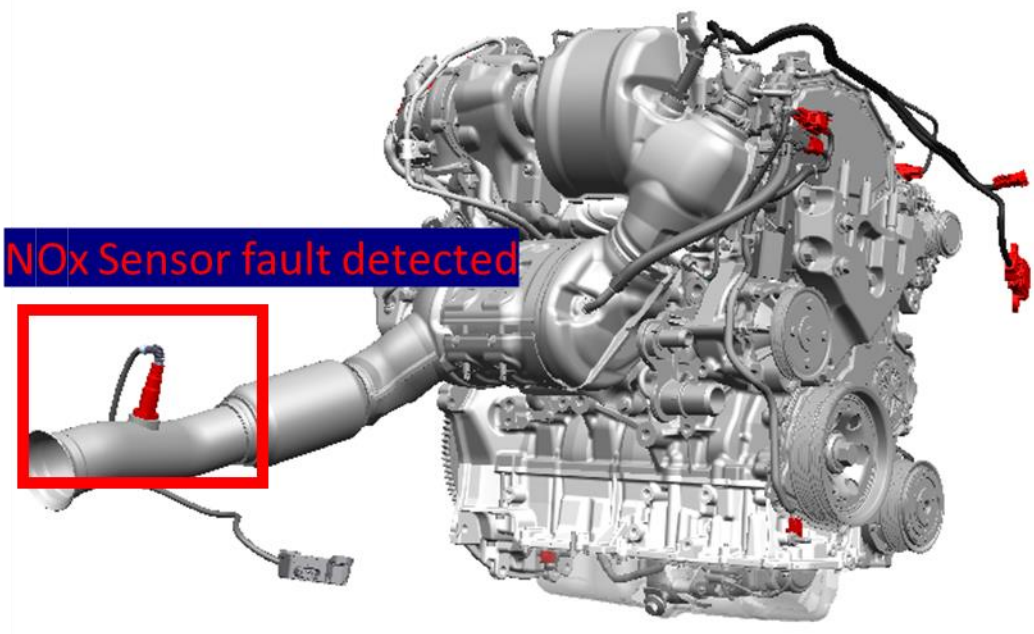


Figure 60. Principle of indicating a defect module with the help of AR

Table 2: Data used in UC-P3A-2 (Exemplary only)

Signal Group	Exemplary Signals	Exemplary Usage
Overall driving condition	Vehicle Speed, Vehicle Acceleration, Outside Temperature, Steering Angle, Engine Status	• Modelling the overall driving condition of the vehicle • Capturing climatic, environmental and driver related aspects
Emissions	Tailpipe NOx, Tailpipe O2, Airmass Flow, Soot load, Diesel Particulate Filter temperature	• Determine In-Service Emissions • Evaluate impact on calibration changes
Vehicle Position	GPS data, Vehicle Speed, Vehicle Acceleration	• Allow differentiation between urban and rural areas, e.g., for specific low emission urban calibrations
Identification	ASSIST-IoT GWEN ID, Vehicle Identification Number (VIN)	• Contact the driver if vehicle needs to be serviced due to detected faults
Detailed failure information	All the above, detailed signal data based on the suspected faulty module	• Create high frequency logfiles in the vicinity of the suspected module and identify the driving conditions which trigger the fault

Use Case: UC-P3A-2, Vehicle's non-conformance causes identification	
Description	A potentially defective vehicle is placed under active monitoring and is diagnosed using intelligent methods that are updated on demand.
Reference Scenario	BS-P3A-2

Plane(s)	Device and Edge, Application and Services
Vertical Capabilities	Self-*
Functionalities within vertical capabilities	Self-diagnosis, federated learning, self-awareness
Objectives	• To identify potential defects or faulty parts • Inform the driver to repair the vehicle in the garage • Vehicles are placed under active monitoring for further investigation if required • Restore a vehicle's in-service conformity
Actors (system actor or natural persons)	• OEM software engineer • Powertrain Control Module • Driver • OEM aftersales services manager • Aftersales service technician
Pre-conditions	The vehicle has on-board diagnostics capabilities. A pool of diagnostics methods is available (UC-P3A-3)
Trigger	The vehicle has been identified as non-conforming with respect to its emissions profile (UC-P3A-1) or the vehicle has not been behaving normally, according to the driver.
Expected results	• Any faulty parts is replaced • The vehicle's emissions profile is within the acceptable limits
Design preferences	Edge intelligence on the vehicle in order to send only relevant data (and complying with data protection policies) to the OEM and to provide local processing power. Federated learning in order to improve diagnostics methods without streaming all the data to the cloud. Augmented reality support in providing repair instructions.
Extends the use case	NA
Includes the use case	NA
Notes and issues	NA
Main execution flow	1. The OEM software engineer or the driver initiates diagnostics on the vehicle 2. The OEM software engineer supervises the deployment of subsystem diagnostics methods to the Powertrain Control Module 3. ASSIST-IoT runs diagnostics on the vehicle and identifies possible fault sources 4. ASSIST-IoT notifies the driver that vehicle has to be serviced 5. ASSIST-IoT notifies the OEM aftersales services manager so that they can schedule pre-ordering of defect spare parts 6. The driver brings the vehicle to the aftersales service garage 7. The aftersales service technician identifies the cause of the fault and ASSIST-IoT records cause and effect

	8. The aftersales service technician repairs the vehicle to meet legal requirements again
Alternative execution	3a. ASSIST-IoT cannot identify possible fault sources 3a.1. ASSIST-IoT enables the active monitoring mode in order to collect detailed high sampling frequency data 3a.2. ASSIST-IoT identifies possible fault sources 3a.3. Continue to step 4
Exceptions	N/A
Requirements involved	R-P3A-1, R-P3A-2, R-P3A-5, R-P3A-6, R-P3A-7, R-P3A-8, R-P3A-9, R-P3A-10, R-P3A-11, R-P3A-12, R-P3A-13
KPI	Cut of 50% of potential vehicle series recalls by monitoring and adapting of fleet emission distribution
Identified by	UPV, FORD-WERKE

5.3.1. UC-P3A-3: Updating the diagnostics methods pool

As described before, identifying the root cause of previously unknown failures is a challenging task in the automotive perimeter. To support this Use Case, Pilot 3A aims to install a pool of innovative diagnostic methods, which can be developed on demand, after the release of the vehicle. If a vehicle is suspected of showing undesired behaviour, one or more enhanced methods from this growing pool of diagnostic functions can be deployed to the affected vehicle, to log high frequency data signals in the vicinity of the suspected faulty module and to analyse the fault directly on the edge. This is considered to be a significant improvement compared to the currently available time- and resource-consuming tools and processes.

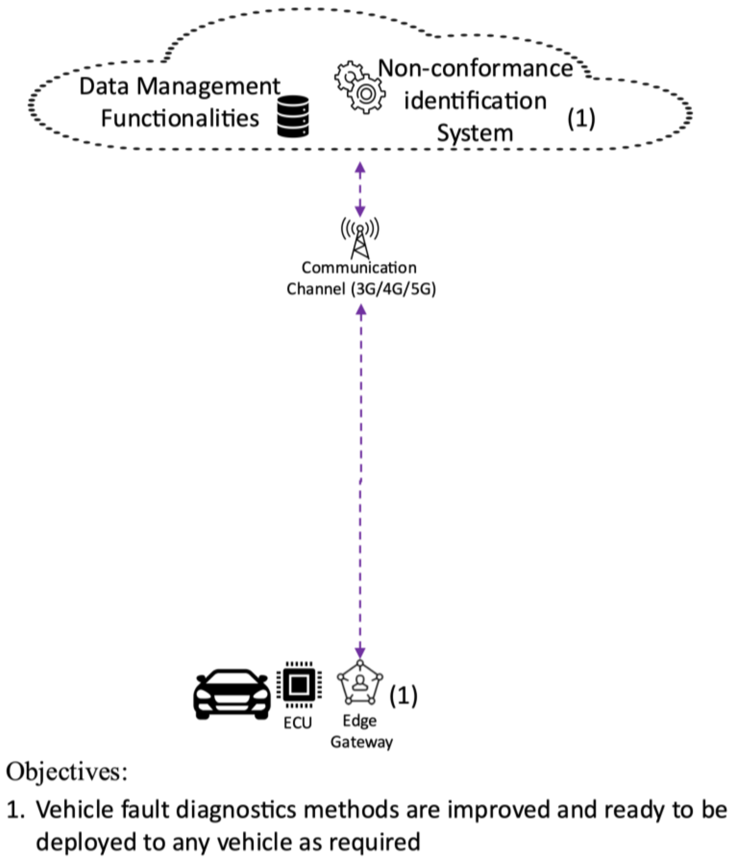


Figure 61. UC-P3A-3 "Updating the diagnostic methods pool" diagram

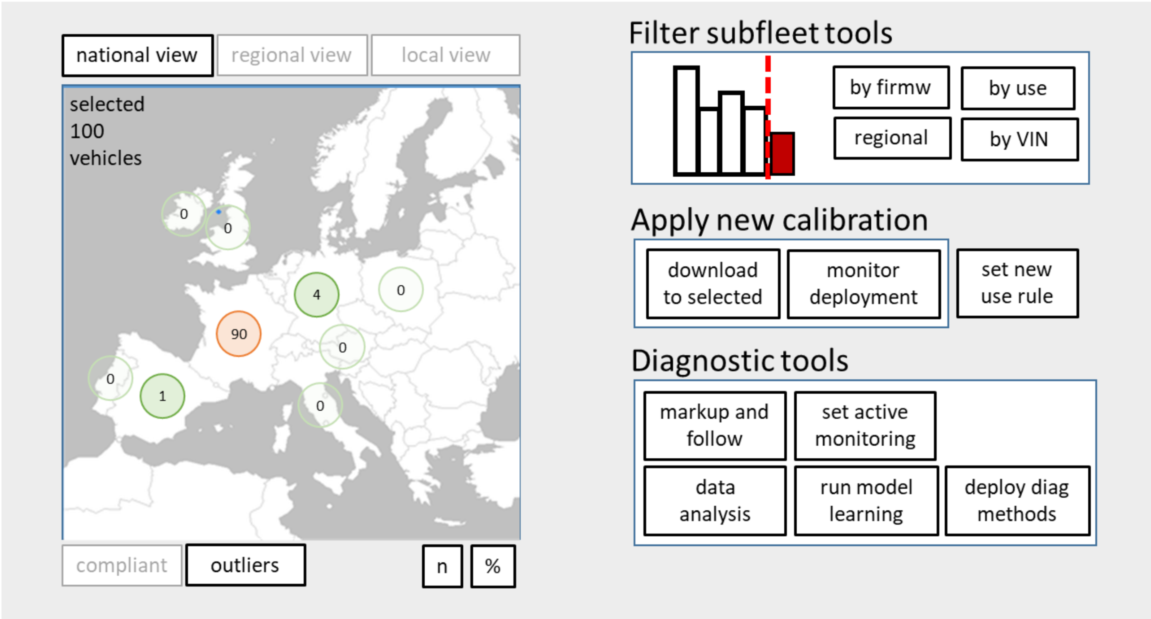


Figure 62. Example of an UI to deploy new calibrations or enhanced diagnostic methods to previously selected vehicles

Table 3. Data used in UC-P3A-3 (Exemplary only)

Signal Group	Exemplary Signals	Exemplary Usage
Overall driving condition	Vehicle Speed, Vehicle Acceleration, Outside Temperature, Steering Angle, Engine Status	• Modelling the overall driving condition of the vehicle • Capturing climatic, environmental and driver related aspects
Emissions	Tailpipe NOx, Tailpipe O2, Airmass Flow, Soot load, Diesel Particulate Filter temperature	• Determine In-Service Emissions • Evaluate impact on calibration changes
Vehicle Position	GPS data, Vehicle Speed, Vehicle Acceleration	• Allow differentiation between urban and rural areas, e.g., for specific low emission urban calibrations
Identification	ASSIST-IoT GWEN ID, Vehicle Identification Number (VIN)	• Contact the driver if vehicle needs to be serviced due to detected faults
Detailed failure information	All the above, detailed signal data based on the suspected faulty module	• Create high frequency logfiles in the vicinity of the suspected module and identify the driving conditions which trigger the fault

Use Case: UC-P3A-3, Updating the diagnostics methods pool	
Description	Improve vehicle fault diagnostics methods
Reference Scenario	BS-P3A-2
Plane(s)	Data Management, Application and Services
Vertical Capabilities	Manageability and Control, Self-*, Security, Privacy and Trust, Interoperability
Functionalities within vertical capabilities	Self-diagnosis, federated learning, self-awareness, authentication, and authorization
Objectives	Vehicle fault diagnostics methods are improved and ready to be deployed to any vehicle as required
Actors (system actor or natural persons)	• OEM software engineer
Pre-conditions	Active monitoring datasets and records of faults and identified causes are available (UC-P3A-2)
Trigger	New monitoring and diagnostics information is made available by the OEM software engineer
Expected results	Updated pool of diagnostics methods
Design preferences	Data-driven diagnostics methods
Extends the use case	N/A
Includes the use case	N/A
Notes and issues	N/A
Main execution flow	1. The OEM software engineer, through ASSIST-IoT, sends gradual OTA Powertrain Control Module parametrisation updates to a vehicle that is equipped with the high-fidelity sensor 2. ASSIST-IoT monitors the vehicle's emissions and driving profiles 3. ASSIST-IoT combines the vehicle's emissions and driving profiles with already available datasets from the entire fleet that include: (i) previous active monitoring data, (ii) corresponding detected faults, and (iii) identified causes records (UC-P3A-2) 4. ASSIST-IoT updates the diagnostics methods pool
Alternative execution	N/A
Exceptions	N/A
Requirements involved	R-P3A-1, R-P3A-4, R-P3A-5, R-P3A-9, R-P3A-12
KPI	Over 50% shortening of development time for ECU diagnostic software updates
Identified by	UPV, FORD-WERKE

5.4. Pilot 3A systems' requirements

Requirement: R-P3A-1, Monitored Data Channels	
Category	Functional
Priority	Must
Use case IDs	UC-P3A-1, UC-P3A-2, UC-P3A-3
Rationale	A data-driven approach for in-service conformity and diagnostics is based on inference based on sensor measurements. There is a huge amount of data that is generated from the vehicle at various frequencies but not all the data sets are relevant to the purposes of the project. However, in order to implement advanced methods, flexible access must be provided to the OEM software engineer, so that measured channels and their frequency may be defined on the fly.
Description	ASSIST-IoT shall be capable of collecting and managing the following data types: CHAR 1 byte representing a character (C data type: char) UINT8 8-bit unsigned integer UINT16 16-bit unsigned integer INT16 16-bit signed integer UINT32 32-bit unsigned integer UINT64 64-bit unsigned integer BOOL Boolean, stored as 16-bit value If != 0 then TRUE, if == 0 then FALSE REAL Floating-point compliant with IEEE 754, double precision (64 bits) Data channels may have the origin in the PCM or be a result of variable manipulation or software code run on the far edge. Data is transferred together with the data channel identification string and timestamp (see "Data Models"). Acquisition frequency may be varied ranging from 100 us (i.e., 10 kHz) to 10 s (0.1 Hz). Data channels may be dynamically defined as *local* (i.e., the value is kept on the far edge) or *global* (i.e., the value is streamed to the cloud). In some cases -as for GPS information- ASSIST-IoT will restrict some data channels to the local operation, so that user personal information is protected. ASSIST-IoT shall evaluate the availability of resources and bandwidth for the local and global streams.
Acceptance criteria	Review of Drivelet data to confirm all relevant data channels are processed
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement: R-P3A-2, Data models' compliance	
Category	Non-functional
Priority	Must
Use case IDs	UC-P3A-1, UC-P3A-2
Rationale	Support the file format used by the automotive industry for the recording of signal data during measurement, calibration and testing electronic control systems.
Description	ASSIST-IoT shall be able to produce and consume measurement of signal values in the MDF4.1 format: https://www.asam.net/standards/detail/mdf/wiki/#:~:text=Measurement%20Data%20Format%20(ASAM%20Standard,the%20loop%20are%20carried%20out
Acceptance criteria	During Pilot demo ASSIST-IoT will illustrate production and consumption of data in MDF4.1 format
Customer satisfaction	5 (Necessary requirement for all other requirements)
Customer dissatisfaction	3 (The final customer will likely not notice a difference, as this is the current state of the art. However as overall customer expectations are likely to rise as well, not delivering this requirement could lead to customer dissatisfaction in the future.)
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement: R-P3A-3, OEM Fleet data storage	
Category	Non-functional
Priority	Must
Use case IDs	UC-P3A-1
Rationale	A database hosting information about the fleet is required by the OEM for efficient fleet management.
Description	ASSIST-IoT shall host information about the fleet's in-service conformity on a dedicated database. The database shall track PCM parametrisation and the corresponding driving conditions. It shall not include sensitive information; any such information shall be anonymised or strictly restricted at the edge. The Database shall: • accommodate vehicles with different sensor sets, monitored variables, and acquisition rates • contain information about NOx sensor drift (caused by an aging vehicle) • contain information about real world driving emissions for the whole fleet (determination of ISE levels) • contain information for different calibrations (parameter datasets) the effect over NOx and CO2 emissions, so that calibration can be optimized

	• allow performing active monitoring of specific vehicles, with extended number of variables and higher acquisition frequency, so that diagnostic methods can be developed • contain information coming from aftersales or service operations for identifying the source of a given fault
Acceptance criteria	The database includes the calibration parameters and allows automatic distribution to ASSIST-IoT edge nodes.
Customer satisfaction	3 (Requirement is needed to achieve Pilot 3A goals, but not directly noticed by customer.)
Customer dissatisfaction	3 (The final customer will likely not notice a difference, as this is the current state of the art. However as overall customer expectations are likely to rise as well, not delivering this requirement could lead to customer dissatisfaction in the future.)
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement: R-P3A-4, PCM Parameterisation (Calibration) Update Safety and Security	
Category	Non-functional
Priority	Must
Use case IDs	UC-P3A-1, UC-P3A-3
Rationale	A vehicle's PCM parametrisation affects the vehicle's behaviour, therefore, the vehicle's condition, the duration of the update, etc., shall be taken into account and a fallback plan shall be available.
Description	ASSIST-IoT shall ensure that updates occur under safe driving conditions and that they have been safely deployed. For that, parametrisation update will be classified as *incremental* or *total*. For the first case, immediate update of the parameters will be allowed, an ASSIST-IoT will keep track of the modifications performed over the base calibration. Updates from reliable sources will only be allowed.
Acceptance criteria	For the case of total update, ASSIST-IoT will perform the update at the end of a driving trip, ensuring that the vehicle is in a safe state. ASSIST-IoT will validate the integrity of the update and will restore the previous version if the update is not successful.
Customer satisfaction	4 (This requirement will allow new and innovative functionalities, which the customer will likely appreciate.)
Customer dissatisfaction	3 (The final customer will likely not notice a difference, as this is the current state of the art. However as overall customer expectations are likely to rise as well, not delivering this requirement could lead to customer dissatisfaction in the future.)
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement: R-P3A-5, Data Storage	
Category	Non-functional

Priority	Must
Use case IDs	UC-P3A-1, UC-P3A-2, UC-P3A-3
Rationale	The vehicle shall be able to have storage capacity in order to support decentralised data-driven methods.
Description	ASSIST-IoT shall store information at the vehicle in order to recall and transmit critical events that have occurred while off-line. ASSIST-IoT shall provide sufficient data storage for the implementation of intelligence at the far edge, and for running algorithms for subsampling, combining and manipulating measurement channels to create manipulated channels.
Acceptance criteria	ASSIST-IoT shall retain detailed information generated during the time when active monitoring is enabled so that they can be recalled when required.
Customer satisfaction	4 (This requirement will allow new and innovative functionalities, which the customer will likely appreciate.)
Customer dissatisfaction	3 (The final customer will likely not notice a difference, as this is the current state of the art. However as overall customer expectations are likely to rise as well, not delivering this requirement could lead to customer dissatisfaction in the future.)
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement: R-P3A-6, Active monitoring mode initiation by the OEM software engineer capability	
Category	Functional
Priority	Must
Use case IDs	UC-P3A-2
Rationale	The OEM software engineer requires more information relating its instantaneous emissions profile to the vehicle's behaviour and driving conditions in order to diagnose increased emissions for a particular vehicle.
Description	ASSIST-IoT shall allow the OEM software engineer to remotely enable the Active Monitoring mode so that the vehicle collects detailed information about its behaviour: When in active monitoring, the number of registered channels is set to its maximum and data persistence is increased, so that data is available for latter analysis. In parallel, data is propagated to the remote system making it available to the OEM software engineer. In parallel, when the vehicle is kept in active monitoring, diagnostic methods are deployed into the far edge node for the identification of possible fault sources.
Acceptance criteria	The OEM software engineer is able to initiate Active Monitoring and retrieve the collected data.
Customer satisfaction	5 (extremely pleased, as this allows detailed analysis of previously unknown failure states)
Customer dissatisfaction	3 (The final customer will likely not notice a difference, as this is the current state of the art. However as overall diagnostic capabilities are increasing, customer expectations are

	likely to rise as well, not delivering this functionality will likely lead to dissatisfaction in the future.)
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement: R-P3A-7, Active monitoring mode initiation by the Aftersales service technician capability	
Category	Functional
Priority	Should
Use case IDs	UC-P3A-2
Rationale	The Aftersales service technician, in order to diagnose faults reported by the driver at the garage, will be able to initiate the Active Monitoring mode in order to acquire detailed data of vehicle's behaviour with respect to driving conditions.
Description	ASSIST-IoT shall support an Active Monitoring mode for the Aftersales service technician so that they can collect detailed information about the vehicle's behaviour while the vehicle is at the garage for service.
Acceptance criteria	The Aftersales service technician receives all the necessary information to diagnose a fault.
Customer satisfaction	5 (It is a common problem in vehicle diagnostics, that the driver is experiencing driving situations, which can't be explained in the garage. This can be caused either by real underlying faults, or by a misunderstanding on certain vehicle functionality. Therefore, it will be highly appreciated by both the customer and the mechanic, if detailed analysis data is available, that explain the driving situation during the potential fault.)
Customer dissatisfaction	4 (Although for most system this is the state of the art, an improved situation is desired by both the customer on the one hand and by mechanics and OEM engineers on the other hand.)
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement: R-P3A-8, Active monitoring mode initiation by the driver capability	
Category	Functional
Priority	Could
Use case IDs	UC-P3A-2
Rationale	The driver suspects a potential issue with the vehicle and initiates the Active Monitoring mode in order to facilitate future diagnosis at the garage.
Description	ASSIST-IoT shall enable the driver to initiate the Active Monitoring process. The subset and frequency of the collected data will be governed by a specialised active monitoring mode in order to avoid misuse. As the activation is expected to take up to several minutes, a recording buffer shall be implemented to cover failure events which happened in the past (within the last hour).

Acceptance criteria	Driver interface to initiate the Active Monitoring process. Results of monitoring from t_b sec before the triggering Active Monitoring Mode shall be collected.
Customer satisfaction	5 (Functionality will be highly appreciated by customer on the one hand and mechanics and OEM engineers on the other hand.)
Customer dissatisfaction	3 (The final customer will likely not notice a difference, as this is the current state of the art. However as overall customer expectations are likely to rise as well, not delivering this requirement could lead to customer dissatisfaction in the future.)
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement: R-P3A-9, Edge Intelligence	
Category	Functional
Priority	Must
Use case IDs	UC-P3A-1, UC-P3A-2, UC-P3A-3
Rationale	The vehicle shall have processing capabilities.
Description	ASSIST-IoT shall be able to locally process emissions information in order to assess the vehicle's conformity or to reduce the amount of data required for the assessment so that they can be transmitted to the OEM. ASSIST-IoT shall also be able to generate data-driven models in order to rectify sensor measurement drift and to identify faults from data describing the vehicle's behaviour. ASSIST-IoT will be able to handle and create new manipulated data channels. ASSIST-IoT will allow deploying AI methods for incremental modification of the PCM parametrisation such that the PCM parametrisation is optimized. ASSIST-IoT will allow the OEM software engineer to supervise this process, so that incremental modifications are safe for the vehicle operation. ASSIST-IoT will allow identifying clusters and correlations between vehicles for identifying common patterns and clusters. ASSIST-IoT will allow the development of data-driven models or grey-box models for these clusters, which could be used for diagnosing common faults.
Acceptance criteria	ASSIST-IoT shall be able to process all necessary data on the edge, without data slippage and the need to process raw data in the cloud.
Customer satisfaction	4 (The final customer will benefit improved diagnostic capabilities, resulting in less vehicle downtime and potential costly repairs)
Customer dissatisfaction	3 (The final customer will likely not notice a difference, as this is the current state of the art. However as overall customer expectations are likely to rise as well, not delivering this requirement could lead to customer dissatisfaction in the future.)
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement R-P3A-10 was updated compared to the initial version of the document. The general goal wasn't changed, only the wording was refined to clarify our goals.

Requirement: R-P3A-10, Vehicle Dashboard Notifications	
Category	Functional
Priority	Must
Use case IDs	UC-P3A-1, UC-P3A-2
Rationale	Notify the driver about the condition of the car.
Description	ASSIST-IoT shall provide information to the driver about the existence of faults requiring a service operation. If Active Monitoring Mode is initiated by the driver, for example if a previously discovered fault could not be fixed during a repair action, ASSIST-IoT shall notify the driver, who will be able to reactivate Active Monitoring. This data can then later help the service technician to find the failure root cause.
Acceptance criteria	The driver receives the necessary information and can activate Active Monitoring.
Customer satisfaction	5 (As this is an innovative feature, the final customer will likely be very pleased)
Customer dissatisfaction	3 (The final customer will likely not notice a difference, as this is the current state of the art. However as overall customer expectations are likely to rise as well, not delivering this requirement could lead to customer dissatisfaction in the future.)
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement: R-P3A-11, Connectivity between OEM and fleet	
Category	Functional
Priority	Must
Use case IDs	UC-P3A-1, UC-P3A-2
Rationale	Some vehicles may not have a stable connection between ASSIST-IoT and OEM when a calibration update is deployed to the fleet or when a vehicle status update is ready to be transmitted to the OEM database.
Description	ASSIST-IoT shall support: • Network connection assessment between vehicle fleet and OEM, prior to any update • Buffer technology for areas with insufficient connectivity
Acceptance criteria	The OEM is aware of success or failure of calibration update.
Customer satisfaction	5 (Extremely pleased, as this is a beneficial tool to address some of the recently raised challenges in the propulsion system controls vehicle segment)

Customer dissatisfaction	2 (Unclear, as also other solutions could be imagined overcoming current challenges within the post EU-6 emission legislation context)
Identified by	**Source**
FORD-WERKE	Partner’s expertise

In the previous version of Requirement R-P3A-12 the benefit of low latency networks was underlined. This sentiment was revised in the meantime, as a low latency connection is not needed at all times to please customer expectations. The focus is now more towards flexibility and reliability, in order to support low latency connection of small data packages on the one hand, and on on-demand transfer of large raw data packages on the other hand, which are uncritical from latency perspective. The requirement was updated accordingly.

Requirement: R-P3A-12, Connectivity	
Category	Functional
Priority	Must
Use case IDs	UC-P3A-1, UC-P3A-2, UC-P3A-3
Rationale	The PCM calibration update, the distribution of the models and the federated learning scheme requires a stable, reliable connection between ASSIST-IoT and OEM. As the package size is changing significantly based on the different Use Cases, for example small data packages to summarize the emission status of a vehicle up to large packages of raw emission or fault data, gathered in Active Monitoring mode, the requirements towards ASSIST-IoT also show a significant range described below.
Description	To support the transferability of the local model parameters quickly and reduce the delay of global model training, ASSIST-IoT shall support: • low communication latency for small data packages • Reliable, low cost connections for larger packages of raw data generation of different transmit tasks at different times
Acceptance criteria	The OEM is aware of success or failure of information transmittance.
Customer satisfaction	5 (As all Use Cases are based on reliable, low-latency and/or cost-efficient connectivity solution, customer satisfaction is directly linked to this requirement)
Customer dissatisfaction	3 (The final customer will likely not notice a difference, as this is the current state of the art. However as overall customer expectations are likely to rise as well, not delivering this requirement could lead to customer dissatisfaction in the future.)
Identified by	**Source**
FORD-WERKE	Partner’s expertise

Requirement: R-P3A-13, Augmented Reality Support at the Garage	
Category	Functional
Priority	Should
Use case IDs	UC-P3A-2

Rationale	Provide fault information to the Aftersales service technician in a quick and user-friendly way
Description	ASSIST-IoT shall support Augmented Reality application in order to provide visual support to the Aftersales service technician about the identified faults. The Aftersales service technician shall be able to use mobile devices in order to receive information from the vehicle in the garage explaining the location and the nature of any problems
Acceptance criteria	The Aftersales service technician receives visual information about the faulty parts.
Customer satisfaction	3 (Augmented Reality has a high potential to support repair actions in the garage once all repair information is available in the supporting database. This is expected to be the limiting factor for the foreseeable future; therefore, the impact is rated as 3 only)
Customer dissatisfaction	2 (As described above, Augmented Reality is highly dependent on the underlying database and current systems without Augmented Reality are working stable)
Identified by	**Source**
FORD-WERKE	Partner's expertise

5.5. BS-P3B-1: Vehicle exterior condition inspection and documentation

The TwoTronic vehicle-scanners are installed at the premises of automotive services providers and offer an automated, efficient, and economical way for the documentation and the inspection of vehicle exterior surface conditions.

Figure 63: TwoTronic scanner in small configuration for passenger cars outdoor

The Vehicle-scanner system comes in various configurations for different vehicle sizes (e.g., car, van, and track) and can be set up and operate in indoor or outdoor mode.

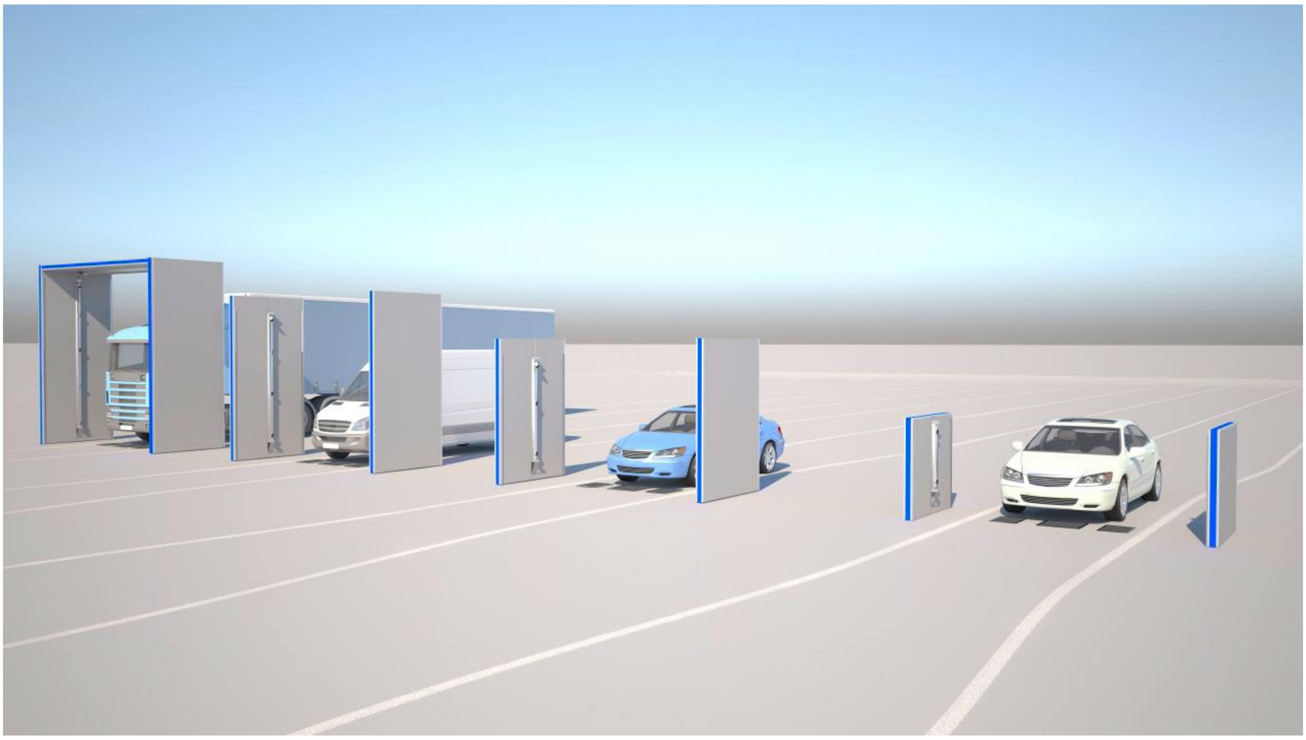


Figure 64 The vehicle scanner supports four vehicle sizes

The scanning operation starts with a human driver passing the vehicle through the scanner at low speed (ideally with 5-8 Km/h). The driver is usually a customer of the enterprise having the scanner typically at its entrance. However, also drivers of the own team can pass a vehicle through the scanner for company purposes. The scanner produces multiple images of the vehicle that are used to document the current exterior condition and particularly to recognize its surface damages manually or automatically. There are different configuration sizes (with increasing system height) of the scanner with various numbers of supporting cameras according to the size of the intended vehicles to be scanned. Finally, the scanner can be optionally equipped with additional modules to capture the vehicle underbody (when 360°-capture is needed) and its treads profiles. Several additional data is also generated and recorded with each scan, like scanner location, scan direction, time and conditions, vehicle identifier, vehicle license plate (if any), etc. They are used as scan-meta data associated with the individual vehicle scans to support the business intelligence of the application in different use cases.

The scanner is the initial component that captures the exterior condition into images and relevant meta data. The next step is the saving of all these data into an intelligent storage system. This can be local or in the cloud or in a hybrid manner. It serves the documentation of the current condition of a vehicle at the time of the scan. For several potential reasons in the future and depending on the individual use cases the data can be again retrieved from a permanent storage system and used accordingly. Optionally an automatic, AI-based inspection of the vehicle's exterior can be configured and could support automated AI-based proposals for surfaces damages to the scan system users. The AI-algorithms may run on the location's scanner computing system, or in the cloud, where the compound data of several scanners may be uploaded.

A dedicated front-end software module facilitates the interaction of the users and the gain data (images + meta data). As hundred thousand pictures are gathered within a short period of time an efficient management of the images and their meta data including their ergonomic visualisation is essential for the user acceptance and the creation of real added value. Hereby, the Augmented Reality (AR) functionalities have the potential to additionally enhance the user experience with their very interactive way, but they should be considered optional (due to the additional computing requirements for smart end-devises, not usually present in many of the current use cases). The exact application processes a sequence of image gaining, archiving, visualisation and retrieval depends on the individual use case of the scanner application. However, all these use cases with the optional AI-configuration have a common need for the generation of high-quality training data for the AI-algorithms. This must be both supported by the front-end software in the context of a dedicated annotation-team as well as with interactive feedback of the end-users about the proposed damages by the AI-algorithms. Ideally this feedback should be also used for further and deeper AI-training improving the overall AI-performance, forming a continuous learning and teaching process.

Business scenario BS-P3B-1, Vehicle exterior condition inspection and documentation
A commercial or privately owned, vehicle (car, van or truck) arrives at the premises of an organisation (like a car dealership) that hosts a vehicle scanner. Its arrival may have been scheduled or even expected from the minute it entered the main gate of the premises. As soon as the vehicle scanner detects with its sensing system the presence of a vehicle at one of the scanner entries (the scanner can be bi-directionally used): • it activates its embedded industrial processing unit, switches on the LED-illumination and proceeds with the image acquisition of the vehicle by rotating its pillar with its embedded cameras following the passing vehicle according to its own vehicle positioning sensor system • it performs a set of image processing tasks such as image enhancement, colour processing, image-segmentation & compression, thumbnailing or panorama generation • it extracts the identification of the vehicle (either via the licence plate, or the Vehicle Identification Number - so-called VIN-number-, or other unique identifiers like timestamps of the scans, or instantly generated by blockchain methods) in order to index the related scan-information for the afterwards processing & archiving steps. This information may optionally need to be not post-manipulable as it is the use case of the formal determination of legal status vehicle determination for rental cars in- & out-processes, insurance-cases, etc.) • it temporarily saves the acquired dataset (images, point clouds and other meta-data) in multiple first-in-first-out queues within a high-performance, temporary front-storage system for further processing, communication / forwarding and archiving purposes of the business intelligence workflows. The

associated communication to the following ITC-systems can take place via cables, Wi-Fi or mobile networks and requires high-bandwidth, high-speed, low-cost and low latencies to be user-acceptable (depending on the use cases there are maximal number of time delays for the arrival and visualisation of the scan images and data till the end-user of the data) At this point, the generated dataset (or part of it) could also be displayed to the driver via installed monitors after the scanner and/or at the mobile devices of the vehicle exterior inspectors for review and potential further processing. The vehicle exterior inspector can proceed to visually inspect the images (using a desktop or mobile device away from the vehicle) and manually identify defects. In addition, if the vehicle scanner has integrated automatic defect detection capabilities, the vehicle exterior inspector is supported by the AI-system with its defect proposals but can also proceed to visually review the AI-results verifying the detected defects. Usually using its smart device as edge computing the vehicle exterior inspectors could also receive AR support and other visual aids for both reviewing and acquiring activities. For long-term storage and for the support of further business intelligence functionalities, the dataset is transferred to a central storage-retrieval-processing system. This system can be: • integrated with the vehicle scanner • local to the premises hosting and supporting more than one vehicle scanners • a central business server in the location of the scanner or a cloud system within the organization potentially having many locations with similar vehicle scanners. Any of the above systems should be able to optionally support data-driven methods for the automatic detection of defects. In all cases, and contingent on the approval of the vehicle scanner owner, the datasets are also transferred to TwoTronic's back-end cloud server to: • process the images to identify defects and generate training datasets for appropriate AI-algorithm training • generate data-driven algorithms for the automatic defect detection The vehicle exterior inspector should be able to retrieve past data for: • a particular vehicle, e.g., ○ retrieve drop-off scanning documentation at the collection after a service at the garage ○ retrieve collection scanning documentation at drop-off at the car rental company • the entire fleet to be able to make business decisions, e.g., ○ manage and schedule the repair work ○ monitor the occurred fleet vehicles damages within a given period	
User/users:	The first user category includes vehicle exterior inspector, private driver, customer consultant of the repair shop, branch / garage manager. They are usually consumer of the system data. The second user category includes all producers of suitable training material and mathematical algorithms of the AI-technology for automatic inspection, who also consume the created data (images and meta data)
Setting / context	The scanners are installed either in an indoor or an outdoor environment. Accordantly two basic environmental conditions are applied: in indoor installations the environment is much more under control and varies less whilst in the outdoor installations the system must fulfil much more varying conditions like day & light illumination, sunny, cloudy, raining or even snowing conditions. Also varying temperatures in winter and summer impose harder operational specifications. To fulfil documentation requirements and take advantage of the incoming visitors / customers the most car garage demand to have the scanners at the entrance of the whole location implying not only strict minimal space requirements but also appropriate architectural & design expectations.

Interacting system	In both indoor as well as outdoor installations the vehicle scanner must be integrated in an operational environment of the individual business case, where space restrictions as well as application workflow procedures impose interacting demands. For all these cases the embedded real-time computer system of the scanner interacts with a local or cloud storage and processing system, an optionally configured AI-subsystem, onsite-displaying monitors for spot-on information to the drivers, some optionally configured additional inspection-subsystems (like tyres scanner) and with a various desktop and mobile devices, who are used by the end-users to use the generated information.

Users' goals	The vehicle scanner supports different business goals in various use cases. The essential goal however independently on whether it has been installed at the premises of automotive OEM supply chains, in repair garages, at workshops in the aftersales business, at rental vehicle or shared mobility services providers, at fleet management suppliers in the logistics area as well as insurance companies is to document the actual condition of the exterior of the vehicle and preserve this information for several purposes over the subsequent time. Thus, different users
	• inspect the exterior condition of a vehicle (truck, van or car)
	• Manually or automatically detect defects that have to
	  ○ be repaired for aesthetic or safety reasons,
	  ○ be individually charged to the assurance or the user of the rent car
	• Document the exterior condition using visual, geometric and contextual information, throughout its lifetime in order to support fleet management but also private vehicle owners
	• Compare the current vehicle status to a previously documented condition e.g., in the business case of rental cars or mobility services
	• manually annotate reviewed damages to build a high-quality, large training set for the AI-training and machine learnings needs

Initial status	Vehicle scanners are installed and ready to scan vehicles. End-users have connected their desktop or mobile devices to the scanner data provision system.
Interaction	The vehicle exterior inspector receives recent vehicle-condition data from the vehicle scanner or historical data from the storage-retrieval-processing system. The vehicle exterior inspector interacts with mobile devices and optional AR applications to input, retrieve and communicate to the driver information about the vehicle's condition.
Data	High-resolution images, 3D point clouds and corresponding metadata and image annotations.
Motivation	• Scan vehicles and document their condition in order to be able to make intelligent business decisions, e.g., make additional offers to the clients based on the current vehicle status, calculate repair costs and create repair offers to customers and insurances • Reduce the time it takes to perform a vehicle inspection by process digitalisation, i.e. substitute the need for a physical presence - base vehicle inspection by a remote review based on digital images • Reduce the time it takes to perform a vehicle scan. • Improve customer-relationship by introducing an objective way to check vehicle conditions for cost claiming • Use information from multiple vehicle scanners to improve the scanner's automatic defect detection capabilities without compromising confidentiality and privacy.

Time	• Usually, a new car is scanned at every arrival and departure to / from a branch / dealer / garage and the results should be available in about 3-5 minutes to be appropriately displayed to the end-users • A privately-owned vehicle is scanned at drop off and pick up from a garage or after an accident. The same applies to rental vehicles in revised order. • For commercial fleets, vehicle conditions are documented every day by the drivers driving their vehicles themselves through the scanner (as well as weekly or monthly by an internal auditor in order to keep the fleet at an acceptable condition at reasonable costs. • The scanning process is expected to be done "on the fly", within 15-30 seconds. The subsequent documentation process can be completed in a time period, that it can keep pace with the use case. In the car garage case, the images should be ready for presentation to the customer consultants within 5 min after the vehicle scan. • In the case of automated inspection, the required time to provide the results to the user varies between 1 min for the rental car case, 2-5 min for the branch / garage case and 60 min for the logistics fleet management needs. If additional safety-critical are optionally demanded in the latter case, then the results must be available to warn the driver for additional safety-check before the vehicle leaves the parking campus, i.e. in maximal 1-2 minutes
System functionalities	Vehicle real-time scanning, edge computing, optionally configurable AI-based surface inspection of vehicle conditions, vehicle status archiving, communication with customer business intelligence of the use case, user-driven wireless or cable communication with the scanner and the local business intelligent computer system, decision support, data interoperability, ergonomic visualisation on mobile devices, advanced visualisation-support for simultaneous display of vehicle and his conditions, user- & data- management security

The scanner with its patented sensing acquisition system with its rotating pilar is shown in the next picture.

Figure 65. Sensing acquisition system with rotating pillar.

The scanner is uses an embedded PC-based computing environment connected via Giga-Ethernet cables to the various colour high-resolution cameras. A LIDAR-sensing system identifies the actual vehicle position within the scanner space. The scanner temporarily saves the acquired images and either sends them together with additional meta data into a location-based storage system, optionally residing within the location-IT-ecosystem of the organisation (e.g., car garage) or to a cloud-system. Vehicle exterior inspectors are accessing by demand the stored data to access the vehicle's exterior conditions at specific time periods depending on the individual needs of the application.

Figure 66 shows the diagram of relationship between actors in this Business Scenario: Vehicle exterior condition inspection and documentation. The figure is enhanced from the one used in D3.2. The "Vehicle Scanner" actor has now an explicit connection with the "Exterior defects detection support" element, in alignment with the changes recently exposed in the previous table.

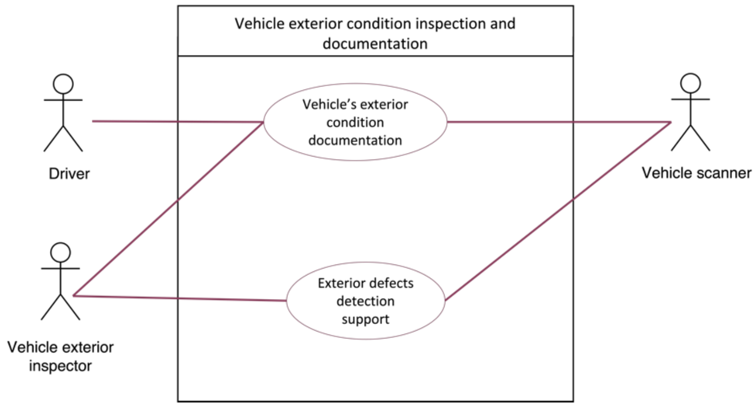


Figure 66. Use case diagram for the "Vehicle exterior condition inspection and documentation" business scenario

5.5.1. UC-P3B-1: Vehicle's exterior condition documentation & visualisation

The functionality of this Use Case is commonly used by various end-users of the underlying application. The scanner supports the digitalisation of the scanned vehicles allowing the increase of the productivity of the organisation's processes. The outcome of the operation is to allow the inspection the vehicle exterior at any time after the scan process and use the information gathered for several goals.

The mechatronics scan architecture consists of the following modules:

- mechatronics:
  - right/left side walls to minimize reflections of the surrounding environment in the vehicles
  - rotating vertical pillars containing the system cameras
  - supporting structures
  - internal and interfacing cabling
  - electrical cabinet with the power supply units
- an adaptive LED-based illumination system
- a motion control and vehicle position determination unit with LIDAR and 3D-sensors
- an industrial PC-system featuring the real-time system control unit with its illumination and motion control units
- a high-performance internal network directly connecting all existing system cameras to the industrial PC-system
- an embedded storage system for intelligent local storage management for vehicle images, associated meta-data and other application parameters.

- a communication system (implemented via local ground cables and / or fibre optics and / or LTE-router-based wireless network provided by mobile network providers. A 5G-communication is not yet implemented)
- an optional AI-supporting inspection system (not all digital scanners feature an automated surface inspection, however depending on the business scenario several customers demand for an automated inspection)
- various optional modules offering individual functionalities according to the user needs, the most important being:
    - underbody-scanning subsystem which typically includes three cameras scanning the vehicle from underneath to inspect for example potential vehicle fluid leakages or mechanical damages. This underbody monitoring system is expected to gain importance over the next years, as most of the new electrical passenger cars have their batteries system underneath the car. Potential damages of the vehicle underbody thus may indicate serious damage impact also for the batteries cell system. There are discussions on EC-level to introduce some relevant inspection rules for those vehicles in the next years as part of increased safety considerations and associated citizen's acceptance for those electrical cars.
    - vehicle tread profiler subsystem which monitors the tire's condition as part of vehicle safety considerations (profile of the tires).

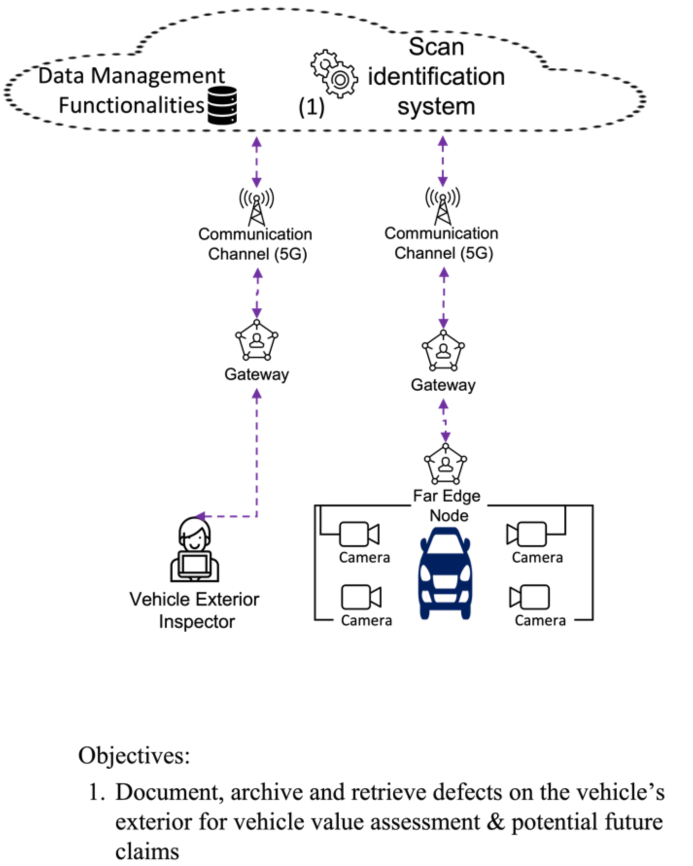


Figure 67: UC-P3B-1 "Vehicle's exterior condition documentation & visualisation" diagram

An example of a user overview of the performed scans (with user filter - selection possibilities) is given in the following picture:

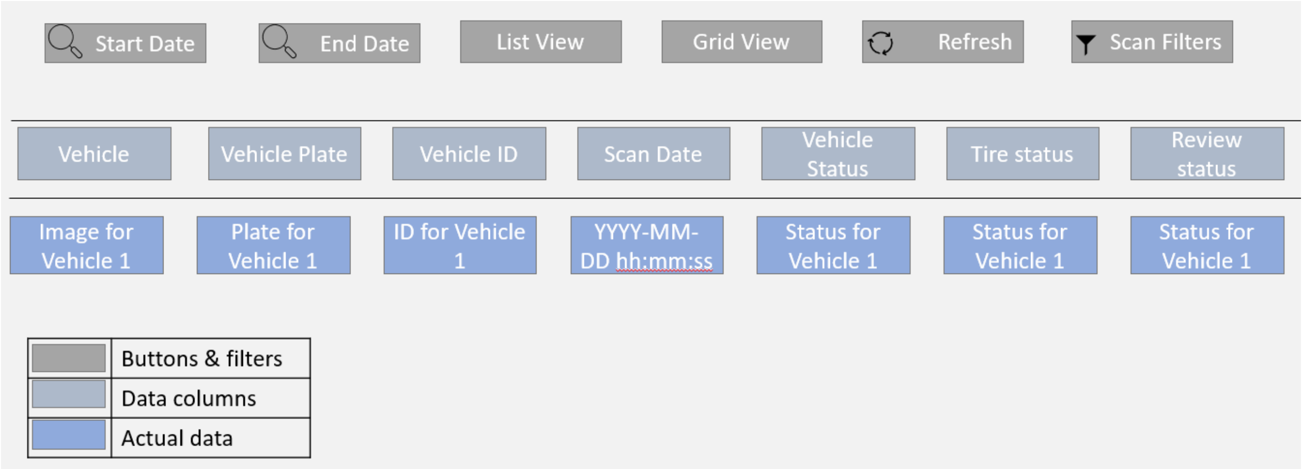


Figure 68. Mock-up for scan UI

After selecting the scan of the vehicle under examination, the user moves to the overview of the images from various perspectives. Two examples for the left side are given in the following pictures:

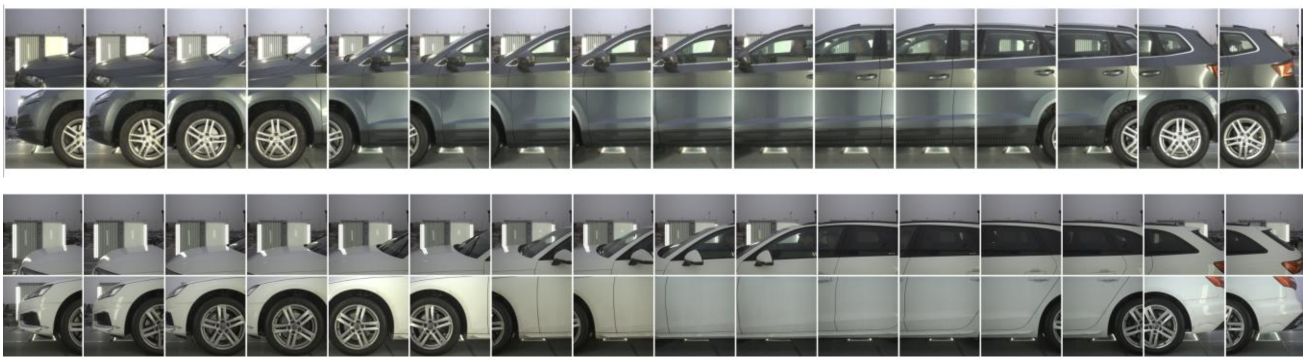


Figure 69. Scan images of the vehicle under examination

The first Use Case description is given in the following table according to the used methodology.

Use Case: UC-P3B-1, Vehicle's exterior condition documentation & visualisation	
Description	Scan a vehicle and document the condition of its exterior via digital images and associated meta data. Provide proper results visualisation to the end-user.
Reference Scenario	BS-P3B-1
Plane(s)	Application and Services
Vertical Capabilities	Interoperability
Functionalities within vertical capabilities	Data security, federated learning
Objectives	Document & archive defects on the vehicle's exterior for vehicle value assessment & potential future claims
Actors (system actor or natural persons)	• Vehicle scanner • Vehicle exterior inspector (various types according to the individual use cases) • Driver

Pre-conditions	The vehicle scanner is installed at the premises and ready to scan vehicles.
Trigger	A vehicle arrives at the gate of the premises hosting a vehicle scanner
Expected results	• The condition of the vehicle's exterior at a specific point in time is documented • All acquired images of the exterior of the vehicle are archived • The documentation images are stored together with all vehicle's meta data (like location, date, license plate, anonymised coding of license plate, etc.) • All person faces haven been anonymised with the help of AI-algorithms to fulfil European rules of personal data protection (option)
Design preferences	Well-balanced, scalable and hybrid architecture for flexible implementations of edge- or cloud-oriented scanner system configurations according to the individual requirements of the various use cases. Ergonomic frontend for images storage, management & visualisation Optional AR support on mobile devices Automatic defect detection capabilities as strongly wished extension for better user-acceptance: • seamlessly integrated within the vehicle scanner architecture • local to the premises hosting or centralized implementation supporting more than one vehicle scanners within the same customer organisation over several sites. Federated learning for defect detection avoiding heavy images communication with high bandwidth demands and DLT support to secure the recording of the vehicle status.
Extends the use case	N/A
Includes the use case	UC-P3B-2
Notes and issues	N/A
Main execution flow	1. A vehicle arrives at the gate of the premises hosting a vehicle scanner. The scanner recognizes the presence of the vehicle, reads his license plates, and can optionally get information from the branch business intelligence about the vehicle type and whether there is a planned visit into the location of the scanner or not. 2. The driver drives the vehicle through the vehicle scanner and the vehicle is scanned. 3. ASSIST-IoT receives the images and other data from the vehicle scanner and pre-processes it locally. 4. ASSIST-IoT optionally displays the information that documents the vehicle's condition to the driver via an external monitor after the scanner. 5. ASSIST-IoT generates a report that documents the vehicle's condition and transmits it to the vehicle exterior inspector and / or to the organisation's local or cloud storage facilities potentially via an interface to their business-intelligence software.

	6. The vehicle-exterior inspector receives all the relevant information and does the necessary analysis for his individual application needs. A physical visit of him together with the driver to scanned vehicle is not anymore needed due to this digitalisation process. 7. The current exterior condition of the vehicle is being stored in the permanent storage for potential future usages like condition requests in the future to compare the vehicle conditions in different moments.
Alternative execution	6a. Due to ambiguous appearance of the vehicle condition on the scanned images a physical inspection of the real vehicle is needed. On the displayed images no clear decision about the condition can be made remotely. The vehicle exterior inspector and the driver need to go and review the vehicle's condition. 6b. The physical inspection of the vehicle may result into several findings. Furthermore, additional pictures of the vehicle may be needed to be made, so that a better documentation can be achieved. ASSIST-IoT supports the interaction of the vehicle inspector via the User-Interface of the hand-held device to feed the existing data sets with this additional, manually Acquired information (human-in-the-loop).
Exceptions	N/A
Requirements involved	R-P3B-01, R-P3B-02, R-P3B-03, R-P3B-04, R-P3B-05, R-P3B-06, R-P3B-07, R-P3B-08, R-P3B-09, R-P3B-10
KPI	• Completeness of the vehicle-scanning report • User-friendliness of the interactive on-screen defect-identification process • Unambiguous identification of the documented vehicle • Over 40% increase on detected defects on the outer body of vehicles that would otherwise be unnoticed. • Over 30% faster vehicle inspection compared to current manual practices. • Over 10% new revenue through additional repair services (called "upselling").
Identified by	TWOTRONIC

5.5.2. UC-P3B-2: Exterior defects detection support

This Use Case describes the additionally configurable functionality of automated surface inspection to detect the vehicle's exterior defects. It is using the scanned vehicle images, associated meta data for vehicle and scanner identification and is based on advanced AI-technologies. The training of the corresponding AI-algorithms uses manually annotated images providing the necessary ground truth. The execution of these algorithms may run as edge computing on the scanner embedded computer system or in a cloud-based server having been provided with the scan data. End users are supported by advanced visualisation techniques to record, review, and verify damage proposals.

Examples of inspected vehicles (van & passenger car) with discrete visualisation of AI-found proposals and manually annotated ground truth areas is given in the following figures.

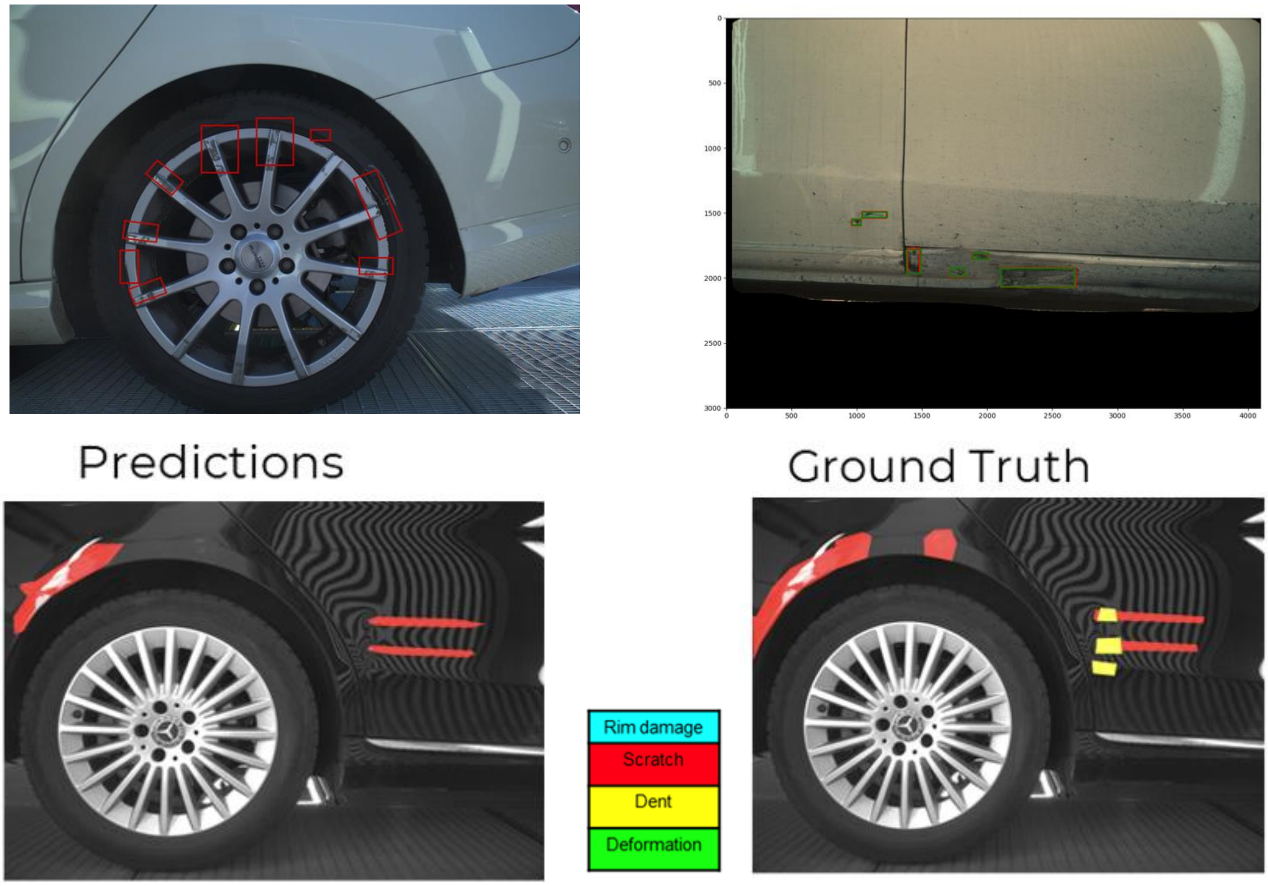


Figure 70. Supporting inspection with AI-based methodologies

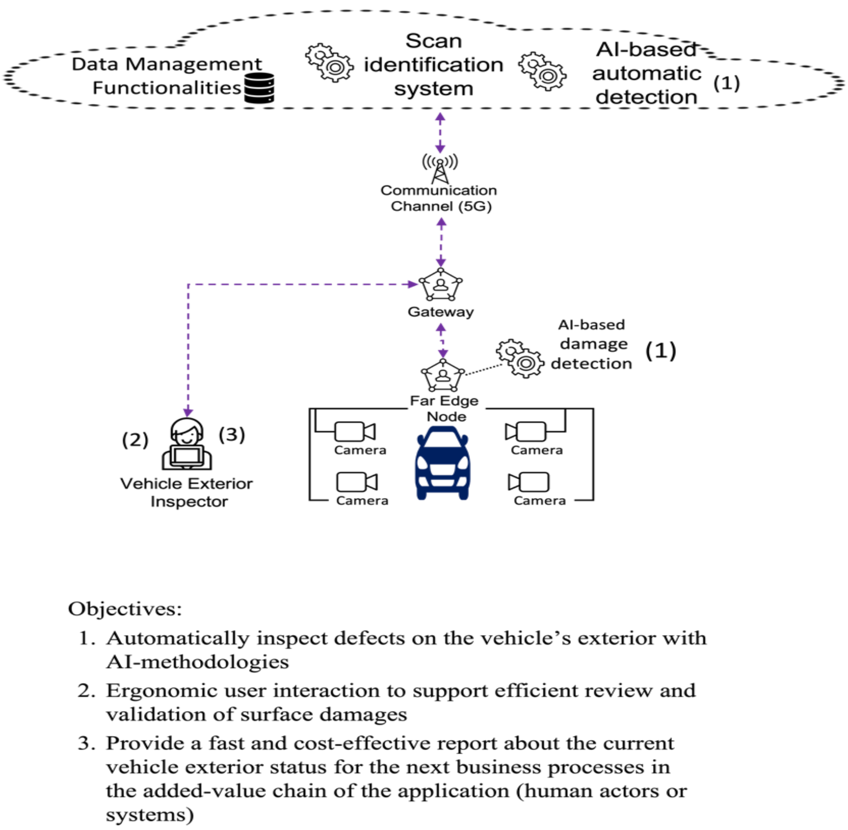


Figure 71. UC-P3B-2 "Exterior defects detection support" diagram

Use Case: UC-P3B-2, External defects detection support	
Description	Verify the information that was recorded by the vehicle scanner and identify any defects with AI-based support from ASSIST-IoT while visually inspecting the vehicle.
Reference Scenario	BS-P3B-1
Plane(s)	Application and Services
Vertical Capabilities	Interoperability
Functionalities within vertical capabilities	Federated learning, data security and safety
Objectives	• Automatically inspect defects on the vehicle's exterior with AI-methodologies • Ergonomic user interaction to support efficient review and validation of surface damages • Provide a fast and cost-effective report about the current vehicle exterior status for the next business processes in the added-value chain of the application (human actors or systems)
Actors (system actor or natural persons)	• Vehicle exterior inspector • Vehicle scanner (with a. his AI-based inspection machine running on his embedded, industrial PC or his intelligent storage system and b. his communication system)
Pre-conditions	The acquired images are provided for inspection An AI-engine is installed either on the scanner-computer or the cloud server AI-training has been executed over time to enable the provision / setting of a suitable AI-engine
Trigger	The vehicle passes through the scanner The AI-engine is fed by a series of scanned vehicle images The vehicle exterior inspector manually initiates the action (to get proposals for vehicle exterior damages from an automatic, AI-based inspection engine
Expected results	For each image, metadata with the detected defect details as overlay of the associated vehicle images, stored either in a separate text file or as an entry in a relevant database
Design preferences	N/A
Extends the use case	N/A
Includes the use case	UC-P3B-1
Notes and issues	N/A
Main execution flow	1. The vehicle arrives at the entrance of the scanner 2. The vehicle is driven through the scanner 3. The scanner is acquiring the images of the vehicle 4. The acquired images are made available to the AI-engine either installed on the scanner - industrial PC or on the associated local storage system or on a

	cloud-server, where they are arriving via fast networks (cable-based or 4G or 5G). 5. The AI-engine automatically inspects all provided scan images and records the images with found defect-proposals in permanent storage for immediate or later usage. A database is supporting the data, images, and storage management of the scans. 6. The inspection system sends both pictures and proposals to the vehicle inspectors. 7. The receiving user utilizes either a PC or a mobile smart device (like smartphone or tablet) to ergonomically review the results of the ASSIST-IoT system with advanced visualisation techniques. He uses them according to his actual need.
Alternative execution	8. Depending on the individual role, scanner operation mode in the specific scan time and user rights the vehicle exterior inspector may want or need to review the AI-proposals and either verify them or modify them on his device. This happens via an ergonomic interaction with the user interface system supported by its advanced visualisation techniques. 9. The results of the reviewing process are stored into the permanent storage system including the support of the underlying database system. 10. Depending on the results of the reviewing procedure the vehicle exterior inspector may need to physically go to the vehicle under evaluation and compare the existing computer-results with the real physical conditions. During this action he may need to also manually take some additional images supported by smart visualisation. The results are saved into the application storage system for further use.
Exceptions	N/A
Requirements involved	R-P3B-01, R-P3B-02, R-P3B-03, R-P3B-05, R-P3B-06, R-P3B-07, R-P3B-08, R-P3B-09, R-P3B-10, R-P3B-11, R-P3B-12, R-P3B-13, R-P3B-14
KPI	User-friendly interface speeding up the reviewing process. AI-based inspection performance (40% minimal defect recognition). Time and overall costs of inspection and reporting execution (30% faster processes). Information retrieval speed and completeness (5 min between scan and information retrieval for the end user).
Identified by	TWOTRONIC

5.6. Pilot 3B specific requirements

Requirement: R-P3B-01, Defect classification categories definition	
Category	Functional
Priority	Must
Use case IDs	UC-P3B-1, UC-P3B-2
Rationale	Define the vehicle surface damage categories and their performance indexes that create real added value for the end-user with affordable costs and with stable integration possibilities into the everyday application operations.
Description	Starting from a basic, application-oriented definition of damage categories, an iterative refinement of the definition of the most important damage categories together with user-relevant performance indicators will be defined. Herewith, the balance between real user needs (with respect to the costs-, performance-, and reaction time-parameters) and the technically possible delivery according to the current scientific state of the art has to be found. As starting point ASSIST-IoT will support f the below categories with the corresponding initial acceptance criteria: 1. rim-related damage 2. dent or bump (with a maximum radius of 10 cm) 3. deformation (any deformation with a diameter greater than 10 cm) 4. corrosion (rust or paint damage due to corrosion) 5. scratch (a small depression in an otherwise flat surface) 6. crack (a separation gap that is created by the tearing of a material object and may also create an opening at the outer skin) 7. dirt 8. specular reflections 9. miscellaneous defects (other vehicle defects than the above ones, e.g., missing mirror or antenna, etc.) As soon as the scan new eco-system will start to produce results in the pilot project an intensive evaluation together with the end user as well as with the developers will take place. The results of this evaluation will be used in an iterative, agile process to drive the development to the best possible results.
Acceptance criteria	**Typical requirements as recognition rates for various damage categories:** • Scratch: 70%-80%, • Rim-related (wheels-level): 75%-90%, • Dent/bump: 60%-80%, • Deformation: 60%-80%, > 2 cm, • Corrosion: 50% - 80%, > 1cm, • Crack: 60% - 80%, > 1cm, • Paint damages: 70% - 80%, > 1 cm, • Miscellaneous (general anomalies): 60% - 80%, > 1cm
Customer satisfaction	5

Customer dissatisfaction	4
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement: R-P3B-02, Automatic Vehicle ID Recognition	
Category	Functional
Priority	Must
Use case IDs	UC-P3B-1, UC-P3B-2
Rationale	The license plates of the vehicles are essential as vehicle identifiers. They must be reliably recognized to form the base for all storage and retrieval operations of the system. On the other hand, they must be also anonymized from the acquired scanner pictures, so that they are not human-recognizable stored together with their images in the long storage documentation.
Description	During the vehicle scan process a suitable vehicle acquisition position is determined by the sensing system of the scanner so, that the system gets suitable images from the license plates of the vehicles. This happens for both, front and back part of the vehicle. A dedicated image processing system detects the content of the license plates to be typically used as vehicle identifiers. Additionally, all appearances of the license plates in the various images are searched, as the scanner must obey to the European personal data protection rules. Thus, the license plates of the vehicles must be anonymized for the permanent storage of the scanned images. For their index-usage they are coded already within the ASSIST-IoT system before they are sent to the remaining data management systems of the business intelligence software. AI-methods are here applied for the license plate detection.
Acceptance criteria	• License plate recognition: 98% • License plate anonymisation (license plate detection and pixelation): 99%
Customer satisfaction	5
Customer dissatisfaction	5
TWOTRONIC	Partner's expertise

Requirement: R-P3B-3, Data sharing with 3rd parties	
Category	Functional
Priority	Must
Use case IDs	UC-P3B-1, UC-P3B-2

Rationale	Third parties' application software should be able to retrieve the won data such as images, damage reports and proposals or other scan meta data. This will facilitate interoperability with several type of users in the various use cases.
Description	Various information levels and kinds of data shall be transmitted. Depending on the situation, sometimes just a few scanned images, or the whole image series, or the complete data set are required to be exchanged with the next level of information systems (like the organization's business intelligence, or the pure archiving server, or advanced storage and retrieval system with legal properties, or just a vehicle inspector as a digital note for his further work). These interfacing systems may be local in the same place as the scanner or in the customer cloud. Hereby different levels of added-value information create business opportunities. Also, manipulation-free archiving and secured actor management impose interfacing challenges to the ASSIST-IoT- backed business information. Thus, an "export" functionality to the outside world of the scanner ecosystem is essential. This requirement is closely related with the requirement R-P3B-5 "Business Frontend".
Acceptance criteria	Existence of API / Export - software interfaces from the local or central storage system
Customer satisfaction	4
Customer dissatisfaction	4
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement: R-P3B-4, Critical image transmission time	
Category	Non-Functional
Priority	must
Use case IDs	UC-P3B-1
Rationale	The acquisition system shall provide the acquired images to the vehicle exterior inspectors within an appropriate time, which fits with the workflow of their application processes. This time is typically within 1-5 minutes after the scan depending on the individual application. The just-in-time provision of the vehicle pictures strongly supports the digitalisation wishes of the market and provide productivity improvement.
Description	ASSIST-IoT delivers to the user the acquired images in time within the application workflow expectations. This is the case, independently whether the images are sent directly from the scanner to the vehicle inspector or via the cloud, potentially with the help of a specific business intelligence, which potentially organizes the whole process landscape with information and data.
Acceptance criteria	The ASSIST-IoT system delivers the necessary information as an added-value within the expected application time. This is 1 to max 3 min later after the scan, depending on the individual installation and application.
Customer satisfaction	5

Customer dissatisfaction	5
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement: R-P3B-5, Business frontend	
Category	Functional
Priority	Must
Use case IDs	UC-P3B-1, UC-P3B-2
Rationale	The representative of an aftersales garage or a vehicle inspector requires interaction possibilities to retrieve the generated information after the vehicle scans, like images, damage reports from the vehicle scan, so that he can verify and discuss the results with the driver as the end user and vehicle owner. A fleet manager requires a systematic reporting for the exterior conditions of the entire fleet in periodic intervals. Furthermore, the manual acquisition of additional, after the scan, user-taken images is expected, where additional information of the vehicle exterior (or even interior) is required to be merged with the remaining scanned images. Also, the reviewing, marking and commenting of the potentially existing damages on the pictures supports the user integration into this automation process and makes the whole application more flexible and user-friendly. The human-centric management of these millions of scanner images in an efficient and ergonomic way is essential for this digitalisation process.
Description	ASSIST-IoT shall support the following functionality, preferably with a browser-supported capability running on multiple types of devices: • guided presentation of the entire image set of a scan for a fast review of the vehicle condition • image management graphical user interface with access to multiple scans • determine and indicate the differences between the current and previous scans of the same vehicle A business frontend to review and handle the scanner data autonomously from the potential existence of other customer-centred software systems is mandatory. However, several times the user-organisation needs the information within its own business intelligence, so that it is more important to allow the scanner-ecosystem via ASSSIT-IoT technologies to flexibly share the won data in several logic levels with the customer's business intelligence world.
Acceptance criteria	Provide access to all available information in a user-friendly way. Web-based access is mandatory for user-acceptance, so that the user can access the information just with a browser running on several devices. The user must retrieve the requested information for his everyday process within a few minutes after the vehicle scan or within an acceptable transaction time for older scans / pictures, around 1-2 min. The user ergonomics as acceptance criteria can be checked by interviewing several users in their respectively roles. Important acceptance criteria is the user ability to see the individual damages on his screen with the provided images. In other words, this is the minimal expected quality from the user point of view.

Customer satisfaction	5
Customer dissatisfaction	4
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement: R-P3B-6, User-ergonomic vehicle visualization from multiple images	
Category	Functional
Priority	Must
Use case IDs	UC-P3B-1, UC-P3B-2
Rationale	Create a unified and coherent view of the vehicle out of the multiple frames of the car to allow the vehicle inspector to do his review job of a vehicle in very short time and with sufficient accuracy supported with corresponding resolution.
Description	The scanner captures with multiple cameras & frames the exterior surface of the vehicle from changing camera positions during the vehicle pass. There is a need to fuse all these image frames into a unified view of the vehicle. Both, the overview from different perspectives as well as the zooming capabilities to review details on these images are essential for this digitalisation process. Overlapping vehicle segments on many pictures and the mapping from 2-D image coordinates into various vehicle pars (and most particular into 3D-vehicle coordinates) imposes a particular challenge to visualize and register.
Acceptance criteria	Review time of the whole scanned images (50-200 images / scan) in about 1-4 minutes, more than 90% of the existing damages detected
Customer satisfaction	4
Customer dissatisfaction	4
TWOTRONIC	Partner's expertise

Requirement: R-P3B-7, Information Pre-fetching	
Category	Functional
Priority	Should
Use case IDs	UC-P3B-1, UC-P3B-2
Rationale	A good balance between historical information kept locally or being intelligently pre-fetched from the server of the business intelligence and a very strong back-up cloud computing (or locally intelligent storage system) is important to reduce image retrieval and reviewing time as well as defect detection & reporting.
Description	For all ready scanned vehicles, the information kept after the last scan about the vehicle's exterior condition can be used to support a better (faster and more accurate) review or

	inspection. Using the existent vehicle-ID, historical information is retrieved and used. Previous damages can be visualised to the user for comparison with the new surface condition as well as to determine the differences between the current and previous vehicle's conditions. This is of particular interest for the application of the logistics fleet management and of rent-a-car applications, where the same vehicle is usually scanned multiple times over time.
Acceptance criteria	All relevant information is available within 1 min to the vehicle scanner for each performed scan and appropriate visualisation techniques allow for an ergonomic and fast comparison.
Customer satisfaction	4
Customer dissatisfaction	3
TWOTRONIC	Partner’s expertise

Requirement: R-P3B-8, Enhanced Data Privacy	
Category	Functional
Priority	Must
Use case IDs	UC-P3B-1, UC-P3B-2
Rationale	The vehicles must be driven by a human to pass by the scanner. The drivers' face is visible in the scanners' photos, but as personal data they have to be anonymised with dedicated pixel operations (also called "mosaicing").
Description	ASSIST-IoT must support the data privacy of the users. In this case, a face blurring/removal procedure is demanded to facilitate the business cases.
Acceptance criteria	- Driver face blurring/removal / anonymisation: 98% as currently technical feasible
Customer satisfaction	5
Customer dissatisfaction	4
TWOTRONIC	Partner’s expertise

Requirement: R-P3B-9, Augmented Reality support	
Category	Functional
Priority	Should
Use case IDs	UC-P3B-1, UC-P3B-2
Rationale	Visualisation of digitalized vehicles and their surface damages for the vehicle exterior inspector as productivity enhancement and human-centered improvement of the inspection activities. User interaction with the system to support a faster, error-minimised,

	and higher-quality documentation & end-user reporting for the vehicle exterior conditions.
Description	ASSIST-IoT shall interact with the inspector by overlaying the defects on digitalized vehicle on a mobile device and / or a desktop PC on the acquired images.
Acceptance criteria	ASSIST-IoT - system interact with the vehicle inspector reviewing the vehicle and annotating damages found in less than 15 sec per damage or less than 1-2 minutes for the whole vehicle.
Customer satisfaction	4
Customer dissatisfaction	2
TWOTRONIC	Partner's expertise

Requirement: R-P3B-10, Interactive Image Annotation Support	
Category	Functional
Priority	Must
Use case IDs	UC-P3B-1, UC-P3B-2
Rationale	An inspector or a member of the annotation team manually identifies new damages or confirms already detected defects using mobile devices or secured remote channels, which implement remote access on scanner images (like VPN-channels). This functionality is not only needed for documentation purposes but also to produce training material for the AI-algorithms (ground truth and validation data). The confirmation results should be made backwards available into the training data for further processing of the AI-algorithms development (e.g., for re-enforced learning). The annotation takes place for both manual inspection / documentation as well as for automated inspection.
Description	ASSIST-IoT shall support the interactive graphical annotation as well as reviewing and validation of defects on images
Acceptance criteria	Support for annotating static images or complete scans. Annotation time for an image is statistically 5 - 15 sec per existing damage on the image.
Customer satisfaction	5
Customer dissatisfaction	4
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement: R-P3B-11, Vehicle, and background segmentation	
Category	Functional
Priority	Must

Use case IDs	UC-P3B-2
Rationale	Isolate the object of interest (vehicle) from his background for further inspection processing within the new object boundaries. Support a better AI-inspection, as the AI-machine concentrates itself on the real vehicle surfaces and is not irritated by surrounding background of the vehicle.
Description	ASSIST-IoT shall segment the vehicle from the background in an image. This will be used as the basis for the next processing step of the AI-models.
Acceptance criteria	The entire vehicle is included in the foreground with sufficient accuracy. It supports the following AI-inspection towards higher performance and execution time.
Customer satisfaction	4, if the following AI works satisfactorily
Customer dissatisfaction	3, if the following AI works satisfactorily
Identified by	**Source**
TWOTRONIC	Partner’s expertise

Requirement: R-P3B-12, Vehicle part segmentation	
Category	Functional
Priority	Should
Use case IDs	UC-P3B-2
Rationale	Isolate the object of interest for further processing. Support a better AI-inspection, as the AI-machine concentrates itself on the vehicle surfaces and cannot distinguish the vehicle parts. Create additional information for better damage evaluation as it is depending on the part, which has the damage.
Description	ASSIST-IoT shall segment and identify the individual vehicle parts. This would be the base to associate damages to individual parts supporting a post-processing of repair-costs estimations & proposals
Acceptance criteria	Major vehicle parts can be defined as an orientation to map the various surface damages in car segments, like motor hood, driver door, wheel, trims etc.
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
TWOTRONIC	Partner’s expertise

Requirement: R-P3B-13, Automatic Defect Detection	
Category	Functional

Priority	Must
Use case IDs	UC-P3B-2
Rationale	Facilitate the detection of defects on a vehicle
Description	ASSIST-IoT shall be able to automatically detect defects on images acquired by the vehicle scanner. Point of cloud support could be delivered in case of cost-effective 3D-cloud of points market existence.
Acceptance criteria	Desired recognition rates and accuracy according to specifications of the various defect categories (see R-P3B-1 quantification of the acceptance criteria).
Customer satisfaction	5
Customer dissatisfaction	3
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement: R-P3B-14, Critical damage report time	
Category	Functional
Priority	Must
Use case IDs	UC-P3B-2
Rationale	The automated inspection system provides additionally to the acquired images potential damage proposals to the vehicle inspectors within an appropriate time fitting in their application processes. Depending on the use case there are different optimal time frames for that. As example for the passenger car garage or for vehicle inspector at rent-a-car organisations the proposals must be shown after 3-5 minutes or 1-2 minutes respectively.
Description	ASSIST-IoT provided the proposals found on the scanned images by the automated, AI-based inspection as overlays on the corresponding images within an appropriate time. This must occur independently on whether the AI-engines run locally on the edge or in the cloud by a central inspection and reporting server. Various advanced overlay visualisation techniques can be applied for fast review by the vehicle inspectors.
Acceptance criteria	The ASSIST-IoT system delivers the damage proposals report to the vehicle inspector within the expected application time. This is usually 2-5 minutes after the vehicle scan
Customer satisfaction	5
Customer dissatisfaction	4
Identified by	**Source**
TWOTRONIC	Partner's expertise

6. Requirements

For any product, design, or project it is necessary to begin by establishing what should be achieved, i.e., to set the scope of the project. To that aim, a thorough analysis of what stakeholders may need has been performed, specifically to understand business scenarios and use cases that will be addressed in the project (described in previous chapters). Moreover, features and functionalities of corresponding product(s) have been identified and formalised as requirements.

Requirements are used to establish agreement between customers and suppliers on what the project product(s) is(are) intended to do in order to develop a successful business model. A complete and correct requirement process reduces the effort wasted on redesign, recoding and retesting. It also provides an efficient mechanism for the product validation and verification.

In order to define detailed requirements, the product has to be decomposed into smaller chunks. This helps to break down the problem into its component parts and facilitates the development of the solution. ASSIST-IoT requirements analysis was performed for all pilots separately, but partial results were periodically synchronised to keep consistency as well as to identify common requirements for the whole project, regardless of the pilot under consideration. The requirements listed in the following subsections are result of intensive communication with stakeholders

6.1. Common non-functional requirements

For the common requirements as part of this section the "customer satisfaction" and "customer dissatisfaction" have been added to comply with the Volere method.

Requirement: R-C-1, Data sovereignty	
Category	Non-Functional
Priority	Must
Rationale	Different data sets are obtained from the pilots
Description	ASSIST-IoT shall guarantee that in order to take better operational decisions, data quality must be ensured
Acceptance criteria	Data integration of at least 3 different sources of information must be interoperable.
Customer satisfaction	3
Customer dissatisfaction	3
Identified by	**Source**
TL	Partner's expertise

Requirement: R-C-2, Data governance	
Category	Non-Functional
Priority	Must
Rationale	Different data sets are obtained from the pilots

Description	ASSIST-IoT shall guarantee that in order to take better operational decisions, data governance must be ensured
Acceptance criteria	Data of at least 3 different sources of information has to be managed.
Customer satisfaction	3
Customer dissatisfaction	3
Identified by	**Source**
TL	Partner's expertise

Requirement: R-C-3, Compliance with legal requirements on data protection	
Category	Non-Functional
Priority	Must
Rationale	Protection of personal data in compliance to the GDPR and any other identified legal requirement that is relevant to project scope.
Description	In any task involving process personal data the following will be required: • copies of ethical approvals for the collection of personal data by the competent National Data Protection Authority, • details on the procedures to be implemented for data collection, storage, protection, retention and destruction and confirmation that the project will comply with the relevant national and EU legislation, • details on the informed consent procedures to be implemented, • confirmation that the existing data is publicly available, or otherwise relevant authorisation.
Acceptance criteria	Tracked user should be aware of the data that is tracked, how it is being used, for what objectives, and has agreed to it e.g. GPS location data are kept in the far edge node and only regional position will be propagated to the remote system.
Customer satisfaction	3
Customer dissatisfaction	3
Identified by	**Source**
TL, FORD-WERKE	Partner's expertise

Requirement: R-C-5, Local Processing Capabilities	
Category	Non-Functional
Priority	Must

Rationale	Transmission of sensitive information shall be kept to a minimum.
Description	ASSIST-IoT shall be able to process sensitive information at the edge and decide which information needs to be transmitted to a central location for storage or further processing.
Acceptance criteria	ASSIST-IoT software is designed to support edge processing operations and provides useful features at the edge.
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
MOW	Partner's expertise

Requirement: R-C-6, Data Persistence and Trust	
Category	Non-functional
Priority	Must
Rationale	The specific kind of data (specific for every pilot) should be retained so that one can demonstrate the integrity and non-repudiation for third party
Description	ASSIST-IoT shall retain information about: 1. List of all manipulation operations with container 2. All the information referring to worker health and safety 3. The vehicle's emissions profile throughput its lifetime so that it can demonstrate its in-service conformity to a third party. The information of the calibration used for every vehicle and the modifications performed on it will be also kept, as well information of parts being replaced (including sensors) 4. The current rented vehicle conditions at the moment of taking the car should be securely saved (nobody could manipulate any data and pictures) till the time he brings the car back. The difference of the rented vehicle conditions is the basis of his potential duties to the car rental company and the potentially existing or closed insurance contracts
Acceptance criteria	ASSIST-IoT will handle local data persistence according to system resources. ASSIST-IoT will increase local data persistence when the system is set to Active Monitoring state.
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement: R-C-7, Edge-oriented deployment

Category	Non-Functional
Priority	Must
Rationale	The deployment of Next Generation IoT systems should not be extremely expensive, and should be scalable
Description	The ASSIST-IoT architecture should support a scalable solution, which would reduce the cost of initial deployments as much as possible
Acceptance criteria	Large-scale deployments with hundreds of gateways with a wide variety of different execution environments should be supported. 10% reduction in time for provisioning new elements in the deployment.
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
TL	Partner's expertise

Requirement: R-C-8, Edge node modularity	
Category	Non-Functional
Priority	Must
Rationale	A modular design of the Edge Node (or gateway) has many advantages, such as reduction of cost, as the baseline hardware is lower, and flexibility, as complementary hardware can be added later on when needed for supporting specific use cases.
Description	The ASSIST-IoT Edge Node must support use cases from different verticals, and therefore it should be prepared to incorporate dedicated hardware ad-hoc. Hardware demanded by all pilots (e.g., WiFi module, Ethernet interfaces, SD card slots) will be added in the main board, whereas a set of Board-to-board (B2B) modules will be incorporated to extend the baseline capabilities.
Acceptance criteria	The Edge Node will be used in the pilots, effectively extending its basic features for those cases that require it (e.g., adding a GPU, extra RAM or a CAN module).
Customer satisfaction	5
Customer dissatisfaction	2
Identified by	**Source**
Partners	Assisted by the comments of EC reviewers in technical review (M8) and the Advisory Board, based on their knowledge and feedback about ASSIST-IoT

Requirement: R-C-9, Workload placement	
Category	Non-Functional

Priority	Must
Rationale	Personnel in charge of deploying the software artifacts in the clusters might not have the necessary knowledge to select their optimal place, especially when there are several nodes and clusters involved.
Description	The Smart Orchestrator of the ASSIST-IoT architecture will include intelligent mechanisms to place the (software) workloads in the managed equipment. This element will include a set of policies that a user can specify when deploying a workload (manual placement will be also allowed). Some of these policies will be: • Placing workloads in edge nodes (i.e., differentiate edge from cloud resources), • Placing workloads in nodes with larger more free resources, • Placing workloads in nodes with smaller number of free resources.
Acceptance criteria	At least three policies will be included and validated for automatically selecting the optimal cluster/s to deploy workloads. At least one of them will be supported by AI to make the decision.
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
UPV	Partner’s expertise

Requirement: R-C-10, Transmission security	
Category	Non-Functional
Priority	Must
Rationale	Business scenarios likely involve critical and/or personal data that must be protected so they cannot be accessed by unauthorised or malignant users.
Description	The ASSIST-IoT architecture must support the introduction of tunnelling technologies for encrypting the transmission of information within the network. To that end, VPN technology will be implemented for allowing the connection of external devices (i.e., (not belonging to a site’s network infrastructure) to ASSIST-IoT, and SD-WAN technology will be leveraged for connecting clusters from different sites.
Acceptance criteria	(A set of) external devices will be effectively incorporated to the network site via VPN, and at least two clusters managed by the project will be connected via SD-WAN. Network sniffers will be used to ensure that involved traffic is encrypted.
Customer satisfaction	4
Customer dissatisfaction	5
Identified by	**Source**
UPV	Partner’s expertise

Requirement: R-C-11, Network optimisation	
Category	Non-Functional
Priority	Must
Rationale	Usually, network-related requirements tackle bandwidth, latency, and security features. Other aspect that could be taken into consideration is the traffic or application type, to be prioritised.
Description	The architecture must support dedicated mechanisms to prioritise specific traffic in the network, so bandwidth is optimised and latency reduced (for these applications).
Acceptance criteria	Different mechanisms will be targeted, and the verified application of (at least) one of them will mark this requirement as fulfilled: • Policy-based SDN, • SD-WAN traffic shaping, • Dedicated (multi-)cluster rules, based on CNI.
Customer satisfaction	4
Customer dissatisfaction	1
Identified by	**Source**
UPV	Partner’s expertise

Requirement: R-C-12, Streaming Latency	
Category	Non-Functional
Priority	Must
Rationale	The streaming latency reflects as a critical factor when high volume of small messages are transmitted in the Next Generation IoT systems. This property enables or prohibits real-time processing and has high impact on responsivity of systems.
Description	The ASSIST-IoT architecture should provide an efficient solution, to stream high volume of messages with low latency and high throughput, enabling high quality data transmission.
Acceptance criteria	Steaming annotation and translation latency between reception of a message at input topic, and processed message arriving at the output topic should be below <10ms
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
SRIPAS	Partner’s expertise

Requirement: R-C-13, Streaming Client Numbers	
Category	Non-Functional
Priority	Must
Rationale	Next Generation IoT systems are highly distributed and must often support a high number of users at the same time.
Description	ASSIST-IoT should provide a scalable message stream, that are able to handle many individual clients at the same time, and process messages in parallel, where (provided hardware resource availability) high parallelism does not significantly impact processing latency
Acceptance criteria	Streaming semantic annotation and translation should both support at least 10 parallel translation or annotation channels (channels may have many clients receiving and sending messages).
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
SRIPAS	Partner’s expertise

Requirement: R-C-14, File Size Support	
Category	Non-Functional
Priority	Should
Rationale	Growth in usage of data in IoT resulted not only in higher volume of network traffic, but also in an increase in the range of file sizes that are considered in IoT. Although IoT messages are very often small, some use cases (e.g. storing and exchanging BIM models) require support for large files.
Description	The ASSIST-IoT is intended to manipulate and store large files that define data models or that facilitate data transformations, such as ontologies, schema files, and semantic alignment files.
Acceptance criteria	The ASSIST-IoT semantic repository should support large file sizes, coming from real-world applications or pilots
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
SRIPAS	Partner’s expertise

Requirement: R-C-15, External access to resources	
Category	Non-Functional
Priority	Must
Rationale	The developments and advancements coming from ASSIST-IoT shall assist open-callers to build new projects under NGIoT architectures.
Description	The ASSIST-IoT architecture must have an API manager that will act as a gateway/entry point for all the internal services that can be accessed by 3rd party authorised actors. Software artifacts should have their APIs published in the manager so they can be later on consumed by authorised users.
Acceptance criteria	An external user can consume the API of an internal software resource (if authenticated in the platform and authorised to access to it).
Customer satisfaction	5
Customer dissatisfaction	4
Identified by	**Source**
UPV	Partner's expertise

Requirement: R-C-16, Resource monitoring	
Category	Non-Functional
Priority	Must
Rationale	A NGIoT environment would most likely consist of (almost every time) of several hardware computing nodes, each of them with different workloads deployed. Having a dedicated monitoring stack supported by graphical tools is essential so administrators have an overall picture of the situation, and hence for detecting misuse and/or lack of resources.
Description	The ASSIST-IoT architecture must provide dedicated mechanisms for gathering resource data from the infrastructure (clusters, mainly RAM and CPU) and from the software artifacts deployed in top of it, Once collected, data will be stored in a dedicated space of the data persistence mechanism, and users will have the option to access it either via commands or dedicated, intuitive graphical dashboards.
Acceptance criteria	A user will be able to access to the collected data via dedicated Graphical User Interfaces.
Customer satisfaction	4
Customer dissatisfaction	4
Identified by	**Source**
PRODEVELOP	Partner's expertise

Requirement: R-C-17, Time-series data visualisation	
Category	Non-Functional
Priority	Must
Rationale	A NGIoT deployment will collect huge amount of data from the unevenly distributed and heterogeneous sources. Among all types of data, time series data (e.g., data from sensors) is becoming the most widespread. Unfortunately, not only collecting, storing, but also analysing massive amounts of this data demands of intuitive visualization tools for providing sufficient analytics needs.
Description	The ASSIST-IoT architecture must provision dedicated mechanisms that allow for rapidly creating dashboards that pull together charts, maps, histograms, and filters to display the full picture of stakeholder's data. It should also be flexible enough to allow building customized dashboard that enable deeper analysis.
Acceptance criteria	A user will be able to access to the collected time-series data via dedicated Graphical User Interfaces.
Customer satisfaction	4
Customer dissatisfaction	4
Identified by	**Source**
PRODEVELOP	Partner's expertise

Requirement: R-C-18, Support for autonomous processing	
Category	Non-Functional
Priority	Must
Rationale	In large-scale highly distributed IoT-based systems human involvement in management should be minimised.
Description	In ASSIST-IoT powered systems decisions that can be taken automatically should be autonomous thanks to self-* mechanisms.
Acceptance criteria	During the deployment of the pilots, the developments will make use of some of the self-* enablers to execute autonomous operations/decisions
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
SRIPAS	Partner's expertise

Requirement: R-C-19, Support for self-aware systems	
Category	Non-Functional
Priority	Must
Rationale	In a large-scale highly distributed IoT-based systems, environment awareness and diagnosability should be supported.
Description	ASSIST-IoT powered systems should be able to understand its state, problems and required actions.
Acceptance criteria	Self-aware capabilities should be utilised in the pilot developments.
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
SRIPAS	Partner’s expertise

Requirement: R-C-20, Support for system self-healing	
Category	Non-Functional
Priority	Must
Rationale	In a large-scale highly distributed IoT-based systems, anomalies should be treated locally and autonomously.
Description	ASSIST-IoT powered systems should be able to discover and fix abnormal behaviours.
Acceptance criteria	During the execution of the pilots, self-healing capabilities should characterize the majority of the deployments.
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
SRIPAS	Partner’s expertise

Requirement: R-C-21, Reduction of computing demands for AI training	
Category	Non-Functional
Priority	Must

Rationale	The recent deployments and advancements in artificial intelligence consume large amount of processing resources.
Description	Within the ASSIST-IoT, distributed AI techniques will be utilised to reduce the communication load and needed processing power.
Acceptance criteria	At least, 2 pilots of the project will perform ASSIST-IoT AI functionalities on their edge-devices, rather than relying on public cloud.
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
PRO	Partner's expertise

Requirement: R-C-22 Support for data privacy during the training process	
Category	Non-Functional
Priority	Must
Rationale	In many real-life scenarios there is a need to preserve sensitive data at local parties (without sharing) to reduce the risk of leakage.
Description	In ASSIST-IoT FL architecture should be promoted to conduct the training process in a distributed and secure way without the need to move the data.
Acceptance criteria	During the continuous training and execution of FL-related use cases, secure and distributed training processes should be utilised.
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
SRIPAS	Partner's expertise

Requirement: R-C-23, Multi-model FL support	
Category	Non-Functional
Priority	Must
Rationale	Federated learning should support various techniques, algorithms and models that can be applied on distributed nodes.

Description	ASSIST-IoT shall be able to support multiple ML algorithms and models suitable for problems and data. ASSIST-IoT should promoted model-agnostic FL architecture.
Acceptance criteria	At least 2 ML algorithms will be used for the FL training.
Customer satisfaction	4
Customer dissatisfaction	3
Identified by	**Source**
SRIPAS	Partner's expertise

Requirement: R-C-24, Cooperative ML training support.	
Category	Non-Functional
Priority	Should
Rationale	The late advancements in AI/ML have led to an increasing interest from different industries to provide these functionalities over their systems. However, in order to support very accurate ML models, huge amount of data should be collected for training. Given the lack of resources, the concept of coopetition (the act of cooperation between competing companies) has gaining momentum, which by means of FL systems, allow competing companies to obtain a common trained model without sharing their data.
Description	ASSIST-IoT will implement a custom private FL system able to support a coopetition environment, allowing different parties to collaborate in an ML training process without sharing their data.
Acceptance criteria	At least 10 simultaneous local parties/clients will be used to train an AI model with ASSIST-IoT FL system
Customer satisfaction	3
Customer dissatisfaction	2
Identified by	**Source**
PRO	Partner's expertise

Requirement: R-C-25, Holistic security/privacy approach	
Category	Non-Functional
Priority	Must
Rationale	Security refers to safeguarding data from dangerous threats, whereas privacy refers to the responsible use of data.

Description	ASSIST-IoT methodologies and tools shall offer security and privacy in a wide range of users and applications, which means that sensitive data and information shall not be published or processed without permission and advanced techniques shall securely protect the data within the enablers.
Acceptance criteria	During the execution of the pilots, the vast amount of sensitive information will be securely process if needed.
Customer satisfaction	5
Customer dissatisfaction	3
Identified by	**Source**
S21Sec	Partner’s expertise

Requirement: R-C-26, Optimised Security notification	
Category	Non-Functional
Priority	Must
Rationale	Increased or decreased number of notifications may lead to unidentified hazards, that may reduce the efficiency of the systems.
Description	Within the ASSIST-IoT, the number of incorrect situations that require visibility on the network shall be optimised. Depending on the deployment case of the ASSIST-IoT architecture, the number of considered events within an hour shall be refined based on the specific use case.
Acceptance criteria	During the execution of the pilots, an estimation of 10 raised alerts per hour shall guarantee the quality of the network infrastructure.
Customer satisfaction	3
Customer dissatisfaction	3
Identified by	**Source**
S21Sec	Partner’s expertise

Requirement: R-C-27, Automated accountability	
Category	Non-Functional
Priority	Must
Rationale	Users and/or applications communicating with a system may lead to unexpected errors. There should exist a method to diagnose such cases on the basis of reliable data.

Description	Within ASSIST-IoT, a secure way to register interactions accurately and reliably shall be provided, utilising Distributed Ledger Technology (DLT) for keeping track of the existing interactions.
Acceptance criteria	Critical processes shall be logged in the DLT to track the interaction within pilots
Customer satisfaction	3
Customer dissatisfaction	3
Identified by	**Source**
CERTH	Partner's expertise

Requirement: R-C-28, Distributed Configuration	
Category	Non-Functional
Priority	Must
Rationale	Distributed Configuration frameworks enables to manage the configurations of multiple enablers from a centralised location without needing to proceed in different machines
Description	ASSIST-IoT shall allow users to configure parameters related to those software artifacts so that changes can be applied during their deployment, enhancing parametrisation and usability of ASSIST-IoT powered applications. To that end, APIs shall be used to modify their configuration, while users will proceed with modification through user-friendly interfaces.
Acceptance criteria	Most of the developed enablers shall be fine-tuned and configured through manageability interfaces, while it shall be possible to modify more than 50 values within ASSIST-IoT.
Customer satisfaction	5
Customer dissatisfaction	3
Identified by	**Source**
UPV	Partner's expertise

Requirement: R-C-29, Configurable data flows	
Category	Non-Functional
Priority	Must
Rationale	Despite the technological advancements and intelligence provided by new technologies, stakeholders have not been focused on the usability of the technologies through user-friendly and multi-functional interfaces.
Description	ASSIST-IoT shall be able to provide a graphical environment in which administrators may instantiate the enablers necessary for work and connect them to form a chain, or

	service workflow, using a Directed Acyclic Graph (DAG) interface. This DAG will allow the user to configure, select, obtain information and (most importantly) connect among and interact with enablers deployed in an ASSIST-IoT controlled environment.
Acceptance criteria	At least 2 different topologies of enablers shall be selected and configured through the provides interface.
Customer satisfaction	5
Customer dissatisfaction	5
Identified by	**Source**
UPV	Partner's expertise

6.2. Requirement's summary

Currently, the project has 91 requirements: 43 functional requirements, and 48 non-functional requirements; 29 of them are common for all the pilots. Requirement's identification is an iterative process that takes place throughout the duration of the project, for this reason existing requirements have been improved or new ones have been added. This document contains the final requirements which must be met. Concerning their priority, approximately three quarters are mandatory. This happens because initial focus is made on identifying the essential features and functionalities that the different products must have.

The main sources of data taken into account when defining the requirements have been the stakeholders' needs and the partner's expertise. The definition of the initial requirements is documented in "D3.1 – Use Cases Manual & Requirements and Business Analysis – Initial". D3.1 has been used as starting point for this document. After D3.1 was finished, implementation has started and business scenario's and use cases have been updated and documented in D3.3. Finally, 25 new requirements have been formulated, while the rest have been verified and/or refined. Nevertheless, it has also been quite important to consider other sources such as IoT associations and projects (IOT-A, AIOTI, etc.), standardization organizations recommendations (IEEE, ITU, ISO, etc.) and national and European regulations.

7. Future Work

The information that is included in D3.2 was identified during six months of the project. Within the scope of WP4 and WP5, the implementation of the enablers needed to implement the required features of the different pilots are in progress and at this moment, business scenarios and requirements have been finalised. The information flow between T3.2 and T3.3 and the other work packages has been bi-directional. Working closely together made it possible to make the business scenario, use cases and requirements even clearer. At the same time there has been a close cooperation with T8.1 to identify the ASSIST-IoT KPI's, since these will be evaluated and assessed in WP8.

Appendix 1: Definitions

Across this deliverable, terms like pilot, pilot site, business scenario, use cases, and requirements are extensively used. In Table 4 a short description of each of those terms is provided for better understanding.

Table 4. Terminology

Term	Definition
Pilot	An initial small-scale implementation that is used to prove the viability of a project idea. ASSIST-IoT pilots represent: (i) port automation, (ii) smart safety of workers and (iii) cohesive vehicle monitoring and diagnostics. Each pilot will include different scenarios, in which different technological pillars and enablers will be executed and validated.
Pilot site	The logical and physical space where a pilot takes place. In ASSIST-IoT, pilot sites are: "Port of Malta", "Mostostal Construction site - building", "Ford's testing plant or UPV's premises where the test car is placed", "TwoTronic's partner premises where the test scanner(s) is(are) placed"
Business scenario[6]	A business scenario is essentially a complete description of a business problem, both in business and in architectural terms, which enables individual requirements to be viewed in relation to one another in the context of the overall problem.
Use case[7]	The behaviour of the system that produces a measurable result of value to an actor. Description of a set of sequences of actions and variants that a system performs that yield an observable result of value to an actor.
Requirement	"A requirement is Statement that identifies a product (includes product, service, or enterprise) or process operational, functional, or design characteristic or constraint, which is unambiguous, testable or measurable, and necessary for product or process acceptability." (ISO/IEC 2007) "A requirement is a statement that identifies a system, product or process characteristic or constraint, which is unambiguous, clear, unique, consistent, stand-alone (not grouped), and verifiable, and is deemed necessary for stakeholder acceptability." (INCOSE 2010)[8]

[6] https://www.opengroup.org/architecture/0210can/togaf8/doc-review/togaf8cr/c/p4/bus_scen/bus_scen.htm

[7] https://www.pmi.org/learning/library/use-cases-project-manager-know-8262

[8] Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities. Version 3.2.1. San Diego, CA, USA: International Council on Systems Engineering (INCOSE), INCOSE-TP-2003-002-03.2.1: 362.

Appendix 2: Methodology changes

The template for the requirements as used in D3.2 has been updated to create a slightly compacter table and to comply with the Volere method. These changes are:

- The requirement identifier, name and description are placed in a single row.
- The fields "Customer satisfaction" and "customer dissatisfaction" have been added to add information about the happiness or unhappiness if a requirement is successful implemented or not.

Table 5. Requirement template

Requirement Identifier: Name (Identifer: R - <Pilot #> - #)	
Category	Functional, Non- functional, or Design constraints
Priority	Must, Should, Could, Won't
Use case id	Ids of involved use cases
Rationale	Reason of inclusion
Description	Brief description of the requirement
Acceptance criteria	A measurement of the requirement such that it is possible to non-subjectively test whether the solution fits the original requirement. In any event, the acceptance criterion is the benchmark to allow the tester to determine whether the implemented product has met the requirement.
Customer Satisfaction	Degree of customer/stakeholder happiness if this requirement is successfully implemented. Scale from 1 = uninterested to 5 = extremely pleased.
Customer dissatisfaction	Measure of stakeholder unhappiness if this requirement is not part of the final product. Scale from 1 = hardly matters to 5 = extremely displeased.
Identified by	**Source**
	Partner's expertise or from another (EU, H2020) project

Appendix 3: Actors in the port automation pilot

Table 6. Actors in the "Port automation" pilot

Actor	Implements	Type	Description
Container Handling Equipment (**CHE**)		System	Cargo handling equipment (CHE) in ports and rail yards generally includes yard tractors, cranes, forklifts, container handlers (e.g., top picks and side picks), and bulk handling equipment, such as tractors, loaders, dozers, excavators, and backhoes. This equipment can be operated by a human on site, remotely, or autonomous.
Rubber-Tyred Gantry (**RTG**)	Container Handling Equipment	System	A rubber-tired gantry crane is a mobile gantry crane used in intermodal operations to ground or stack containers. Inbound containers are stored for future pickup by drayage trucks, and outbound are stored for future loading onto vessels.
Terminal Tractor (**TT**)	Container Handling Equipment	System	Semi-tractor owned by the terminal intended to carry containers within a cargo yard, warehouse facility, or intermodal facility
External Truck	Container Handling Equipment	System	A truck carrying containers, from outside the terminal. The port does not have full control over the equipment carried by the external trucks.
RTG camera system		System	A system of cameras mounted on the RTG, to allow for remote RTG operation.
RTG LIDAR		System	Tracks the position of the truck below the RTG.
Remote RTG operator		Person	RTG operator using a remote-control console to operate the crane.
Terminal Operating System (**TOS**)		System	Terminal Operating System, responsible for issuing and tracking work orders.
CHE Position Detection System (**PDS**)		System	Tracks the movements of the CHE which is mounted on, and include information about the job instruction and container positions from the TOS. It is also connected to the Crane Programmable Logic Controller (PLC). With both data, the PDS can inform the driver which container should be in each position and also inform the TOS which container was moved by the CHE. This will prevent the driver from making a mistake: for RTG driver – misplace a container; for TT (driver) – transport the wrong container. PDS automatically updates the TOS with data about the last move.
Remote Operating Station (**ROS**)		System	The cranes are operated with a Remote Operating Station that is a dedicated workstation for the remote operation. From ROS the operator has full control of the crane. The ROS desk is equipped with controls that can be normally found from the crane cabin. The main components on the workstation are the video display, control sticks and the touch panel. The access to the ROS is restricted and the operator must login to the system before the cranes can be operated.

Actor	Implements	Type	Description
OEM software engineer		Person	• Responsible for PCM parameterisation during the development phase • Updates PCM parameterisation using data from a limited number of test vehicles during the first stages of the production phase • Establishes and maintains propulsion system models • Issues a parameterisation update only if ISE tests, after the start of production, demand it
OEM aftersales services manager		Person	• Works at the OEM department which supports the Aftersales service technicians, e.g., by providing spare parts • Provides spare parts after a garage has placed an order • Gathers information from garages on frequent vehicle issue
Aftersales service technician		Person	• Receives information about vehicle defects by direct contact with the vehicle owner • Performs maintenance and diagnostics tasks using the vehicle's service handbook • Orders defect parts after they have been identified in the garage • Repairs the vehicles • Provides feedback to the manufacturer about vehicle issues that were discovered while in garage • Drives alongside the vehicle owner/driver in order to reproduce the reported issue • Manually reads out data from vehicle to support fault investigation
Driver		Person	• Owns or operates a private or commercial vehicle, respectively • Is unaware of the vehicle state and is only informed by OBD lights and performance reduction • Follows predefined regular service schedule • Can visually inspect the vehicle's exterior condition but does not formally document it
Vehicle exterior inspector		Person	• Works for aftersales service or leasing or insurance company • Responsible for the documentation of a vehicle's exterior condition • Manually inspects a vehicle's exterior for defects • Supervises the automatic inspection of a vehicle's exterior for defects

Powertrain Control Module (**PCM**)		System	• The PCM has tens of thousands of parameters that are relevant to engine performance and emissions • some parameters may compromise driving or system safety if changed to the wrong value or if changed the while vehicle is moving • PCM parameterisation is a large set of parameters ('calibration') and data maps to allow the functionality of the propulsion system • Pre-defined reaction to a limited set of pre-set environmental conditions • Is set during pre-production phase using test vehicles and models and remains unchanged during the vehicle's lifetime[9] [10] • Vehicles are equipped with standard NO_x emissions sensor with expected drift due to ageing. The sensor remains within the vehicle for its entire lifetime • Some vehicles are equipped with an additional HiFi NO_x sensor which is handpicked from standard production to ensure high accuracy. It is frequently replaced to ensure minimal drift and allow the determination of the measurement bias for the entire fleet
Vehicle scanner		System	• The core function of the scanner is to acquire high-quality images of vehicles and document their current exterior condition.
AI-based surface inspection		System	• It additionally adds the possibility for automated inspection of the vehicles exterior conditions and supports an efficient documentation of evaluation procedure for the vehicles as single entity or as part of a whole vehicle fleet

[9] Interfaces exist (e.g., CCP) for modifying calibration and reading PCM parameters over existing buses (e.g., CAN)

[10] ~100 Hz acquisition is normal for most sensors in the ECU. Some functions are triggered in a crankshaft angle synchronous mode and need sub 1 µs precision

Appendix 4: Actors in the diagnostics pilot

Table 7. Actors in the "Cohesive vehicle monitoring and diagnostics" pilot

Actor	Type	Description
OEM software engineer	Person	• Responsible for PCM parameterisation during the development phase • Updates PCM parameterisation using data from a limited number of test vehicles during the first stages of the production phase • Establishes and maintains propulsion system models • Issues a parameterisation update only if ISE tests, after the start of production, demand it
OEM aftersales services manager	Person	• Works at the OEM department which supports the Aftersales service technicians, e.g., by providing spare parts • Provides spare parts after a garage has placed an order • Gathers information from garages on frequent vehicle issue
Aftersales service technician	Person	• Receives information about vehicle defects by direct contact with the vehicle owner • Performs maintenance and diagnostics tasks using the vehicle's service handbook • Orders defect parts after they have been identified in the garage • Repairs the vehicles • Provides feedback to the manufacturer about vehicle issues that were discovered while in garage • Drives alongside the vehicle owner/driver in order to reproduce the reported issue • Manually reads out data from vehicle to support fault investigation
Driver	Person	• Owns or operates a private or commercial vehicle, respectively • Is unaware of the vehicle state and is only informed by OBD lights and performance reduction • Follows predefined regular service schedule • Can visually inspect the vehicle's exterior condition but does not formally document it
Vehicle exterior inspector	Person	• Works for aftersales service or leasing or insurance company • Responsible for the documentation of a vehicle's exterior condition • Manually inspects a vehicle's exterior for defects • Supervises the automatic inspection of a vehicle's exterior for defects
Powertrain Control Module (PCM)	System	• The PCM has tens of thousands of parameters that are relevant to engine performance and emissions • some parameters may compromise driving or system safety if changed to the wrong value or if changed the while vehicle is moving • PCM parameterisation is a large set of parameters ('calibration') and data maps to allow the functionality of the propulsion system • Pre-defined reaction to a limited set of pre-set environmental conditions

		• Is set during pre-production phase using test vehicles and models and remains unchanged during the vehicle's lifetime[11] [12] • Vehicles are equipped with standard NO_x emissions sensor with expected drift due to ageing. The sensor remains within the vehicle for its entire lifetime • Some vehicles are equipped with an additional HiFi NO_x sensor which is handpicked from standard production to ensure high accuracy. It is frequently replaced to ensure minimal drift and allow the determination of the measurement bias for the entire fleet
Vehicle scanner	System	• The core function of the scanner is to acquire high-quality images of vehicles and document their current exterior condition.
AI-based surface inspection	System	• It additionally adds the possibility for automated inspection of the vehicles exterior conditions and supports an efficient documentation of evaluation procedure for the vehicles as single entity or as part of a whole vehicle fleet

[11] Interfaces exist (e.g., CCP) for modifying calibration and reading PCM parameters over existing buses (e.g., CAN)

[12] ~100 Hz acquisition is normal for most sensors in the ECU. Some functions are triggered in a crankshaft angle synchronous mode and need sub 1 µs precision