This project has received funding from the European's Union Horizon 2020 research innovation programme under Grant Agreement No. 957258

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

D3.2 – Use Cases Manual & Requirements and Business Analysis – Initial

Deliverable No.	D3.2	Due Date	30-APR-2021
Type	Report	Dissemination Level	Public
Version	1.0	WP	WP3
Description	Initial 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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History

Date	Version	Change
05-Mar-2021	0.1	ToC and task assignments
15-Apr-2021	0.5	Integrated version of the document
19-Apr-2021	0.8	Version for internal review
27-Apr-2021	0.9	Draft ready for submission
30-Apr-2021	1.0	Final version

Key Data

Keywords	use case, business analysis, pilot, requirement
Lead Editor	P03 SRIPAS – Maria Ganzha
Internal Reviewer(s)	P04 CERTH, P15 OPL

Executive Summary

This deliverable outlines the results of Tasks 3.2 and 3.3 activities during the first six months 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 formalised the pilot scenarios, which were briefly described in the Grant Agreement.

To this end, the industrial and academic leaders of each pilot collaborated with all the consortium partners in order 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 based on the expertise and experience of all partners. This initial version of the manual includes 19 use cases, 35 functional and 39 non-functional requirements (74 in total; 7 of them common to all pilots).

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
BLE	Bluetooth Low Energy
CAN	Controller Area Network
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 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. In order to extract the fundamental requirements for the project, we have conducted interviews with key stakeholders of the three pilots of the project – Terminal Link and Konecranes, CIOP-PIB and Mostostal, FORD-WERKE and TwoTronic. Based on gathered information, the business scenarios for all three pilots were defined. Later on, for every business scenario, use cases were formulated against which requirements fulfilment will be verified and interactions with ASSIST-IoT components will be tested. Simple use case diagrams, identifying primary actors and activities that form each system, were prepared. Use case specification includes (among other): (i) actors (persons, devices or digital entities) that interact and participate in the use cases; (ii) requirements, assumptions and/or pre-conditions to be satisfied for the use case to be performed; (iii) flow of events between actors, and sequences of interactions focusing on differences from current operations, and (iv) expected outcomes after the use case execution. After business scenarios and use cases were formulated, requirements were collected, defined, verified (whether they are clear, complete, and consistent), classified (functional, non-functional, etc.) and analysed. In-depth analysis of legal requirements will be 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 first one is to define the scope and reduce the development effort, since the definition of rigorous requirements before the design can reduce later redesign, recoding, and retesting. Moreover, the requirements can be considered as an agreement between the customers and the suppliers about the product (to be developed), for instance, facilitating the business model and marketing. Furthermore, a detailed description of the requirements can accurately estimate costs and time planning. Finally, the requirements can set the evaluation and validation criteria to obtain a quality product. Requirement analysis helped to identify technical and business needs and solutions to problems, related to use cases. Requirements and business analysis help: (i) to identify technical and business needs and solutions to problems related to use cases, (ii) to initially assess and refine action coverage, identifying existing gaps (technical, functional and organisational) to fulfil the operational concept, approach and goals, (iii) to make the outcome of the pilots measurable and provides input for the technical evaluation of the project results. 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 were used to ensure general coherence and to maximize usefulness for all the technical stages. Requirements will be revisited several times within the project as they may evolve as the work progresses and their priorities may change. The used methodology is explained in this deliverable to provide the required foreground to understand the work in WP3 that will be completed in the following deliverables. The ongoing development in business scenarios and use cases was initiated in Miro[3] - the online collaborative white boarding platform that enables distributed teams to work effectively together, from brainstorming with digital sticky notes to planning and managing agile workflows. In Miro, one can create concepts, map user stories or customer journeys, or conduct roadmap planning easily. The information gathered there is later included in the deliverable in a more formal structure. This deliverable is the result of the activity carried out in T3.2 and T3.3. It also uses some results obtained in T3.1 (State-of-the-art and market analysis), and the interviews with the stakeholders. The results of this deliverable will influence other work packages: it 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] https://www.volere.org/
[2] https://www.agilebusiness.org/page/ProjectFramework_10_MoSCoWPrioritisation
[3] https://help.miro.com/hc/en-us

2. Introduction

2.1. Scope of ASSIST-IoT project

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 will be required for guaranteeing the successful deployment of NG-IoT reference 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[4].

ASSIST-IoT follows the AIOTI[5] 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.

2.2. Scope of the document

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 information identified up to the delivery date of this deliverable are included, but the work will continue to complete and update necessary information throughout the project. Different methods and criteria have been considered to extract requirements. The most important input is the needs expressed by the stakeholders in the interviews, as they are the final users of the project outcome. Additionally, the most important requirements for other IoT systems have been investigated. Finally, the wide experience of the partners was taken into account.

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 section 2. In sections 3, 4, 5, business scenarios and use cases, grouped by the pilots defined in the project, are described and analysed. In section 6, all requirements have been listed. Finally, in section 7 summary, an overall conclusion and future work are provided.

2.3. Definition

Across this deliverable, terms like pilot, pilot site, business scenario, use cases, and requirements are extensively used. In Table 1 we provide a short description of each of those terms for better understanding.

Table 1. 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)

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

	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 behavior 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]

2.4. Methodology

The business scenarios, use case and requirements were identified iteratively using an agile approach. A series of workshop-like structured meetings with stakeholders (including partners responsible for pilots' representatives) was conducted. Here, three pilots proposed in ASSIST-IoT were discussed and divided into business scenarios and use cases that should be supported by the project outcomes. Information was gather using the whiteboarding technique to be later put in the appropriate templates.

The methodology that has been used as a reference for most of the tasks involved in work package 3 (WP3) is Volere[9].

Volere has been used by thousands of organizations around the world to discover, define, communicate, and manage all the necessary requirements for any type of system development (e.g., software, hardware, commodities, services, organizational, etc.). Volere can be applied in all kinds of development environments, with any other development methods or with most requirements tools and modelling techniques. To produce accurate and unambiguous requirements, the Volere methodology uses techniques that are based on experience from worldwide business analysis projects, and are continually improved.

The Volere methodology provides several templates to deal with the different techniques and activities that it includes. In a quick view, the Volere Requirement Process[10] suggests a methodology that can be summarised as follows:

1. Define the purpose of the project (project proposal)
2. Stakeholder identification and analysis (T3.1&T3.2)

[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.
[9] Volere Requirements: How to Get Started, http://www.volere.co.uk/pdf%20files/VolereGettingStarted.pdf
10 http://www.volere.co.uk/pdf%20files/VolereGettingStarted.pdf

3. Business scenarios (T3.2)
4. Use cases (T3.2)
5. Writing the requirements: functional requirements and non-functional requirements (T3.3)
6. Validation of requirements: completeness, relevance, testability, coherency, traceability, and several other qualities before such requirements are used by developers (T3.3)
7. Communicating the Requirements (internally)
8. Requirement completeness (WP3 – D3.3, verification by other work packages).

Thus, the ASSIST-IoT project consortium considered that choosing this methodology for WP3 could help to achieve project objectives by structuring the gathered knowledge according to well established standards. Applying the Volere for the requirement discovery process is essential to ensure that the real problem is addressed. The ASSIST-IoT partners consider the method to be excellent and drive the development success, as it is imperative to go deeply into how our pilot owners are understood, and how to find better solutions by discovering and communicating a better understanding of their problems.

All requirements described in this document are identified during this first phase of the project. As the project progresses the requirements will be polished, and new ones will be included as they appear during the project duration so that they are continuously verified and, if necessary, adjusted.

2.4.1. Business scenario

A Business Scenario describes[11]:

- a business process, application, or set of applications, that can be enabled by the architecture,
- the business and technology environment,
- the people and computing components (called "actors") who execute the scenario,
- the desired outcome of proper execution.

A **use case** is finer-grained and more detailed than a business scenario. A **business scenario** describes some purpose for which a user might use your system and all of the features of the software that they would require to achieve that purpose. **Business scenarios** describe the system at a high level and give a rationale for each feature of the existing system. Use cases give a detailed account of what each feature does.

2.4.1.1. Template

Each business scenario identified in the ASSIST-IoT project is described using the template from Table 2. In this table, the guidelines on how to fill the template are provided, followed by examples in the next section.

Scenarios should be written from the point of view of an external viewer that should understand the problem/case without in-depth knowledge about the project.

Table 2. Business scenarios template

Business scenario	
Scenario ID ***#1***	**Scenario name** *Self-explanatory. Choose short title*
Illustration of system's behaviour in a specific	*Write here the scenario: description of users' interaction with a system in users' perspective, covering a short story of an individual user(s), interacting with a system, to achieve a specific outcome, under specific circumstances, over a*

[11] http://www.opengroup.org/public/arch/p4/bus_scen/bus_scen.htm

situation, flow of events	*certain time interval. Check that the scenario covers at least the following elements.*	
	User/users:	*What are the characteristics of the user(s)? (e.g., age, gender, education, technical skills) Are they producer or consumer with respect to the system/service?*
	Setting / context	*What is the physical environment? (e.g., place, location, another person(s) involved).*
	Interacting system	*If possible, give an overview of the technical environment (e.g., devices and network, services and platform, etc.).*
	Users' goals	*What the user(s) wants to achieve?*
	Initial status	*What is the initial condition of the interacting system, or initial situation of the actors?*
	Interactions	*How the user(s) interacts with the system? (in addition, a schematic of the interacting system, if relevant, could be helpful)*
	Data	*What information (data) is produced and /or consumed?*
	Motivation	*Why to choose the particular way to act?*
	Time	*When? How long? At what frequency?*
System functionalities	**General description**: *Short description of the main functionalities needed for this business scenario shown above.*	
Identified by	*Partner who identified the business scenario*	

2.4.2. Use case

Use cases are described with UML use case diagrams and template tables provided below (Table 3). For each pilot in ASSIST-IoT an UML use case diagram should be created that will outline key actors and all identified use cases related to this pilot. Use cases are related to business scenarios as "components" to achieve the goal set by the business scenario.

A use case diagram[12] is a diagram that shows the relationships among actors and use cases within a business scenario. This diagram aims at facilitating a preliminary overview of the functionality, that the system should have, and discovering/specifying the involved actors. The initial results of the analysis will lead to the definition of actors and use cases that describe high-level functional requirements, in general terms. This information is relevant because it is able to provide the limits and purposes of the pilot to be developed.

The full functionality within a pilot is represented by a set of use cases. Each use case captures specific functionality or capability.

In the graphic representation, a symbol is used especially for the actor (a user, or another system), which is the entity that interacts with a use case, by starting the sequence of actions described by the use case itself and, possibly, receiving precise answers.

[12] https://warren2lynch.medium.com/use-case-learn-by-examples-5a63b67fa64d

The name of the actor appears just below the picture of the same actor, while the name of the use case appears either inside the ellipse or below it. An association between an actor and a use case representing a communication between actor and use case is drawn as a line connecting the two modelling elements.

The name of a use case is a sentence with the verb in the active tense.

It is possible to re-use the use cases, and to do so, one can proceed in four ways:

- Extension: with this method you can create a new use-case by simply adding steps to an existing use case. **A dotted line with an arrow end is used to represent the extension**, along with a stereotype that shows the word << extend >>. <<Extend>> is a directed relationship that specifies how and when the behaviour defined in usually supplementary (optional) extending use case can be inserted into the behaviour defined in the extended use case.
- Inheritance: a use case child can inherit the behaviour and meaning from its father and adds its specific characteristics. **The inheritance is represented with a continuous line that has a triangle that points to the father**. The relation inheritance can exist also between actors.
- Grouping: in some use case diagrams, there could be many use cases and you want to organize the diagram better. Such a situation may occur when you are designing a system that consists of several subsystems. The easiest way to handle such situations is to organize groups of use cases that are somehow related.

In Figure 1 and Figure 2 two examples of use case diagrams are given.

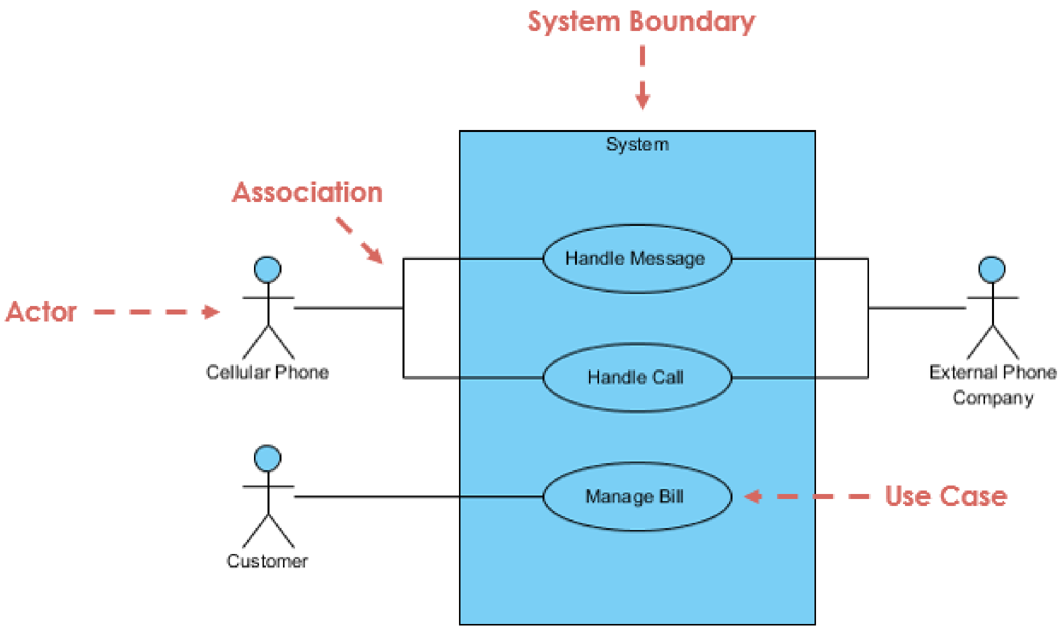


Figure 1. Use case diagram example for a phone system

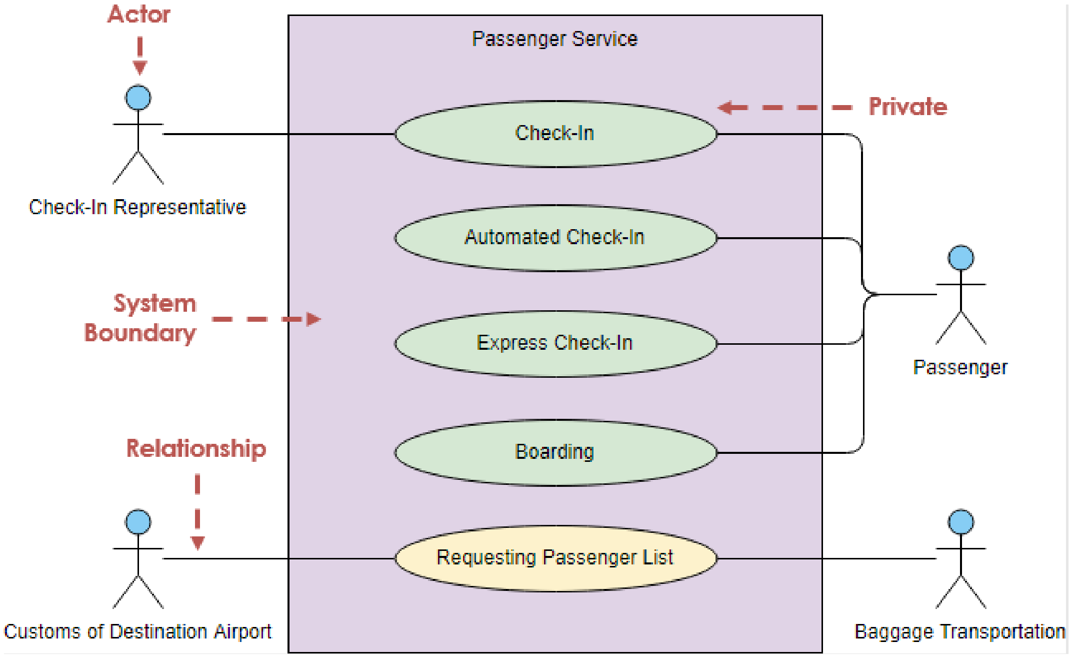


Figure 2. Use case diagram example for a passenger service

2.4.2.1. Template

Each use case identified in the ASSIST-IoT project is described using the template from Table 3. which provides guidelines on how to fill each field while examples are also provided in the next section. Use cases reference specific business scenarios.

Table 3. Use case template

Use case	
ID	*#N*
Name	*Self-explanatory. Choose short, catching title*
Description	*Description of the use case (~2 lines)*
Reference Scenario	*Id and name of the business scenario referred to by the use case*
Plane(s)	*Device and Edge, Data Management, Smart Network and Control, Application and Services*
Vertical Capabilities	*Manageability, Scalability, Security, Privacy and Trust, Interoperability, Self-**
Functionalities within vertical capabilities	*Specific functionalities within identified vertical capabilities (e.g., encryption for Security, self-healing for Self-*)*
Objectives	*Objectives of the use case*
Actors (system actor or natural persons)	*Enumerate (primary and secondary) actors/systems involved in the execution of the use case. Primary Actors often coincide with the actors that trigger the execution of the use case or those who benefit directly of the result.*
Pre-conditions	*What must be already there*
Trigger	*Which action triggers this use case*
Expected results	*What the user sees/obtains after completion of the scenario*

Design preferences	*Optional. Enumerate potential technological approaches and/or methodologies*
Extends the use case (if applicable)	*Name of the "base" use case that can be extended by this use case*
Includes the use case (if applicable)	*Name of the "generic" use case of which this use case is a specialization of*
Notes and issues	*Enumerate aspects to be considered, such as special requirements, assumptions or issues. TODO add explanation*
Main execution flow	*The sequence of actions (steps) that describe the execution of "normal" use case. This should be in Present Simple, in the active form where possible.* *1. STEP 1* *2. STEP 2* *3. STEP 3* *4. …*
Alternative execution (if applicable)	*1. STEP 1* *2. STEP 2* *3. STEP 3* *4. …*
Exceptions (if applicable)	*List of actions of exceptions to the use case.*
Requirements involved	*List of requirements identifiers involved*
KPI	*Optional. Describe reasonable KPI that you believe can be achieved during the project*
Identified by:	*Partner who identified the use case*

2.4.3. Requirements

While various definitions exist of what is a requirement, in this study, we agreed to use the definitions of ISO and INCOSE:
"*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) [13]
"*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) [14]

2.4.3.1. Characteristic of requirements

The characteristics of good requirements are variously stated by different writers.
There are several characteristics of requirements that are used to aid their development and verify their implementation into the solution (ISO 2011, Sections 5.2.5 and 5.2.6).

[13] ISO/IEC. 2007. Systems and Software Engineering -- Recommended Practice for Architectural Description of Software-Intensive Systems. Geneva, Switzerland: International Organization for Standards (ISO)/International Electrotechnical Commission (IEC), ISO/IEC 42010:2007
[14] INCOSE. 2010. 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

- ***Necessary***
  The requirement defines an essential capability, characteristic, constraint, and/or quality factor. If it is not included in the set of requirements, a deficiency in capability or characteristic will exist, which cannot be fulfilled by implementing other requirements.
- ***Appropriate***
  The specific intent and amount of detail of the requirement is appropriate to the level of the entity to which it refers (level of abstraction). This includes avoiding unnecessary constraints on the architecture or design to help ensure implementation independence to the extent possible.
- ***Unambiguous***
  The requirement is concisely stated. It expresses objective facts, not subjective opinions. It is subject to one and only one interpretation.
- ***Complete***
  The requirement sufficiently describes the necessary capability, characteristic, constraint, or quality factor to meet the entity need without needing other information to understand the requirement.
- ***Singular***
  The requirement should state a single capability, characteristic, constraint, or quality factor.
- ***Feasible***
  The requirement can be realized within entity constraints (e.g., cost, schedule, technical, legal, or regulatory) with acceptable risk.
- ***Verifiable***
  The requirement is structured and worded in such a way that it will be possible to verify its accomplishment, as well as the degree of customer's satisfaction regarding its realization.
- ***Correct***
  The requirement must be an accurate representation of the entity need from which it was transformed.
- ***Consistent***
  The requirement does not contradict any other requirement and is fully consistent with all authoritative external documentation.
- ***Comprehensible***
  The set of requirements must be written clearly to reflect what is expected by the entity and its relation to the system that it is a part of.

2.4.3.2. Types of requirements

The Volere methodology[15] categories requirements[16] into several groups:

- ***Functional requirements*** are the fundamental subject matter of the system and are measured by concrete means like: data values, decision-making logic, and algorithms.
- ***Non-functional requirements*** are the behavioural properties that the specified functions must have, such as performance, usability, etc. Non-functional requirements can be assigned to a specific measurement. This template will give examples of quantifying non-functional requirements.
- ***Project constraints*** identify how the eventual product must fit into the world. For example, the product might have to interface with or use some existing hardware, software, or business practice, or it might have to fit within a defined budget or be ready by a defined date.
- ***Project drivers*** are the business-related forces. For example, the purpose of the product is a project driver, as are all the stakeholders - each for different reasons.
- ***Project issues*** define the conditions under which the project will be done. We include these in the requirements specification to present a coherent picture of all the factors that contribute to the success or failure of the project.

[15] Volere Requirements Specification Template:
https://www.st.cs.uni- saarland.de/edu/se/2009/slides/volere_specification_template_v6.pdf
[16] https://www.visual-paradigm.com/guide/requirements-gathering/requirement-analysis-techniques/

In this document, we focus on the first two described groups: functional and non-functional requirements. The other groups will be examined at WP3, T3.2, T3.4 throughout the life of the project.

2.4.3.2.1. Functional requirements

As indicated in the previous point, the Volere methodology defines functional requirements as the fundamental subject matter of the system: an action that the product must be able to take, something that the product must do. The Volere methodology classifies them into the following two groups:

- ***Functional Requirements:*** To specify the details for each individual functional requirement, that must be supported by the system.
- ***Data Requirements***: A specification of the essential subject matter/business/objects/ entities/classes, which are germane to the system.

These requirements clarify the system's subject matter and thereby trigger requirements that have not yet been thought of.

2.4.3.2.2. Non-functional requirements

Regarding non-functional requirements, the Volere methodology indicates that they are the behavioural properties that the specified functions must have, such as performance, usability, etc. Additionally, the non-functional requirements describe how the system works which is an important a property that the final product must have.

The Volere Methodology classifies the non-functional requirements in the following groups:

Look and Feel Requirements

- *Interface*: to ensure the appearance of the product. There are requirements relating to the interface, such as corporate branding, style, colours to be used, degree of interaction and so on. These requirements capture the needs for interface to ensure that the appearance of the product conforms to the organization's expectations.
- *Style of the product:* a description of salient features of the product that are related to the way a potential customer will see the product. The requirements that you record here will guide the designers to produce a product as envisioned by your client. These requirements have the task to determine precisely how the product shall appear to its intended consumer.

Usability

- Ease of use: describes the client's aspirations of how easy it will be, for the intended users of the product, to operate it. The product's usability is derived from the abilities of the potential users and the complexity of its functionality. It is necessary to ensure that the usability requirements from the perspective of all the different types of users have been considered.
- *Personalization and internalization requirements:* describe the way in which the product can be altered or configured to consider the user's personal preferences. The personalization requirements should cover things such as languages, currencies (including the symbols and decimal conventions), personal configuration options, etc.
- *Ease of learning*: how easy it should be to learn to use the product. To quantify the amount of time that the client feels is allowable before a user can successfully use the product. This will range from zero time, for products intended for placement in the public domain, to a considerable time for complex, highly technical products. This requirement will guide designers in how users will learn the product. For example, the designers may build elaborate interactive help facilities into the product, or the product may be packaged with a tutorial.
- *Accessibility requirements:* how easy it should be for people with common disabilities to access the product. These disabilities might be to do with sight, physical disablement, hearing, cognitive, or others.

Performance Requirements

- *Speed and latency requirements:* Specify the amount of time available to complete specified tasks. These often refer to response times. They can also refer to the product's ability to fit into the intended environment.
  Some products, usually real-time products, must be able to perform some of their functionality in a given time slot.
- *Safety critical requirements:* Quantification of the perceived risk of possible damage to people, property, and environment. To understand and highlight the potential damage that could occur when using the product within the expected operational environment.
  If safety critical systems are being built, then the relevant safety critical standards are already well specified.
- *Precision requirements*: Quantification of the desired accuracy of the results produced by the product. To set the client and user expectations for the precision of the product.
- *Reliability and Availability requirements:* quantifies the necessary reliability of the product. This is usually expressed as the allowable time between failures, or the total allowable failure rate. It also quantifies the expected availability of the product.
- *Robustness requirements:* specifies the ability of the product to continue working under abnormal circumstances.
- *Capacity requirements:* specifies the volumes that the product must be able to deal with and the numbers of data stored by the product.
- *Scalability or extensibility requirements*: specifies the expected increases in size that the product must be able to handle. As a business grow (or is expected to grow), software products must increase their capacities to cope with the new volumes.

Operational Requirements

- *Expected physical environment*. To highlight conditions that might need special requirements, preparations or training. These requirements ensure that the product is fit to be used in its intended environment. It should also be taken into consideration that there are users with disabilities other than the commonly-described, such as for low-visibility and poorly lit environments.
- *Expected technological environment*. To identify all the components of the new system so that the acquisition, installation, and testing can be effectively managed. It may be that the operating environment is complex, and becomes a subject of requirements study itself. Special considerations should also be given if the product is to be embedded in a device.
- *Partner applications.* Requirements for interfacing to other applications often remain undiscovered until implementation time.
- *Production requirements.* Any requirements needed to make the product distributable or saleable. It is also appropriate to describe here the operations to be performed to have a software product successfully installed.
  Some products have special needs to turn them into a saleable, or usable product. You might consider that the product must be protected such that only paid-up customers can access it. This might be implemented as a dongle, a daily keyword, a check that no other copy of the product is running on the network at the same time.

Maintainability and Support requirements

- *How easy must be to maintain this product*. Time quantification necessary to make specified changes to the product. There may be specific requirements for maintainability, such as whether this product must be maintained by its end-users, or developers who are not the original developers. This influences the way that the product is developed, and there may be additional requirements for documentation or training.
  Special conditions that apply to the maintenance of this product. To make everyone aware of how often it is intended to produce new releases of the product.

- *Supportability*. This specifies the level of support that the product requires. This is often done using a help desk. If there are going to be people who provide support for the product, this will be a part of the product and there will be requirements for that support. Support into the product itself might also be built. In that case this is the place to write the respective requirements.
- *Portability requirements.* Description of other platforms or environments to which the product must be ported.

Security requirements

- *Access requirements.* Specify the authorized person with product access, the circumstances under which the access is granted, and the parts of the product that the access is valid.
- *Integrity requirements*. Specification of the required integrity of databases and other files, and of the product itself. To specify the actions that the product will follow to ensure its integrity in the case of an unwanted event such as an attack from the outside or an unintentional misuse by an authorized user.
- *Privacy requirements.* Specification of what the product has to do to ensure the privacy of individuals that it stores information about. The product must also ensure that all laws about the privacy of individual's data are observed.
- *Audit requirements.* Specification of what the product has to do (usually retain records) to permit the required audit checks.
- *Immunity requirements.* The requirements for what the product has to do to protect itself from infection by unauthorized or undesirable software programs, such as viruses, worms, Trojan horses, and others.

Cultural and Political Requirements.

Requirements that are specific to the sociological and political factors that affect the acceptability of the product. If a product for foreign markets is being developed, then these requirements are particularly relevant.

Legal Requirements[17]

As the system falls under the jurisdiction of any law, a statement specifying the legal requirements for this system is necessary.
Additionally, some standards with which the product must comply require a statement specifying applicable standards and referencing detailed standards descriptions.

2.4.3.2.3. Requirement's harmonisation process step

The **methodology** used is a 5-step iterative process of identifying, capturing, defining, analysing, and reconciling the requirements (see Figure 3).
The requirements harmonization process steps are defined as follows:

- **Identify sources of requirements**

The first step is to identify new sources that can provide the know-how for requirements. In addition to our own knowledge, other sources could be stakeholders, regulation, standards, etc.

- **Requirement Capturing**

Make an inventory of identified requirements by product. This can be accomplished in a number of ways but in our case, each partner collects the requirements needed for each product. This includes the requirement name, and a brief description.

- **Defining**

Defining the information requirement is critical. Although the requirement is identified by the name, completing the proposal requirement template is essential for the identification of the needs that the requirement explains.

[17] In-depth analysis of legal requirements will be provided in D3.4

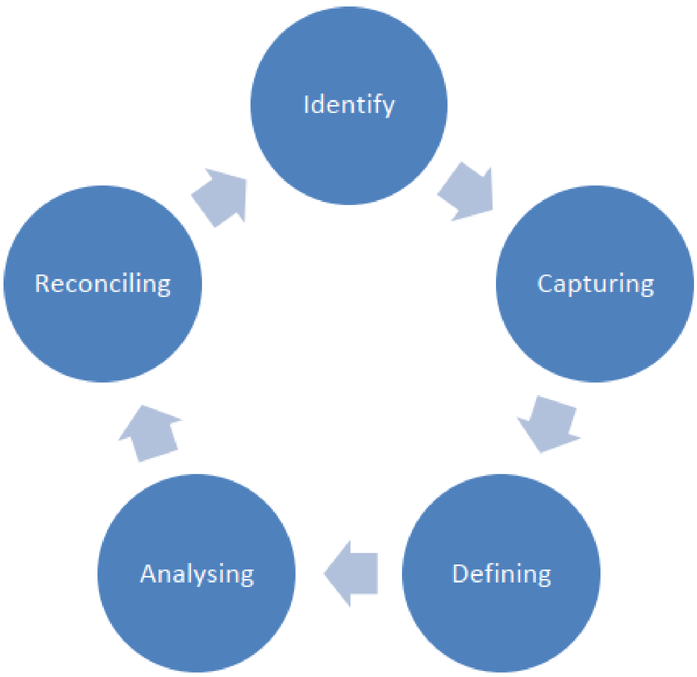


Figure 3. The requirements capture methodology

For all this, a requirement template has been prepared with the main information needed in order to be collected from the requirements identified (see Table 4).

Table 4. Requirement template

Requirement	
Name	Name
Identifier	**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	Conditions that must be satisfied so that fulfilment of the requirement can be verified
Identified by	**Source**
	Partner's expertise or from another (EU, H2020) project

- **Analysing**

A process of analysing the information is needed. It consists of assessing the requirements obtained. The following tasks need to be completed for each requirement:

- Filling in the description
- Correcting and homogenizing the relevant classifications
- Grouping similar requirements

- Validating requirements
- Locating new requirements not identified in other sources of information

- **Reconciling**

This is the final step in which there is the agreement to incorporate the requirement into the list.

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 has experienced remarkable growth since its inception, and currently is one of the largest ports of transshipment in the Mediterranean region with more than 2,000,000 containers/year. MFT amalgamates activities of container handling and industrial storage, establishing as a critical node of European maritime logistics. Containers are managed by heavy machinery equipment like Rubber Tired Gantry cranes (RTGs), Rail Mounted Gantry Cranes (RMGs), or Ship-To-Shore Cranes (STSs). However, they always require the intervention of on-board operators and on-site clerks, who interact with each other by various means and signals, including information sources required to handle and deliver freight. The pilot aims to demonstrate the benefits of ASSIST-IoT executing several business scenarios to show how the developed technologies can transform complex industrial processes, infrastructure and equipment managed in the maritime industry.

MFTL has almost reached its maximum capacity, with almost permanent congestion in the terminal area and occasional services collapse with an important impact on the business operations, due to the high volume of TEUs managed and the increased number of port calls. Congestion or a collapse of terminals result in four major negative effects: (i) longer vessel stay times; (ii) increase in the vessels berthing-wait-time; (iii) vessels being diverted to other terminals; and (iv) increase of wait and turn-around times of landside trucks all causing increased environmental load, inefficiency of the logistics chain and cost of productive movements. Even though digital information is used in diverse stages of terminal and shipping lines processes, data exploitation potential is still far from optimal. The main hurdles in the data exploitation are caused mainly by the lack of computational resources, high latency of existing networks, throughput bottlenecks in the intermediate layers of current IoT architectures, and lack of trust/confidence among stakeholders of pertinent management systems. While data acquisition and availability is mostly solved, for current container terminals, there is lack of improvements in the following: (i) industry ready, reliable and cost-effective solutions for distributed data analysis and processing, (ii) decentralized combinations of multi-source heterogeneous data, (iii) low-latency actuation loops (especially for data processing from different endpoints, or synchronized cooperation of equipment), or (iv) trusted data sharing for supply chain inter-business integration. Solutions like the one provided in ASSIST-IoT will address the aforementioned industrial challenges, leading to a paradigm shift in the sector and an important evolution compared to the current state of the art technologies. Physical expansion of terminals may solve problems temporarily. However, it is often not possible due to infrastructure constraints. Moreover, a more sustainable and expandable solution is sought, based on optimization of logistic processes and use of technology to put operators in the centre of operations. In particular, ASSIST-IoT will help operators by means of smart devices to interact and to make better decisions in real time, by improving availability of information, and the way operators interact with it. These aspects, within the port environment, where several stakeholders coexist, have to interoperate and share data in a secure and trustable fashion.

The following Table 5 provides a list of all the actors participating in the Port Automation Pilot that are needed in order to describe the ASSIST-IoT solution.

Table 5. 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-Tired 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.

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

In a large terminal like the one in MFTL, ~2.5 million containers are being handled yearly. Due to the lack of digitization, several containers are being lost every year. The traceability recovery of lost containers is particularly challenging, leading to customer dissatisfaction. In theory, it might be easy to consider the problem of container's location as conceptually very simple. However, containers only have an ID number and do not include any GPS or other type of location device. To cope with such lack of location capabilities, terminal operations register every container movement, and, therefore, its relative location, by means of CHE movement registries. Until the 2010s, this registration was manual, so that if the person in charge of registering, made a mistake (wrongly locating it or forgetting to register it), **container traceability was lost**.

Therefore, several issues were needed to be solved.

1) Automatic CHE identification problem: not all crane machines carry RFID readers, so that the movement must be registered manually. It can also happen that the RFID reading is not correct, or PDS for any IT/communications/electrical incident is deactivated, ceasing to record movements.
2) Container recognition: The driver does not know exactly what container number is being transported, potentially loading a wrong container. Moreover, external trucks (that do not belong to the terminal company) do not have access to the TOS, and they are only informed of their job order when accessing the port gates with some printed papers.

It should be noticed that even considering a proper use of latest PDS/RFID/OCR/TOS operating systems, they provide a general overview of where all the containers and CHEs in the terminal are located. Hence, current job orders assigned to both internal and external drivers only notify the bay number in which the containers they have to be loaded/unloaded, and with the help of which RTGs. The lack of additional contextual information leads to **lower operational efficiencies.** For example, it may happen that the assigned container to a truck driver arrives to a terminal later than the initial Estimated Time of Arrival (ETA) of a ship. This would lead to an increase of waiting/idling truck driver time, until vessel finally arrives. Furthermore, only terminal administrators have access to the reported data (about containers movements and /or CHEs (geo)localization).

<table>
<tr><th colspan="3">Business scenario</th></tr>
<tr><td>Scenario ID
BS-P1-1</td><td colspan="2">Scenario name
Tracking assets in terminal yard</td></tr>
<tr><td rowspan="3">Illustration of system's behaviour in a specific situation,
flow of events</td><td colspan="2">The main problem to solve is to enable traceability of containers within the port to avoid losing them, and to enhance the operational efficiency of terminal operators (including internal-external drivers). To achieve this, the positions of all CHEs within the yard, including external trucks as well, must be tracked. Additionally, CHEs using PDS or other external positioning system report all container handling operations, such as picking up and placing down a container by an RTG, or being loaded or unloaded by a TT. The containers being handled must be identified by CHEs, either automatically or manually by the driver.

All this information is combined in the TOS in order to track the location of all containers and CHEs within the yard. ASSIST-IoT's edge-oriented and scalable architecture (by means of containerized microservices) will allow to reuse the gathered information on the edge, so that those actors that require this type of data from specific assets can obtained in a fast and secure manner.</td></tr>
<tr><td>User/users:</td><td>• Terminal management
• CHE drivers</td></tr>
<tr><td>Setting / context</td><td>Port terminal</td></tr>
</table>

	Interacting system	Terminal Operating System (TOS), Container Identification System, Device with Temporary ID (for External drivers), Frontend adapted to mobile screens
	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, 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 must have received a mobile device with a temporary identity.
	Interaction	Terminal managers – viewing the position of all CHEs and containers in the yard using the TOS and PDS. Historical data collection. CHE 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	Gain better insight into the operational status of the port, monitoring the situation in real-time, and limiting idling periods. Improve container traceability and minimize the number of containers lost. Create a robust/secure/private system for tracking assets and reusing that information on the edge.
	Time	Ongoing operation of the terminal yard.
System functionalities	TBD	
Identified by	TL, PRODEVELOP	

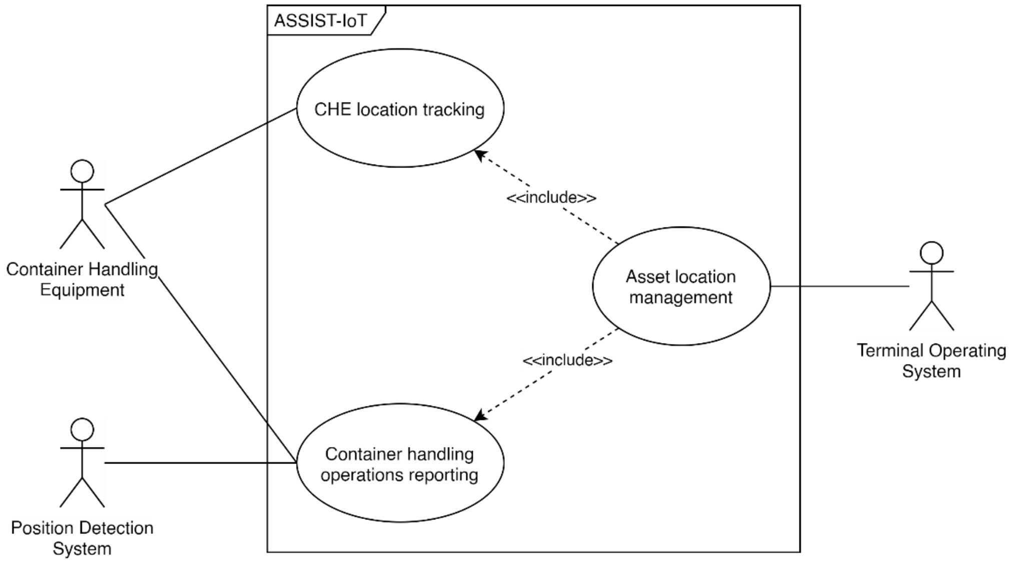


Figure 4. Use case diagram for the "Tracking assets in terminal yard" business scenario

3.4.3. UC-P1-1: Asset location management

Use Case	
ID	UC-P1-1
Name	Asset location management
Description	All assets (CHEs and containers) within the terminal yard are continuously tracked. The information can be made available to authorized actors.
Reference Scenario	Tracking assets in terminal yard
Plane(s)	Device and Edge, Smart Networking and Control, Applications and Services
Vertical Capabilities	Cybersecurity components, Manageability and control, DLT decentralized infrastructure for privacy, trust and interoperability
Functionalities within vertical capabilities	TBD
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
Pre-conditions	CHEs are equipped with devices for reporting their operational status.
Trigger	N/A
Expected results	End-user is presented with information about assigned asset's location in a given moment.
Design preferences	Location management shall be done in an edge-oriented, distributed, and scalable manner.
Extends the use case (if applicable)	N/A

Includes the use case	• **UC-P1-2** (CHE location tracking) • **UC-P1-3** (Container handling operations reporting)
Notes and issues	Access control to the CHE geolocalization data
Main execution flow	1. CHEs report their location and container handling operations (UC-P1-2, UC-P1-3) 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 information to other actors with necessary authorization (see for example UC-P1-7)
Alternative execution (if applicable)	N/A
Exceptions (if applicable)	N/A
Requirements involved	R-C-1, R-C-2, R-C-3, R-P1-1, R-P1-2, R-P1-4, R-P1-6, R-P1-9
KPI	All CHEs involved in the real-time demo will be located
Identified by:	TL, PRODEVELOP

3.4.4. UC-P1-2: CHE location tracking

Use Case	
ID	UC-P1-2
Name	CHE location tracking
Description	The location of all container handling equipment (CHE) within the port is always known.
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 enablers
Functionalities within vertical capabilities	TBD
Objectives	ASSIST-IoT is constantly aware of the position of every CHE with accuracy of ±0.5m.
Actors (system actor or natural persons)	• CHE
Pre-conditions	• CHE is within a defined operational area
Trigger	• CHE is turned on

Expected results	CHE position is reported to the ASSIST-IoT.
Design preferences	Technologies that can be used: • GPS – accurate for machines with permanent Line of Sight with satellite transponders, stops working reliably otherwise. • BLE – using beacons placed within the terminal yard
Notes and issues	
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)	2a. CHE is unable to retrieve its absolute location, or the measurement precision is too low 2a.1. CHE determines its relative location using nearby beacons and/or machines 2a.2. CHE reports its relative location to ASSIST-IoT 2a.3 ASSIST-IoT translates the relative location into absolute coordinates
Exceptions (if applicable)	In the case there is no network connectivity temporarily, the information will be buffered locally and retransmitted later.
Requirements involved	R-C-1, R-C-2, R-C-3, R-P1-6, R-P1-7, R-P1-8, R-P1-9
KPI	CHE location with accuracy of 0.5m
Identified by:	TL, PRODEVELOP

3.4.5. UC-P1-3: Container handling operations reporting

Use Case	
ID	UC-P1-3
Name	Container handling operations reporting
Description	CHE carrying out a work order reports every container being handled to the system, including the type of action performed.
Reference Scenario	Tracking assets in terminal yard
Plane(s)	Device and Edge, Smart Network and Control, Data Management, Application and Services
Vertical Capabilities	DLT decentralized infrastructure for privacy, trust and interoperability
Functionalities within vertical capabilities	TBD
Objectives	To enable container tracking 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 operation is reported to the asset location management system.
Design preferences	Reporting methods: • CHEs equipped with PDS should report this automatically. The PDS is a system detecting the machine's movements that is able to recognize container handling operations. • 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). • Otherwise, the container has to be identified manually by the driver. • In some cases (e.g., for truck drivers) the identification will be impossible to perform. Then, ASSIST-IoT has to assume the container being handled is the one that was specified in the work order.
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 container 2. CHE identifies the container 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
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-C-1, R-C-2, R-P1-1, R-P1-10,
KPI	All CHEs involved in the real-time demo will report every related movement of containers
Identified by:	TL, PRODEVELOP

3.5. BS-P1-2: Automated CHE cooperation

During the last decades, technological innovations in cargo handling equipment have made it possible to automate certain processes in container terminals. Despite the increasing terminal automation, automated cooperation of CHEs (e.g., container/STS crane, ship/STS crane, etc.) is actually done manually, or driven by a semi-aid out-of-the box systems provided by CHE proprietary and non-integrated solutions OEMs. In the port industry, the RTG-spreader has very little mobility (about 40 cm at most) when one RTG crane must pass the load to a truck. Consequently, before starting the cargo transfer process, both CHEs must be very aligned between legs on the assigned yard-street (±20 cm in one direction, and ±50 cm in the other). 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.

Business scenario		
Scenario ID BS-P1-2	**Scenario name** Automated CHE cooperation	
Illustration of system's behaviour in a specific situation, **flow of events**	Enhance the operational performance by the CHEs cooperation from an alignment automation perspective. The machines should be able to identify and authenticate each other before starting the operation. Then, the RTG guides the truck (TT or external) to the correct position using LIDAR sensors. The guidance can be provided in a variety of ways, depending on the type of truck. For unmanned vehicles, this can be achieved using machine-to-machine communication. Manned vehicles can be signalled using positioning guidance traffic lights, or through some movement recommendation on mobile application available in truck driver's cabin.	
	User/users:	• RTG operator • Truck operator
	Setting / context	Port Terminal
	Interacting system	TOS, Container Identification System, LIDAR, Traffic lights, Mobile application
	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 to be performed by them cooperatively (container transfer).
	Interaction	NA
	Data	Location of the truck, work order information, LIDAR information, Movement recommendations
	Motivation	Improve the efficiency and safety of the RTG-truck alignment process.
	Time	
System functionalities	Machine-to-machine communication, CHE mutual authentication and identification, machine-to-human communication	
Identified by	TL, PRODEVELOP, KONECRANES	

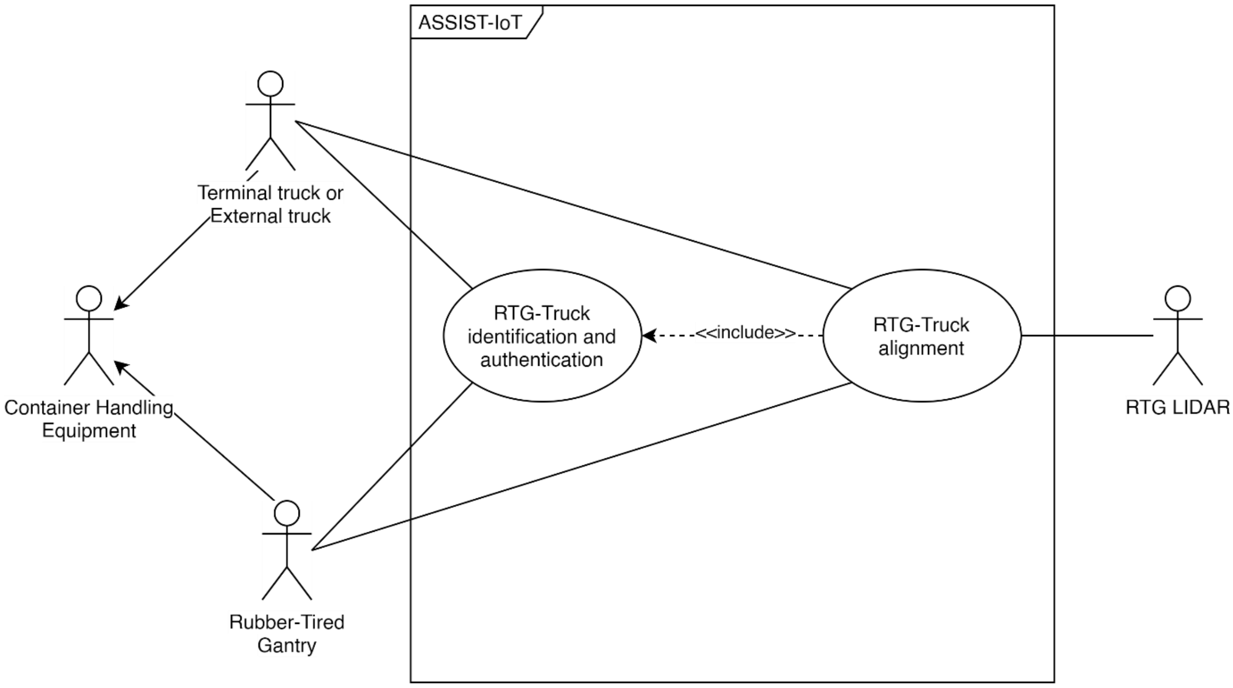


Figure 5. Use case diagram for the "Automated CHE cooperation" business scenario

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

Use Case	
ID	UC-P1-4
Name	RTG-truck identification and authentication
Description	RTG and the truck identify each other upon the TT approaching the RTG.
Reference Scenario	Automated CHE cooperation
Plane(s)	Device and Edge, Smart Networking and Control, Data Management? Applications and services
Vertical Capabilities	Cybersecurity component
Functionalities within vertical capabilities	TBD
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 TT is assigned a work order to perform with the RTG • The external truck driver was given a mobile device and is assigned to an operation with the RTG • The RTG is assigned a work order to perform with the TT or external 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 geofencing and location sensors on the truck.
	• The communication should be able to be performed directly between the machines, without any third party.
	• If manned operations are needed:
	  ○ For terminal tractors, the identification on its side should be handled by a mounted device with a screen (e.g., a tablet).
	  ○ For external trucks, the identification on its side should be handled by a mobile device given to the truck driver (e.g., a tablet).
	• The RTG should have an embedded device to handle the authentication..

Notes and issues	
Main execution flow	1. The truck approaches the RTG 2. ASSIST-IoT detects the truck is in proximity of the RTG 3. ASISST-IoT establishes a connection between the truck and the RTG 4. Using ASSIST-IoT, the truck sends its ID to the RTG. The RTG sends its ID to the truck 5. Using ASSIST-IoT, RTG verifies the truck’s ID, and confirms if it is the one that it was in principle expected. The truck verifies RTG’s ID, and determines it is the one that it was assigned to its work order. 6. RTG and truck can commence the cooperation.
Alternative execution (if applicable)	3a. ASISST-IoT establishes a connection between the mobile app (truck’s driver) and the RTG 3a.1 Using ASSIST-IoT, the mobile app sends truck ID to the RTG. The RTG sends its ID to the mobile app. 3a.2 Truck operator verify if the RTG ID is the assigned to its work order. 3a.3 Using ASSIST-IoT, RTG verifies the truck’s ID, and determines it is the one that it was expected. 3a.4 Proceed to step 6
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	All CHEs involved in the real-time demo will be identified and handshake processes in all demo scenarios will be fulfilled.
Identified by:	TL, PRODEVELOP, KONECRANES

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

Use Case	
ID	UC-P1-5
Name	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 hardware present on the truck.
	  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	

Main execution flow	1. The RTG and the truck are mutually identified and authenticated (UC-P1-4).
	2. Repeat until aligned:
	  a. ASSIST-IoT receives a request from the RTG LIDAR to 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
	3. The truck stops
	4. Using ASSIST-IoT, the truck signals to the RTG that it is ready for the container loading/unloading operation.
	5. RTG loads/unloads the container on/from the truck
	6. 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	TBD
Identified by:	TL, PRODEVELOP, KONECRANES

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

In a traditional container terminal layout, the yard cranes can be manned-RTGs or manned-RMGs. 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 6): 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%.

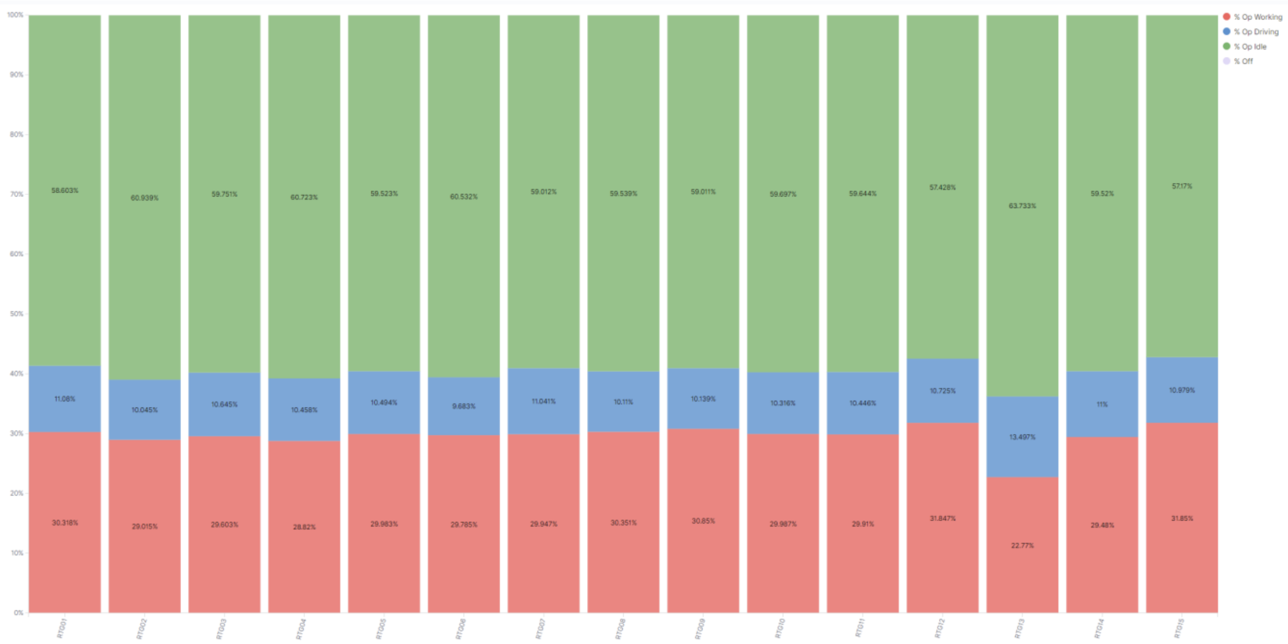


Figure 6. Average MFT RTG time breakdown during 60 days (working - red, gantrying – blue, idle - green)

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 takes 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 crane operators themselves.

Remote operation allows for the control several cranes by one driver who can virtually jump from one location to another. This allows to optimize 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).

Business scenario	
Scenario ID BS-P1-3	**Scenario name** RTG remote control with AR support
Illustration of system's behaviour in a specific situation, **flow of events**	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. Success of

	implementing this pilot testbed will ultimately unleash two main impacts: improvement of the working conditions of thousands 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.
	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.
	Initial status	There is a stable connection between the RTG and RTG remote operator terminal.
	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	
Identified by	TL, PRODEVELOP, KONECRANES	

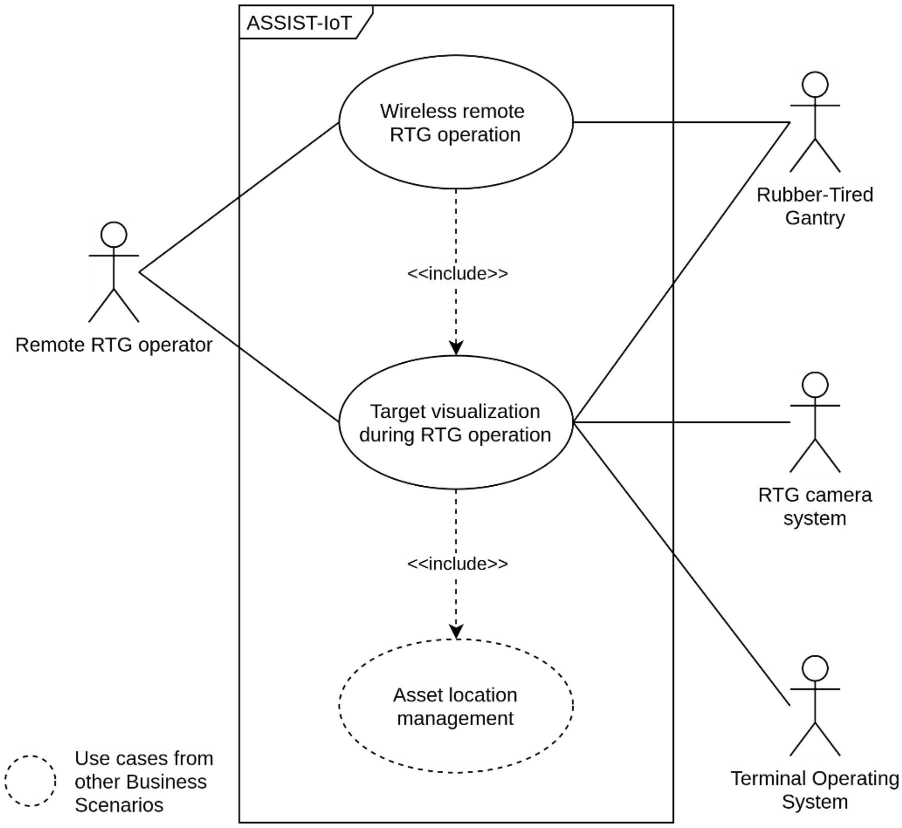


Figure 7. Use case diagram for the "RTG remote control with AR support" business scenario

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

Use Case	
ID	UC-P1-6
Name	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	TBD
Objectives	Allow for wireless remote operation of RTGs.
Actors (system actor or natural persons)	• Remote RTG operator • RTG
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 controlling an RTG remotely is already available in the market (although not deployed in MLFT 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	
Main execution flow	1. The operator receives work orders on their terminal 2. The operator selects the work order to perform from their terminal 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, R-P1-25
KPI	RTG idling time is reduced from 60% up to 25% (35% savings)
Identified by:	TL, PRODEVELOP, KONECRANES

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

Use Case	
ID	UC-P1-7
Name	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 and where should it be placed afterwards and indicating crane positioning
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-P1-1** (Asset location management)
Notes and issues	
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. ASSIST-IoT guides the operator to the container 5. The RTG camera system provides the video feed from the RTG 6. ASSIST-IoT identifies the container to be picked up in the video feed, based on the previously retrieved information 7. ASSIST-IoT provides AR support to the operator by highlighting the container to be picked up on the RTG video stream from the RTG camera system. 8. The operator orders the RTG to pick up the container 9. ASSIST-IoT guides the operator to the target yard slot 10. ASSIST-IoT identifies the target slot in the video feed 11. ASSIST-IoT provides the operator with AR video feed from the RTG camera system. The target slot is highlighted 12. The operator orders the RTG to place the container
Alternative execution (if applicable)	N/A
Exceptions (if applicable)	N/A

Requirements involved	R-C-2, R-C-5, R-C-7, R-P1-18, R-P1-19, R-P1-20, R-P1-21, R-P1-22, R-P1-23, R-P1-24, R-P1-25
KPI	Object (i.e., container) detection mean Average Precision > 75%
Identified by:	TL, PRODEVELOP, KONECRANES

4. Pilot 2: Smart safety of workers

All the stakeholders involved in the procurement of small or large, private or public infrastructure works have a vested interest in maintaining a safe construction environment. Compliance with occupational safety and health regulations, and managing the related risk, at the construction site is of outmost priority to construction companies and the relevant administrative bodies, such as the European Agency for Safety and Health at Work (EU-OSHA). The owner of a project expects the smooth operation of the construction site and timely commissioning of the project within budget. The main contractor has to manage large complex and unpredictable environments, deliver on time and make a profit while ensuring the safety of everyone in or around the construction site. 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. Their training, good practices and risk prevention culture provides construction workers with a layer of protection but does not guarantee the aversion of all hazards. 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 at any worksite 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 the construction processes that keeps the human in the forefront. The main objective of ASSIST-IoT in this application area is the prevention and near real-time detection of common 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.

Table 6. Actors in the "Smart safety of workers" pilot

Actor	Implements	Type	Description
Construction worker		Person	They are occupied at a building construction project. Their day-to-day work involves erecting temporary and permanent structures, craftwork, using various types of tools and lifting objects • The job often involves working outside or in confined spaces under extreme temperatures or other unfavourable weather conditions • They have to comply with health and safety regulations and report any incidents or unsafe practices. • This role includes site office employees such as engineers, managers, administrators, etc., as they work within the construction site often perform duties at the various worksites. Employees who are subcontracted by the main contractor are also included.
Construction plant operator	Construction worker	Person	• Operates construction plant. They are employed by companies that are subcontracted by the main contractor that manages the project and the construction site. When

			the Construction worker's wristband is close to the Construction Plant's device, the Worker becomes an Operator
Occupational Safety and Health (**OSH**) manager		Person	• They are responsible for overseeing compliance to OSH regulations and for managing the related risks at the construction site
OSH inspector		Person	• Conducts on-site inspections in order to verify compliance with OSH regulations • Inspections may be conducted by external auditors or senior construction site employees, e.g., construction managers, senior engineer etc.
Building Information Modelling (**BIM**) system		System	• The system of software systems and services that are used for hosting and authoring the digital description of every aspect of the built asset. • Contains 2D and 3D geometric information (as-designed and as-is in CAD, GIS or text format) along with associated information related to the construction schedule, construction methods, cost, performance, safety hazards, etc. • Hosted on the Common Data Environment (CDE), which is the agreed source of information for any given project or asset, for collecting, managing and disseminating each information container, in various digital formats, through a managed process. • The Building Information Modelling process and the Building Information Model itself are described in detail in the project's BIM Execution Plan (BEP) • Contains OSH and quality assurance information which is used to manage and communicate with companies that are subcontracted to work on the project on behalf of the main contractor
Smart fall arrest equipment		System	• Enables the safe stopping of a person who is already falling in order to prevent any further injury. • It provides freedom of movement to the workers while working at height allowing them to reach the point where a fall could occur, such as the edge of a roof. • In the event of a fall, the fall will be arrested and the person will either return to safety or be rescued.
Controlled-access point		System	Doors or gates providing access to areas where entry is controlled and requires authorisation.

4.4. 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 giving emphasis to personal data protection and user-friendliness. Minimising intrusiveness that causes distraction from normal activities will be a priority in order to gain user acceptance.

Business scenario		
Scenario ID BS-P2-1	**Scenario name** Occupation safety and health monitoring	
Illustration of the system's behaviour in a specific situation, flow of events	Use of personal protective equipment is required at any construction site. Proper use of the personal protective equipment that is required for each construction activity should be ensured. The physiological parameters of the construction workers are being monitored in real-time using wearable sensors in order to ensure that their health and safety is 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 assessment is based on combining measurements and information related to their identity, training and medical records as well as their assigned activity for the day; environmental conditions are also taken into account, 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. The main gate to the construction site, and any secondary access points (gates and doors), are controlled and only authorised construction workers and Plant (e.g., excavators) are permitted entry. Interfaces between construction workers and construction plant (red zones) are also monitored as the system is able to detect when a construction worker operates in the construction plant. The motion patterns of the construction workers are also monitored in order to ensure that they haven't suffered a severe forceful impact, e.g., fall from height or hit by a vehicle, and that they are not immobile, e.g., unconscious after a fall. 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 are manually provided from the entire workforce via existing management and collaboration platforms in order to assess and report the overall risk status for the construction site.	
	User/users:	• Construction worker • OSH manager • Construction plant operator

	Setting / context	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.
	Interacting system	Wearable sensors and actuators (e.g., thermometer, cooling system etc.), BIM system, weather station, PPE tags.
	Users' goals	• Ensure the construction workers' health and safety at the worksite (including crane operator) • 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 an 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.
	Initial status	All the construction workers wear their personal protective equipment and smart wearables. A construction worker may be operating 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.
	Interaction	Smart devices and wearables are paired together in order 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.
	Data	Location and proximity data, physiological parameter measurements, weather conditions measurements, personal identification information, training and medical records, building information, users' thermal comfort preferences, alerts and notifications.
	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	**General description**: Device-to-Device communication, parameter monitoring and analysis	
Identified by	MOW, CIOP-PIB	

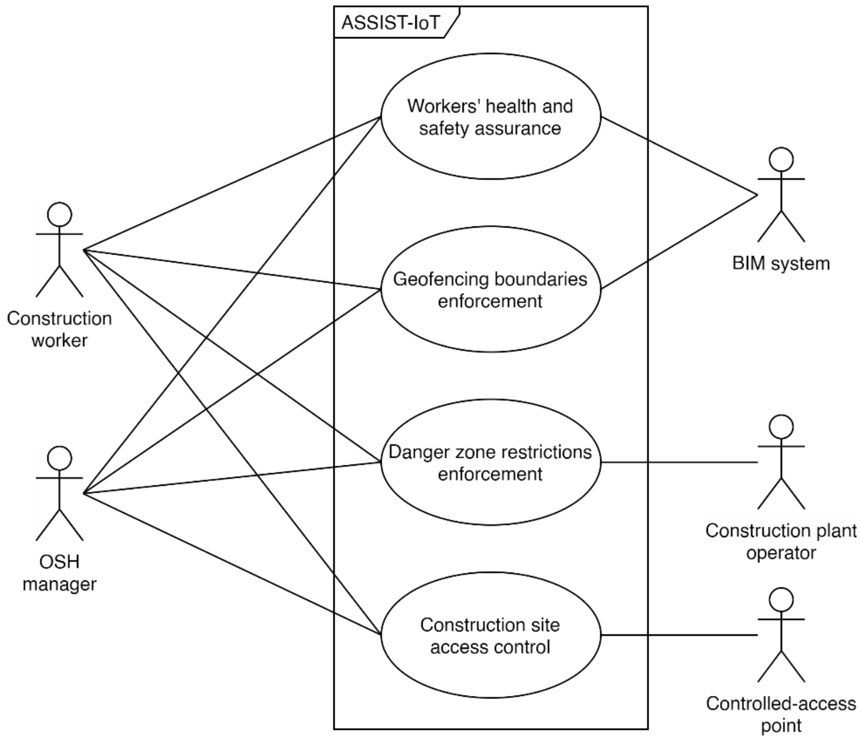


Figure 8. Use case diagram for the "Occupation safety and health monitoring" business scenario

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

Use Case	
ID	UC-P2-1
Name	Workers' health and 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 • Detect construction worker's slips, trips, falls and immobility • Prevent unauthorised access to restricted construction zones • 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 • Unauthorised access to restricted worksite zones is prevented • The construction site's incident log is updated
Design preferences	• Wristbands for personal identification, physiological parameters and location monitoring, alarm button and notification interface. • Weather conditions and air quality monitoring station • Personal cooling system, with a user interface, integrated with the vest • Identification devices inside the construction plant's cabin and at the controlled-access points • Tags integrated with PPE • Thin film capacitive sensor and/or identification tag inside the protective helmet • Federated learning with DLT support in order to keep sensitive data at the edge and record any detected incidents
Extends the use case	N/A
Includes the use case	N/A
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 and UC-P2-3) 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, and the motion pattern of the construction worker's body 5. ASSIST-IoT analyses all the collected data from all 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 analyses the motion patterns of the construction worker in order to verify that they are normal with respect to their assigned activity 7. 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 an access-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 5a.4. ASSIST-IoT notifies the OSH manager about the incident 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 6a. ASSIST-IoT detects abnormal motion patterns 6a.1. ASSIST-IoT notifies 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-C-1, R-C-2, R-C-3, R-C-5, R-C-6, R-C-7, R-P2-1, R-P2-3, R-P2-4, R-P2-6, R-P2-7, R-P2-8, R-P2-9, R-P2-10, R-P2-11, R-P2-12, R-P2-16, R-P2-17
KPI	Incident detection time; user acceptance, friendliness and usability. Successful lab tests before on-site deployment of devices that detect life-threatening incidents
Identified by	MOW, CIOP-PIB

4.4.4. UC-P2-2: Geofencing boundaries enforcement

Use Case	
ID	UC-P2-2
Name	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	TBD
Objectives	• Prevent construction workers from entering areas without authorisation
Actors (system actor or natural persons)	• Construction worker • BIM system • OSH manager
Pre-conditions	Restricted areas are defined in the system (GPS coordinate of Construction plants, dangerous area, within the BIM System) by the OSH manager
Trigger	Time-based, continuous monitoring while the construction worker is in the construction site
Expected results	• Construction workers are alerted • 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	N/A
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
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
Exceptions	N/A

Requirements involved	R-C-7, R-P2-1, R-P2-3, R-P2-11, R-P2-12, R-P2-15
KPI	All movements within a monitored boundary are detected and reported.
Identified by	MOW, CIOP-PIB

4.4.5. UC-P2-3: Danger zone restrictions enforcement

Use Case	
ID	UC-P2-3
Name	Danger zone restrictions enforcement
Description	Enforce dynamic geofencing in the zone around construction plant in operation
Reference Scenario	BS-P2-1
Plane(s)	Device and Edge, Application and Services
Vertical Capabilities	Interoperability
Functionalities within vertical capabilities	Self-awareness, devices interoperability
Objectives	• Support construction plant operators to avoid hazardous situations • Protect construction workers in the vicinity of operating Construction Equipment
Actors (system actor or natural persons)	• Construction plant operator • Construction worker • OSH manager
Pre-conditions	Construction plant is in operation
Trigger	Construction plant in operation and construction worker are in close proximity
Expected results	• The construction plant operator is aware of hazards • Construction workers are prevented from entering the danger zone near the operating construction plant • The OSH manager is notified about any unsafe behaviour or incidents • The construction site's incident log is updated
Design preferences	The construction plant is equipped with an identification device inside the operator's cabin which is paired with the Construction Operator's wristband. The location of the construction plant is tracked via the location of their operator. The proximity of a construction worker to the construction plant could be detected either directly (direct geolocation) or indirectly (machine-to-machine). The construction plant's identification device could also include the 3D model of the plant and its orientation so that it's volume can be taken into account if properly calibrated.
Extends the use case	N/A
Includes the use case	N/A

Notes and issues	N/A
Main execution flow	1. ASSIST-IoT is aware that a construction worker is operating the construction plant and assigns them the construction plant operator role. 2. ASSIST-IoT verifies that no construction workers is within the danger zone around the construction plant 3. ASSIST-IoT alerts the construction plant operator and notifies the OSH manager when the risk level exceeds a predefined threshold
Alternative execution	2a. ASSIST-IoT detects that a construction worker is within the danger zone around the construction plant 2a.1. ASSIST-IoT alerts the construction plant operator and the construction worker and notifies the OSH manager
Exceptions	N/A
Requirements involved	R-C-7, R-P2-1, R-P2-3, R-P2-5, R-P2-12
KPI	No worker within the red zone of operating plant goes unnoticed by the operator while the number of false alarms to the operator is minimised.
Identified by	MOW, CIOP-PIB

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

Use Case	
ID	UC-P2-4
Name	Construction site access control
Description	Control access to the construction site and any worksite within. Applies to both construction workers and construction plant.
Reference Scenario	BS-P2-1
Plane(s)	Device and Edge, Application and Services
Vertical Capabilities	Security, Privacy and Trust, Interoperability
Functionalities within vertical capabilities	TBD
Objectives	• Verify that construction workers have permission to enter based on medical tests and safety trainings • Verify that both the construction plant and its operator are authorised to enter or leave a 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 plant and construction workers

Trigger	A construction worker or plant approaches a controlled-access point for entry or exit.
Expected results	• Only authorised construction workers and plant, which are operated by trained personnel, are granted entry
Design preferences	• Identification device mounted in the cabin of construction plant • Device to handle the authentication at the controlled-access point • The communication should be able to be performed directly between the machines, without any third party.
Extends the use case	N/A
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 and the controlled-access point exchange IDs via ASSIST-IoT 4. ASSIST-IoT verifies that the construction worker is authorised to pass through the controlled-access point 5. ASSIST-IoT grants access and logs the event
Alternative execution	4a. The construction worker is operating construction plant 4a.1. ASSIST-IoT verifies that the construction plant is operated by an authorised construction worker and that they are both authorised to pass through the controlled-access point 4a.2. ASSIST-IoT proceeds to step 5 5a. ASSIST-IoT does not grant access 5a.1. ASSIST-IoT notifies the OSH manager and logs the event
Exceptions	N/A
Requirements involved	R-C-3, R-P2-1, R-P2-2, R-P2-3, R-P2-5, R-P2-12
KPI	Minimise delays especially at busy unsupervised access points.
Identified by	MOW, CIOP-PIB

4.5. BS-P2-2: Fall arrest monitoring

Business scenario		
Scenario ID **BS-P2-2**	**Scenario name** Fall arrest monitoring	
Illustration of the system's behaviour in a specific situation, flow of events	A construction worker is working at height and uses smart fall arrest equipment to attach themselves to an anchor point. If the worker falls off the platform they are standing on, the smart fall arrest equipment will prevent them from falling on the ground. If the worker is able to return to the safety of the platform, 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 the smart fall arrest equipment, an alert should be raised and help should be sent to the location of the incident immediately.	
	User/users:	A construction worker using smart fall arrest equipment in order to attach themselves to an anchor point.
	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.
	Interacting system	An activation detector is connected in line to typical smart fall arrest equipment
	Users' goals	• Receive urgent help if a construction worker is suspended from the smart fall arrest equipment, after a fall, and unable to return to safety • 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 using the smart fall arrest equipment
	Interaction	The construction worker is attached to the smart fall arrest equipment that includes an activation detector. The construction worker's smart wearable device is paired to the fall arrest detector and transmits its status and location.
	Data	• Identity of the user • Status of the fall arrest detector • Location of the incident
	Motivation	• Provide help to a construction worker suspended in the air by a fall arrest system and avoid suspension trauma.
	Time	Continuous monitoring which is activated when the construction worker is using the smart fall arrest equipment
System functionalities	**General description:** Device-to-device communication, geolocation, alerting	
Identified by	MOW, CIOP-PIB	

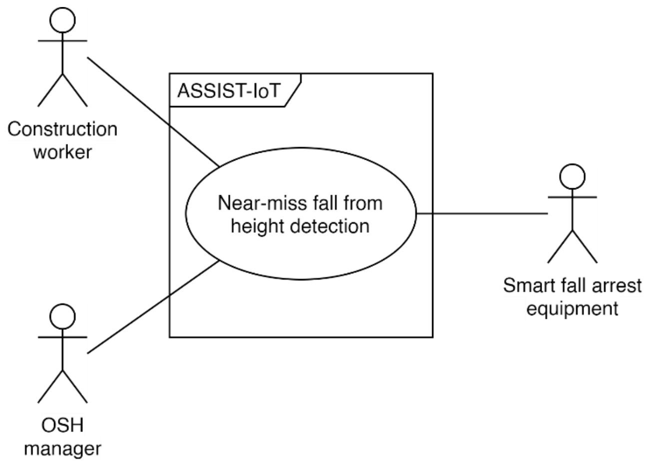


Figure 9. Use case diagram for the "Fall arrest monitoring" business scenario

4.5.3. UC-P2-5: Near-miss fall from height detection

Use Case	
ID	UC-P2-5
Name	Near-miss fall from height detection
Description	Identify any incident related to a construction worker suspended by their smart fall arrest equipment by attaching a deployment detection device to it.
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, TBC
Objectives	• Detect the deployment of smart fall arrest equipment • Notify first responders when a construction worker is suspended from their smart fall arrest equipment
Actors (system actor or natural persons)	• Construction worker • Smart fall arrest equipment • OSH manager
Pre-conditions	The worker uses the smart fall arrest equipment which is attached to an anchor point
Trigger	The smart fall arrest equipment is paired to the construction worker who is using it
Expected results	• The construction worker is rescued in case of an incident • The construction site's incident log is updated
Design preferences	A fall arrest detector is connected to the smart fall arrest equipment. The detector can be paired to the user's wearable device
Extends the use case	N/A

Includes the use case	N/A
Notes and issues	N/A
Main execution flow	1. ASSIST-IoT pairs the smart fall arrest equipment with the construction worker and tracks their location 2. ASSIST-IoT monitors the status of the smart fall arrest equipment 3. ASSIST-IoT detects the activation of the smart fall arrest equipment 4. ASSIST-IoT detects the subsequent deactivation of the Fall Arrest System and notifies the OSH manager about the incident 5. ASSIST-IoT records the incident
Alternative execution	4a. The smart fall arrest equipment remains activated 4a.1. The OSH manager is notified by ASSIST-IoT and sends the rescue team to the location of the incident
Exceptions	N/A
Requirements involved	R-C-3, R-C-7, R-P2-1, R-P2-3, R-P2-5, R-P2-12, R-P2-13, R-P2-16
KPI	Acceptable detection time; user acceptance, friendliness and usability. Successful lab tests before on-site deployment of devices that detect life-threatening incidents
Identified by	MOW, CIOP-PIB

4.6. BS-P2-3: Safe navigation

Business scenario		
Scenario ID BS-P2-3	**Scenario name** Safe navigation	
Illustration of the system's behaviour in a specific situation, flow of events	A construction worker requests navigation instructions from their current location to a worksite. They should follow approved walking paths through areas the worker is authorised to access. In case of an emergency the workers receive evacuation instructions along predefined routes. The emergency routes are updated by the OSH manager according to the evolving situation based on the routes followed by safely evacuated workers. All paths and routes should be indicated on the BIM.	
	User/users:	Construction workers navigating to a worksite where they need to perform a task or evacuating the construction site during an emergency.
	Setting / context	A construction site; in particular, a building under construction.
	Interacting system	Mobile devices, BIM system.
	Users' goals	• Arrive at the desired destination within an ever-changing environment • Safely move away from hazards

	Initial status	The construction worker is at the construction site
	Interaction	The construction worker requests navigation instructions from their current location to a worksite. The construction worker receives evacuation instructions during an emergency and confirms safe evacuation.
	Data	• Location data • Navigation instructions along predefined or dynamically updated routes
	Motivation	Construction workers need support while moving around as the area around a building under construction is constantly changing. Navigations instructions are required by all workers during an emergency situation in order to be safely guided to the designated assembly area or by persons who have not been on the construction site before so that they can find their way to a specific worksite.
	Time	Navigation instructions are provided on demand after a construction worker requests it or during an emergency.
System functionalities	**General description**: Geolocation, device-to-device communication	
Identified by	MOW, CIOP-PIB	

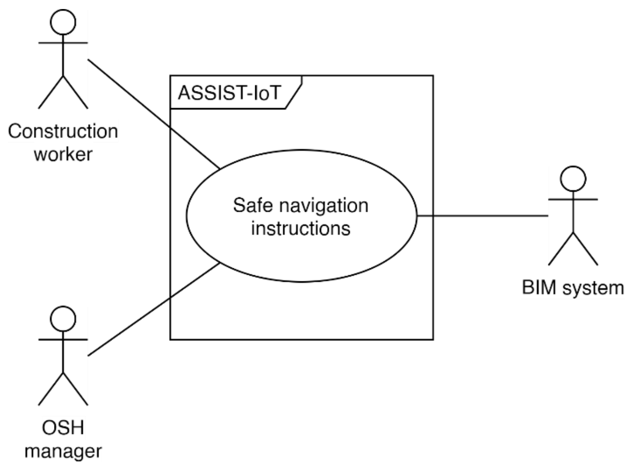


Figure 10. Use case diagram for the "Safe navigation" business scenario

4.6.3. UC-P2-6: Safe navigation instructions

Use Case	
ID	UC-P2-6
Name	Safe navigation instructions
Description	Provide construction workers with navigation instructions during normal operating conditions and safe evacuation instructions during an emergency.
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
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	N/A
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	
Requirements involved	R-C-3, R-C-5, R-C-7, R-P2-1, R-P2-12, R-P2-14, R-P2-15
KPI	Safe arrival at the destination without passing through hazardous or inaccessible areas. Clarity of navigation instructions based on user feedback.
Identified by	MOW, CIOP-PIB

4.7. BS-P2-4: Health and safety inspection support

Business scenario		
Scenario ID BS-P2-4	**Scenario name** Health and safety inspection support	
Illustration of the system's behaviour in a specific situation, flow of events	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 the nature of the activity and the safety plan that needs to be followed. 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
	Users' goals	Conduct an inspection to ensure that they have checked all the necessary requirements for the inspected activities
	Interaction	The OSH inspector receives relevant information on a portable device
	Initial status	The OSH inspector is at the construction site office getting ready to conduct an inspection at different worksites
	Data	Work briefs, safety procedures, required PPE for each type of activity at any location, workers' training records.
	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.

	Time	On demand; initiated by the OSH inspector.
System functionalities	**General description**: Decision support, AR visualization, Data safety and security	
Identified by	MOW, CIOP-PIB	

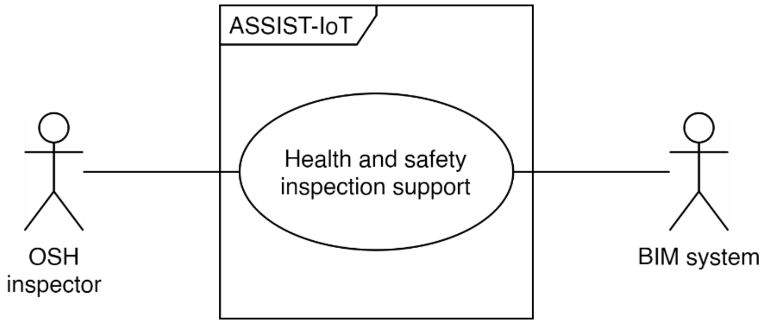


Figure 11. Use case diagram for the "Health and safety inspection support" business scenario

4.7.3. UC-P2-7: Health and safety inspection support

Use Case	
ID	UC-P2-7
Name	Health and safety inspection support
Description	Provide relevant information to a person that conducts a health and safety inspection at the construction site
Reference Scenario	BS-P2-4
Plane(s)	Data Management, Application and Services
Vertical Capabilities	Security, Privacy and Trust
Functionalities within vertical capabilities	TBD
Objectives	Provide the OSH inspector with information about: • the type of activity that is being performed at their location • the safety measures that have to be followed for the type of activity • the training records of the construction workers that participate in the activity
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 a certain time that is linked to details about the necessary safety measures.
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	Augmented Reality Glasses
Extends the use case	N/A
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-C-5, R-C-7, R-P2-1, R-P2-3, R-P2-5, R-P2-12, R-P2-15
KPI	Completeness and duration of information retrieval. Perceived efficiency of the inspection.
Identified by	MOW, CIOP-PIB

5. Pilot 3: Cohesive vehicle monitoring and diagnostics

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 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 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, supplier and operators of rental cars or vans or shared mobility services, fleet managers, 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.

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 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 based on 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, will 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.

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[18] [19] • 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.

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

[19] ~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

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

The certification of vehicle emissions, before the adoption of the Euro 7 standards[20], 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 makes reference to tests to 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 aftertreatment and 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 to avoid incertitude when tested through ISC procedure.

Business scenario	
Scenario ID BS-P3A-1	**Scenario name** Fleet in-service conformity verification
Illustration of the system's behaviour in a specific situation, flow of events	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

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

	vehicles before it is deployed to the entire fleet. Any vehicles with a non-conforming emissions profile are identified.	
	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 as 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.
	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 describing 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 provide for 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	**General description**: Device-to-device communication, real-time monitoring and data analysis, federated learning, alerting	
Identified by	FORD-WERKE	

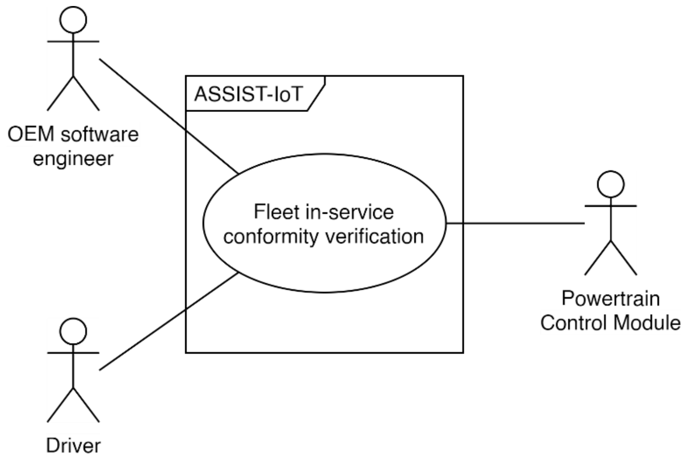


Figure 12. Use case diagram for the "Fleet in-service conformity verification" business scenario

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

Use Case	
ID	UC-P3A-1
Name	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 to the emission regulations • Vehicles that exceed the emission thresholds are identified
Design preferences	Local resource processing unit integrated to the PCM, capable to support 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 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. 6a.1. ASSIST-IoT uses the already available emissions models to automatically define and deploy updates to the Powertrain Control Module parametrisation of 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	
Requirements involved	R-C-1, R-C-2, R-C-3, R-C-6, 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	Estimate statistically significant results, at a 95% confidence level, from the comparison between the legal and the empirical emissions distribution.
Identified by	FORD-WERKE, UPV

5.5. 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 operation. The advantage of this approach over the current OBD system is twofold: on one hand, the methods can be evolved along 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 to develop advanced diagnostics with expected higher failure identification capabilities.

Business scenario	
Scenario ID BS-P3A-2	**Scenario name** Vehicle diagnostics
Illustration of the system's behaviour in a specific situation, flow of events	If any of the vehicle's emissions profile is considered to be an outlier or there is suspicion about potential defects the problem is diagnosed. The OEM software engineer may update the on-board diagnostics methods in order to identify the source of the fault if existent methods are not able to do it. If needed, the vehicle is put on active monitoring. The OEM software engineer is able to update the Powertrain Control Module parameterisation of the vehicles equipped with the high-fidelity sensors in order to monitor how it affects the emissions measurements and generate emissions models. When the on-board diagnostics identify the faulty part, the driver is informed to bring the vehicle to a garage. OEM

	Aftersales Manager is informed about the detected failure to proactively send spare parts to the garage, reducing the vehicle down-time.	
	User/users:	OEM software engineer, Driver, OEM aftersales services manager, Aftersales service technician
	Setting / context	The vehicle potentially has a defect that is affecting its performance or emissions profile
	Interacting system	Powertrain Control Module
	Users' goals	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.
	Initial status	A potentially defective vehicle has been identified.
	Interaction	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
	Data	Sensor measurements at very high sampling frequencies and thousands of parameters describe the vehicles' operation.
	Motivation	The expected benefits from the implementation of the described approach are the following: • increased customer trust and satisfaction; • better management of aftersales services.
	Time	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.
System functionalities	**General description**: Device-to-device communication, data safety, security and provenance (communication and storage),	
Identified by	FORD-WERKE	

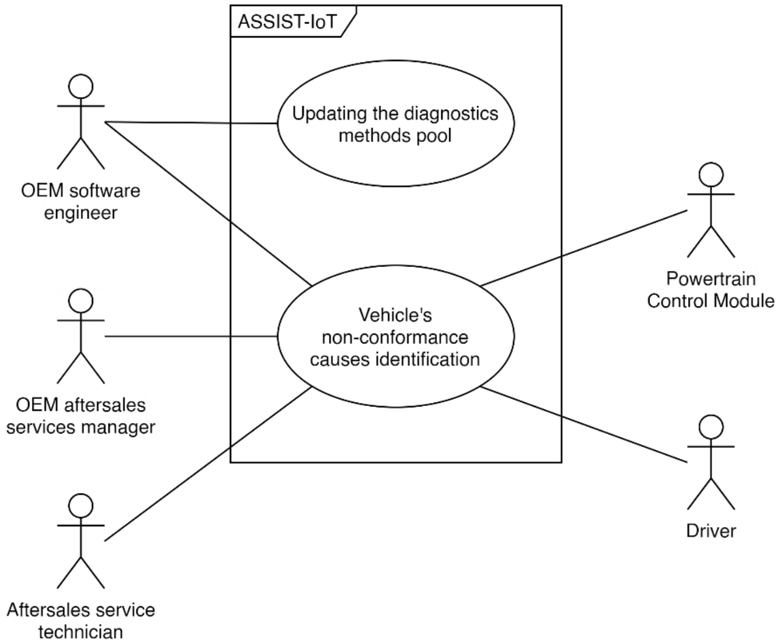


Figure 13. Use case diagram for the "Vehicle diagnostics" business scenario

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

Use Case	
ID	UC-P3A-2
Name	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	• Identify potential defects or faulty parts • 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 are 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-C-1, R-C-2, R-C-3, R-C-6, 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	Reduce vehicle series recalls by narrowing down the potential fault sources.
Identified by	UPV, FORD-WERKE

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

Use Case	
ID	UC-P3A-3
Name	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	N/A
Functionalities within vertical capabilities	TBD
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-C-1, R-C-2, R-C-6, R-C-7, R-P3A-1, R-P3A-4, R-P3A-5, R-P3A-9, R-P3A-12

KPI	Utilisation of information from vehicle monitoring in combination with information collected at the garage.
Identified by	UPV, FORD-WERKE

5.6. 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 condition. The Vehicle-scanner system comes in various configurations for different vehicle sizes (e.g., car, van and track), can be set up and operate indoors or outdoors and consists of the following modules:

- mechatronics:
    - right/left side walls
    - rotating 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 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
- 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-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 the majority of the customers in the meantime demand for one)
- 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
    - vehicle tread profiler subsystem which monitors the rims condition.

During the scanning operation, the vehicles are driven at low speed through the vehicle-scanner which acquires high-quality colour images of their exterior. Additional modules with dedicated functionalities, such as underbody imaging and tire tread profilers etc., may be optionally configured in the scanner. In most cases the vehicle-scanner also provides automated, AI-based, surface inspection capabilities. A front-end software module provides efficient user-interaction with the acquired data, by offering innovative visualization techniques including optional Augmented Reality (AR) functionalities.

Business scenario	
Scenario ID BS-P3B-1	**Scenario name** Vehicle exterior condition inspection and documentation
Illustration of the system's behaviour in a specific situation, flow of events	A commercial or privately owned, vehicle (car, van or truck) arrives at the premises of an organisation that hosts a vehicle scanner. Its arrival may have been scheduled or even expected from the minute it entered the main gate of premises. As soon as the vehicle scanner detects the presence of a vehicle with the sensor to be about to pass through it: • activates its integrated industrial processing unit, switches on the LED-illumination and proceeds with the image acquisition and scanning by rotating its pillar with the embedded cameras following the passing vehicle according to its own vehicle positioning sensor system • performs a set of image processing tasks such as image enhancement, colour processing, segmentation, compression, thumbnailing or panorama generation • extracts the identification of the vehicle (either licence plate, Vehicle Identification Number, so-called VIN-number, or other unique identifiers like time-stamp, or instantly generated by blockchain methods) in order to index the related information. This information may optionally needs to be not-manipulative later on during the workflow of certain application use-cases (like legal status determination for rental cars in- & out-processes) • temporarily saves the acquired dataset (images, point clouds and other meta-data) in a 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 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. At this point the generated dataset could be displayed to the driver via installed monitors and at the mobile device of the vehicle exterior inspectors for review and potential further processing. The vehicle exterior inspector can proceed to visually inspect the dataset (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 can also proceed to visually inspect the vehicle itself in order to verify the detected defects using a mobile device. To this end, the vehicle exterior inspectors should receive AR support and other visual aids while using their mobile device. For long-term storage and in order for the extraction of further business intelligence, the dataset is transferred to a 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 or cloud system. Any of the above systems should be able to 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 in order 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

<table>
<tr><td></td><td colspan="2">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 in order to be able to make business decisions, e.g.,
manage and schedule the repair work</td></tr>
<tr><td></td><td>User/users:</td><td>Vehicle exterior inspector, driver</td></tr>
<tr><td></td><td>Setting / context</td><td>The vehicle scanner can support the business goals (or be installed at the premises) of: automotive OEM supply chains, workshops in the aftersales business, rental vehicle or shared mobility services providers, fleet management suppliers in the logistics area as well as insurance companies</td></tr>
<tr><td></td><td>Interacting system</td><td>Vehicle scanner, local or cloud storage and processing systems, desktop and mobile devices that display information</td></tr>
<tr><td></td><td>Users' goals</td><td>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
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</td></tr>
<tr><td></td><td>Initial status</td><td>Vehicle scanners are installed and ready to scan vehicles.</td></tr>
<tr><td></td><td>Interaction</td><td>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 AR applications in order to input, retrieve and communicate to the driver information about the vehicle's condition.</td></tr>
<tr><td></td><td>Data</td><td>High-resolution images, 3D point clouds and corresponding metadata and annotations.</td></tr>
<tr><td></td><td>Motivation</td><td>Scan vehicles and document their condition in order to be able to make intelligent business decisions.
Reduce the time it takes to perform a vehicle inspection.
Reduce the time it takes to perform a vehicle scan.
Use information from multiple vehicle scanners in order to improve the scanner's automatic defect detection capabilities without compromising confidentiality and privacy.</td></tr>
<tr><td></td><td>Time</td><td>A new car is scanned within 24 hours from its arrival at a dealership.
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.
For commercial fleets, vehicle conditions are documented every day by the drivers themselves as well as weekly or monthly by an internal</td></tr>
</table>

		auditor in order to keep the fleet at an acceptable condition at reasonable costs. • The whole scanning and documentation process should be completed within 10-25 minutes. In the case of daily scans of commercial vehicles, safety-critical assessment should be completed within 30-60 seconds after scanning, so that the driver is prevented from leaving the premises without verification that the vehicle is roadworthy.
System functionalities	**General description**: Decision support, Data interoperability, AR	
Identified by	TWOTRONIC	

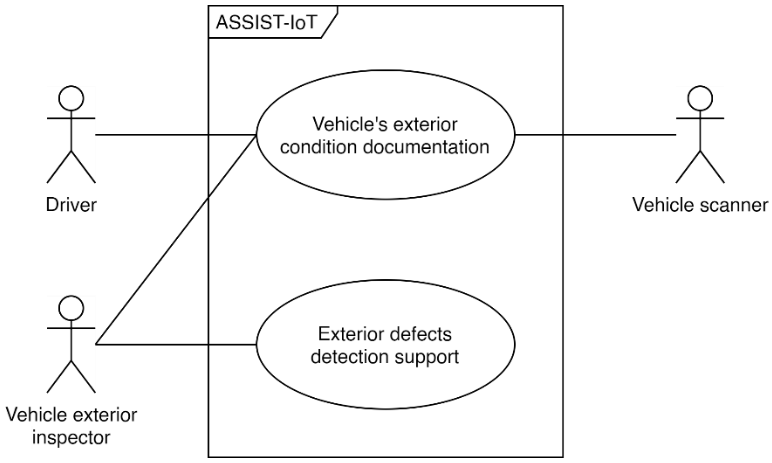


Figure 14. Use case diagram for the "Vehicle exterior condition inspection and documentation" business scenario

5.6.3. UC-P3B-1: Vehicle's exterior condition documentation

Use Case	
ID	UC-P3B-1
Name	Vehicle's exterior condition documentation
Description	Scan a vehicle and document the condition of its exterior
Reference Scenario	BS-P3B-1
Plane(s)	Application and Services
Vertical Capabilities	Interoperability
Functionalities within vertical capabilities	Data security, federated learning
Objectives	• Detect and document defects on the vehicle's exterior
Actors (system actor or natural persons)	• Vehicle scanner • Vehicle exterior inspector • 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 • Defects on the exterior of the vehicle are detected • Additional defects, compared to the vehicle's previous status, are identified
Design preferences	Automatic defect detection capabilities: • integrated with the vehicle scanner • local to the premises hosting and supporting more than one vehicle scanners • a central business server or cloud system. Federated learning for defect detection and DLT support to record 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 2. The driver drives the vehicle through the vehicle scanner and the vehicle is scanned 3. ASSIST-IoT receives the raw data from the vehicle scanner and pre-processes it locally 4. ASSIST-IoT displays the information that documents the vehicle's condition to the driver 5. ASSIST-IoT generates a report that documents the vehicle's condition and transmits it to the vehicle exterior inspector and the organisation's local or cloud storage facilities
Alternative execution	5a. The vehicle exterior inspector and the driver need to review the vehicle's condition away from the vehicle 5a.1. ASSIST-IoT supports the Vehicle-Inspector to review images of the vehicle with the driver and identify defects on the display of a device 5a.2. ASSIST-IoT records the verification of the vehicle's status 5b. The vehicle exterior inspector and the driver approach the vehicle in order to verify the report 5b.1. ASSIST-IoT proceeds to UC-P3B-2
Exceptions	N/A
Requirements involved	R-C-5, R-C-6, R-C-7, R-P3-1, R-P3-2, R-P3-3, R-P3-4, R-P3-5, R-P3-6, R-P3-7, R-P3-8, R-P3-10, R-P3-11
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.
Identified by	TWOTRONIC

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

Use Case	
ID	UC-P3B-2
Name	External defects detection support
Description	Verify the information that was recorded by the vehicle scanner and identify any defects with 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	• Identify defects on the vehicle's exterior
Actors (system actor or natural persons)	• Vehicle exterior inspector
Pre-conditions	The vehicle exterior inspector is standing next to a vehicle
Trigger	The vehicle exterior inspector initiates the action
Expected results	• For each image, metadata with the detected defect details
Design preferences	AR support on mobile devices
Extends the use case	N/A
Includes the use case	N/A
Notes and issues	N/A
Main execution flow	1. The vehicle exterior inspector requests from ASSIST-IoT available information for the specific vehicle 2. The vehicle exterior inspector inspects the vehicle, identifies defects, 3. ASSIST-IoT supports the vehicle exterior inspector to take images, marks the defects on the images and record them
Alternative execution	1a. ASSIST-IoT retrieves previously recorded images and defects for the specific vehicle 1a.1. The vehicle exterior inspector uses the camera of their mobile device in order to overlay the location of previously identified defects on the video stream

	1a.2. The vehicle exterior inspector verifies the defects and updates the ASSIST-IoT record
Exceptions	N/A
Requirements involved	R-C-5, R-C-6, R-C-7, R-P3-9, R-P3-10, R-P3-11
KPI	User-friendly interface. Information retrieval speed and completeness.
Identified by	TWOTRONIC

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 should be 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) need to be identified and formalized as the definition of requirements.

The requirements are used to establish the basis for agreement between the customers and the 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, we need to decompose the product into smaller chunks. This helps to break down the problem into its component parts and makes it easier to establish the solution. ASSIST-IoT requirements analysis was performed for all pilots separately, but partial results were periodically synchronized to be able to consistency and to identify common requirements that are for the project's outcome irrespective of which pilot is under consideration.

The requirements listed in the following subsections are results of intensive communication with stakeholders.

6.4. Common requirements

Requirement	
Name	Data sovereignty
Identifier	R-C-1
Category	Non-Functional
Priority	Must
Rationale	Different data sets are obtained from the pilots
Description	ASSIST-IoT must 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
Identified by	**Source**
TL	Partner's expertise

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

Description	ASSIST-IoT must 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
Identified by	**Source**
TL	Partner's expertise

Requirement	
Name	Compliance with legal requirements on data protection
Identifier	R-C-3
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.
Identified by	**Source**
TL, FORD-WERKE	Partner's expertise

Requirement	
Name	Local Processing Capabilities
Identifier	R-C-5
Category	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 design support edge-processing.
Identified by	**Source**
MOW	Partner's expertise

Requirement	
Name	Data Persistence and Trust
Identifier	R-C-6
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 with container 2) All the information referring to worker health and safety 3) The vehicle's emissions profile throughput it's lifetime so that it can demonstrate its in-service conformity to a third party. ASSIST-IoT will retain the information of the calibration used for every vehicle and the modifications performed on it. ASSIST-IoT will also retain the 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.
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	Edge-oriented deployment
Identifier	R-C-7
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
Identified by	**Source**
TL	Partner's expertise

6.5. Pilot 1 requirements

Requirement	
Name	CHE location services
Identifier	R-P1-1
Category	Functional
Priority	Must
Use case IDs	UC-P1-1, UC-P1-2, 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
Acceptance criteria	All CHEs involved in the real-time demo will be located
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	CHE identification
Identifier	R-P1-10
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	All CHEs involved in the real-time demo will be identified
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	CHE machine-to-machine communication
Identifier	R-P1-11
Category	Functional
Priority	Must
Use case IDs	UC-P1-4, UC-P1-5
Rationale	CHE-to-CHE communication possibility will decrease the time of operations fulfilment (container manipulations)
Description	The CHEs have to be able to communicate between each other without the need of a third entity in the process
Acceptance criteria	A M2M network communication protocol shall be available
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	CHE authentication
Identifier	R-P1-12
Category	Functional
Priority	Must
Scenario / Use case IDs	UC-P1-4
Rationale	The CHEs have to carry out an authentication process before starting the fulfilment the work order
Description	The CHEs have to carry out an authentication process before starting the alignment
Acceptance criteria	Handshake process should be available for the machines
Identified by	**Source**

TL, KONECRANES	Partner's expertise

Requirement	
Name	Open/Accessible Remote capabilities
Identifier	R-P1-16
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 (hoist, spreader, and twistlocks) remotely
Acceptance criteria	At least two RTGs shall be equipped with remote operation capabilities compatible with ASSIST-IoT framework
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	Customizable remote desktop
Identifier	R-P1-17
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 customized to allow the integration of built-in enhanced visuals
Acceptance criteria	At least one remote desktop shall be installed in terminal offices
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	Industrial and safety protocols support
Identifier	R-P1-18
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	Remote RTGs can work with and without PROFINET network protocols thanks of ASSIST-IoT network interoperability
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	Wireless remote capabilities
Identifier	R-P1-24
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 wireless network technology
Acceptance criteria	A stable and redundant wireless connectivity must be integrated in the Remote Operating System (ROS)
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	AR support

Identifier	R-P1-23
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) for which container has to pick up and where has to place it
Acceptance criteria	Digital recommendations shall be overlapped in real-time with the video streams of the ROS
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	Terminal data access
Identifier	R-P1-6
Category	Non-Functional
Priority	Must
Use case IDs	UC-P1-1
Rationale	The information obtained from the terminal assets cannot be exposed to everyone
Description	ASSIST-IoT architecture must guarantee that the data managed is only be exposed after authentication processes are carried out
Acceptance criteria	100% matching between role privileges and data sets
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	Remote bandwidth capabilities
Identifier	R-P1-19
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 30 Mbps shall be guaranteed
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	Remote latency capabilities
Identifier	R-P1-20
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	End-to-end latencies below 50 ms shall be guaranteed
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	Remote reliability capabilities
Identifier	R-P1-21
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 able to 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
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	CHE location availability
Identifier	R-P1-2
Category	Non-Functional
Priority	Should
Use case IDs	UC-P1-1, 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 90% of working time, the location should be guaranteed
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	CHE positioning accuracy
Identifier	R-P1-3
Category	Non-Functional
Priority	Should
Use case IDs	UC-P1-1, UC-P1-2, UC-P1-3
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 ≤ 1 m

Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	CHEs authentication range
Identifier	R-P1-13
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	The CHEs are in a proximity range < 15m
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	Multilink wireless network capabilities
Identifier	R-P1-22
Category	Non-Functional
Priority	Should
Use case IDs	UC-P1-2, UC-P1-3, 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
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	Mesh network capabilities
Identifier	R-P1-25
Category	Non-Functional
Priority	Could
Use case IDs	UC-P1-3, UC-P1-4, UC-P1-5
Rationale	Wireless connectivity in some areas of the terminal is blocked due to some CHEs, so that trucks can only communicate with their closer ones and not wirelessly to a further server
Description	To guarantee that data from blocked CHES is sent via an auxiliary mesh access point
Acceptance criteria	At least one mesh service is available between an RTG and a TT or external truck
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	Alignment exposure
Identifier	R-P1-15
Category	Non-Functional
Priority	Should
Use case IDs	UC-P1-5
Rationale	The CHEs have to precisely perform the alignment process
Description	The backwards/forwards movement extracted from the LIDAR system must be exposed to a Graphical User Interface (GUI)
Acceptance criteria	At least two GUIs will present the alignment recommendations (traffic lights + smartphone app)
Identified by	**Source**
TL, KONECRANES	Partner's expertise

Requirement	
Name	Container ID tracking system
Identifier	R-P1-5

Category	Non-Functional
Priority	Could
Use case IDs	UC-P1-1, UC-P1-3
Rationale	The containers/cargo shall be always identified with the maximum precision
Description	Some RTGs can be equipped with an external container identification system like the use of Positioning Detecting System and Terminal Operating System.
Acceptance criteria	The list of movement of containers are successfully recorded in the PDS and TOS
Identified by	**Source**
TL, KONECRANES	Partner's expertise

6.6. Pilot 2 requirements

Requirement	
Name	Personal location tracking
Identifier	R-P2-1
Category	Functional
Priority	Must
Use case IDs	UC-P2-1, UC-P2-2, UC-P2-3, UC-P2-4, UC-P2-5, UC-P2-6, UC-P2-7
Rationale	Provide location-based services.
Description	ASSIST-IoT shall track the location of workers within the construction site, both outdoors and indoors, with an accuracy of 1 m. The elevation context shall also be discerned using the Building Information Model in order 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	Track the location of all construction workers in the construction site.
Identified by	**Source**
MOW	Partner's expertise

Requirement	
Name	Monitoring the weather conditions at the construction site
Identifier	R-P2-7
Category	Functional

Priority	Must
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.
Identified by	**Source**
CIOP-PIB	Partner's expertise

Requirement	
Name	Personal Cooling System
Identifier	R-P2-8
Category	Functional
Priority	Must
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 on 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 environment, according to their personal preferences.
Acceptance criteria	Cooling temperature not lower than 15 °C. Weight of the PCS not higher than 1.5 kg.
Identified by	**Source**
CIOP-PIB	Partner's expertise

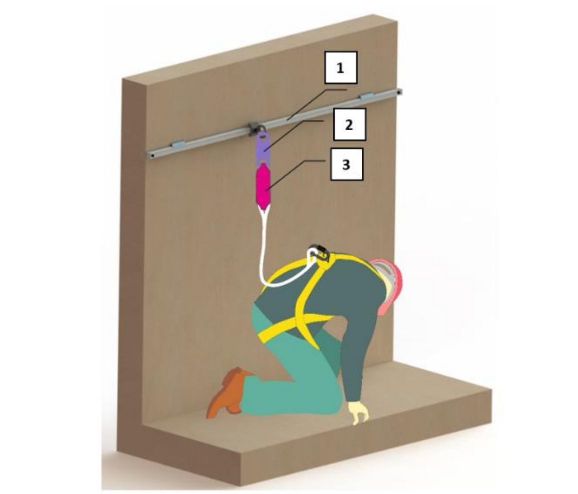
Requirement	
Name	Geofencing
Identifier	R-P2-11

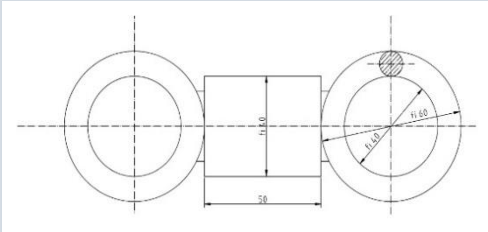
Category	Functional
Priority	Must
Use case IDs	UC-P2-2
Rationale	Workers should be prevented from entering areas where they are not authorised to be.
Description	ASSIST-IoT shall monitor the location of workers and constantly assess whether or not they are authorised to be at that location, which depends 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	TBD
Identified by	**Source**
MOW	Partner's expertise

Requirement	
Name	Motion Pattern Monitoring and Analysis
Identifier	R-P2-10
Category	Functional
Priority	Must
Use case IDs	UC-P2-1
Rationale	The worker's motion pattern will be monitored in order to identify hazards such as slips, trips, falls, forceful body impact, using a triaxial accelerometer placed close to their centre of gravity.
Description	ASSIST-IoT shall monitor the workers' body acceleration, level of physical activity and detect prolonged immobility or suffering a forceful impact.
Acceptance criteria	Provide the motion pattern classification confidence level.
Identified by	**Source**
MOW	Partner's expertise

Requirement	
Name	Fall arrest detection
Identifier	R-P2-13
Category	Functional
Priority	Must
Use case IDs	UC-P2-5

Rationale	A rescue operation has to be initiated if a worker is suspended by a fall arrest system.

Description	ASSIST-IoT shall be able to identify near-miss fall events by detecting the fall arresting force applied to the smart fall arrest equipment. Information about such an event shall be transmitted to the OSH manager.
	The detector shall have ends compatible with typical connectors so that it can be connected in series with other components of a typical personal smart fall arrest equipment e.g., between an anchor device and a lanyard, a lanyard and an energy absorber, an anchor device and a retractable fall arrester, etc.
	
	
	1 – horizontal rigid anchor line, 2 – a fall arrest detector, 3 – energy absorber.
	Technical parameters:
	• Tensile strength: 15kN;
	• measurement of the tensile force in the range from 0.5 to 15 kN;
	• detection of exceeding the threshold force value in the range from 0.5 to 15 kN (with the possibility of setting the threshold value by the service. The predicted value is approximately 2kN and will be accurately determined in the planned laboratory tests);
	• powered by an internal battery;
	• battery charge status indication;
	• manual reset of the detector;
	• generating and remotely transmitting, directly (100 m minimum range) or indirectly, the signal of exceeding the threshold force value.
	
	The fall arrest detector shall have the below indicative dimensions:
	• cylindrical body
	    o height: 50 mm
	    o radius: 40 mm
	• connectors
	    o inner radius: 40 mm
	    o outer radius: 60 mm

	
Acceptance criteria	Fulfilment of the above mechanical requirements and the relevant requirements of the following standards: EN 363:2018, EN 362:2004
Identified by	**Source**
CIOP-PIB	Partner's expertise

Requirement	
Name	Evacuation Instructions
Identifier	R-P2-14
Category	Functional
Priority	Must
Use case IDs	UC-P2-6
Rationale	Safe evacuation 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. Preferably, the accuracy of the workers' localisation shall be within 0.5 m and the latency of the provided instructions shall be about 1 sec.
Identified by	**Source**
CIOP-PIB	Partner's expertise

Requirement	
Name	Wristband pairing with other devices capability
Identifier	R-P2-5
Category	Functional

Priority	Must
Use case IDs	UC-P2-3, UC-P2-4, UC-P2-5, UC-P2-7
Rationale	Verify that the worker is close to smart PPE or construction plant.
Description	ASSIST-IoT shall support machine-to-machine communication between smart equipment such as wristbands, PPE or construction plant.
Acceptance criteria	Contextual status of the construction worker is known, based on their proximity to other devices.
Identified by	**Source**
MOW	Partner's expertise

Requirement	
Name	Smart wristband for construction workers
Identifier	R-P2-3
Category	Non-Functional
Priority	Must
Use case IDs	UC-P2-1, UC-P2-2, UC-P2-3, UC-P2-4, UC-P2-5, UC-P2-7
Rationale	Each construction worker should be able to prove their identity, including permissions and training record, in order to gain access to different areas of the worksite. Moreover, in the case of regular workers, the wristband should provide personal health and safety monitoring, as well as location.
Description	ASSIST-IoT shall be able to identify each construction worker and track their location via a wearable device. Personal details, training records and photograph shall be included. Moreover, the wristband shall be equipped with sensors for physiological parameters measurements that are enabled to be performed on the wrist, such as: heart rate, blood oxygen saturation, respiratory rate, blood pressure and temperature. It will also provide an interface for the worker to send and receive alerts and notifications, respectively.
Acceptance criteria	User acceptance.
Identified by	**Source**
CIOP-PIB	Partner's expertise

Requirement	
Name	Device number minimisation
Identifier	R-P2-6
Category	Non-Functional
Priority	Must

Use case IDs	UC-P2-1
Rationale	Reduce the number of distinct wearable sensors or integrate them within the same devices in order to increase usability and limit a 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	User acceptance
Identified by	**Source**
CIOP-PIB	Partner's expertise

Requirement	
Name	BIM data models and interoperability compliance
Identifier	R-P2-15
Category	Non-Functional
Priority	Must
Use case IDs	UC-P2-2, UC-P2-3, UC-P2-6, UC-P2-7
Rationale	Location-based services and navigation routes will be provided based on support from BIM authoring applications using industry-specific formats (buildingSMART, 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.
Identified by	**Source**
MOW	Partner's expertise

Requirement	
Name	Wireless Coverage
Identifier	R-P2-17
Category	Non-Functional
Priority	Must
Use case IDs	UC-P2-1, UC-P2-2, UC-P2-3, UC-P2-4, UC-P2-5¸ UC-P2-6, UC-P2-7
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 be above 95% of the construction area
Identified by	**Source**
MOW	Partner's expertise

Requirement	
Name	Temporary Storage
Identifier	R-P2-18
Category	Non-Functional
Priority	Must
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
Identified by	**Source**
MOW	Partner's expertise

Requirement	
Name	Construction plant location tracking
Identifier	R-P2-2
Category	Functional
Priority	Should
Use case IDs	UC-P2-3, UC-P2-4
Rationale	Vehicles entering the construction site should be tracked in order to increase safety of people working in their close vicinity.
Description	ASSIST-IoT shall track the location of construction 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 all construction plants in the construction site.

Identified by	**Source**
MOW	Partner's expertise

Requirement	
Name	Assessment of Personal Exposure to UV Radiation
Identifier	R-P2-9
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 exposure to UV radiation is estimated for every construction worker at the construction site
Identified by	**Source**
CIOP-PIB	Partner's expertise

Requirement	
Name	Continuous authentication for wristband
Identifier	R-P2-4
Category	Functional
Priority	Should
Use case IDs	UC-P2-1
Rationale	Ensure that a construction worker is wearing their wristband 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.
Identified by	**Source**
CERTH	Partner's expertise

Requirement	
Name	Device Reliability and Durability
Identifier	R-P2-16
Category	Non-Functional
Priority	Should
Use case IDs	UC-P2-1, UC-P2-5
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.
Identified by	**Source**
MOW	Partner’s expertise

Requirement	
Name	Alerts and notifications minimization
Identifier	R-P2-12
Category	Non-Functional
Priority	Should
Use case IDs	UC-P2-1, UC-P2-2, UC-P2-3, UC-P2-4, UC-P2-5¸ UC-P2-6, UC-P2-7
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	User acceptance
Identified by	**Source**
MOW	Partner’s expertise

6.7. Pilot 3 requirements

Requirement	
Name	Monitored Data channels
Identifier	R-P3A-1
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, a 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 being a result of variable manipulation or software code run in 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 in 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 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	TBD
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	Active monitoring mode initiation by the OEM software engineer capability
Identifier	R-P3A-6
Category	Functional
Priority	Must
Use case IDs	UC-P3A-2
Rationale	The OEM software engineer, in order to diagnose increased emissions for a particular vehicle, requires more information relating its instantaneous emissions profile to the vehicle's behaviour and driving conditions.
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 identification of possible fault sources.
Acceptance criteria	The OEM software engineer is able to initiate Active Monitoring and retrieve the collected data.
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	Edge Intelligence
Identifier	R-P3A-9
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 shall be able to process the information from different vehicles with different variants, sensor sets and available channels in order to derive in-service emission metrics. 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 to develop data-driven models or grey-box models for these clusters, which could be used for diagnosing common faults.
Acceptance criteria	TBD
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	Vehicle Dashboard Notifications
Identifier	R-P3A-10
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, and a fault is not detected, ASSIST-IoT shall notify the Driver, who will be able to reactivate Active Monitoring and request the vehicle to be serviced.
Acceptance criteria	The driver receives the necessary information.
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	Connectivity between OEM and fleet
Identifier	R-P3A-11
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.
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	Edge Connectivity
Identifier	R-P3A-12
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 stable, reliable connection with low latency between ASSIST-IoT and OEM.
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 • generation of different transmit tasks at different times
Acceptance criteria	The OEM is aware of success or failure of information transmittance.
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	Automatic Defect Detection
Identifier	R-P3B-15
Category	Functional
Priority	Must
Use case IDs	UC-P3B-1
Rationale	Facilitate the detection of defects on a vehicle

Description	ASSIST-IoT shall be able to automatically detect defects on images or point clouds acquired by the vehicle scanner
Acceptance criteria	Desired recognition rates according to the defect category Damage category required recognition rate for business case • 70-80% small paint damages, like chips • 80-90% for scratches • 80-90% cracks • 80-95% for deformations • 80% for dents • 70-80% for corrosion
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement	
Name	Business Frontend
Identifier	R-P3B-23
Category	Functional
Priority	Must
Use case IDs	UC-P3B-1, UC-P3B-2
Rationale	The representative of an aftersales garage requires a report from the vehicle scan in order to verify and discuss the result with the driver. A fleet manager requires reporting for the entire fleet.
Description	ASSIST-IoT shall support the following functionality: • guided presentation of the entire image set of a scan for a fast review of the vehicle condition • image management interface on mobile devices with access to multiple scans • determine and indicate the differences between the current and previous scans
Acceptance criteria	Provide access to all available information in a user-friendly way
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement	
Name	Vehicle Image Segmentation
Identifier	R-P3B-16
Category	Functional

Priority	Should
Use case IDs	UC-P3B-1
Rationale	Isolate the object of interest for further processing
Description	ASSIST-IoT shall segment the vehicle from the background in an image
Acceptance criteria	The entire vehicle is included in the foreground
Identified by	**Source**
TWOTRONIC	Partner’s expertise

Requirement	
Name	Augmented Reality Support at the Garage
Identifier	R-P3A-13
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.
Identified by	**Source**
FORD-WERKE	Partner’s expertise

Requirement	
Name	Active monitoring mode initiation by the Aftersales service technician capability
Identifier	R-P3A-7
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.
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	Information Pre-fetching
Identifier	R-P3B-20
Category	Functional
Priority	Should
Use case IDs	UC-P3B-1
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 is required in order to reduce defect detection and reporting time.
Description	ASSIST-IoT shall be able to predict demand and deliver relevant historical information about the vehicle and previously available training data sets and machine learning models to a vehicle scanner.
Acceptance criteria	All relevant information are available to the vehicle scanner for each scan.
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement	
Name	Automatic Recognition
Identifier	R-P3B-21
Category	Functional
Priority	Should
Use case IDs	UC-P3B-1
Rationale	Recognise licence plate, legal stamps and driver face on images
Description	ASSIST-IoT shall be able to automatically detect the following artefacts on the images: • Legal driving permission stamp on car plate • Number plate recognition

	• Driver face blurring/removal
Acceptance criteria	Desired recognition rates according to the task: • Legal driving permission stamp on car plate: 70% • Number plate recognition: 98% • Driver face blurring/removal: 98%
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement	
Name	Augmented Reality Support
Identifier	R-P3B-22
Category	Functional
Priority	Should
Use case IDs	UC-P3B-2
Rationale	Visualisation of surface damages for the vehicle exterior inspector and the driver
Description	ASSIST-IoT shall overlay detected defects on a video stream of the vehicle on a mobile device
Acceptance criteria	The indicated area should be able to guide the user to visually identify an already detected potential defect.
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement	
Name	Interactive Image Annotation Support
Identifier	R-P3B-24
Category	Functional
Priority	Should
Use case IDs	UC-P3B-1, UC-P3B-2
Rationale	An inspector may want to manually identify new or confirm already detected defects using mobile devices.
Description	ASSIST-IoT shall support the interactive annotation of defects on images
Acceptance criteria	Support for annotating static images or video streams
Identified by	**Source**

TWOTRONIC	Partner's expertise

Requirement	
Name	Active monitoring mode initiation by the driver capability
Identifier	R-P3A-8
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.
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. The
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	Data models compliance
Identifier	R-P3A-2
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
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	OEM Fleet data storage
Identifier	R-P3A-3
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 CO_2 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
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	PCM Parameterisation (Calibration) Update Safety and Security
Identifier	R-P3A-4
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.
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	Data Storage
Identifier	R-P3A-5
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.
Identified by	**Source**
FORD-WERKE	Partner's expertise

Requirement	
Name	Defect Classification Categories
Identifier	R-P3B-14
Category	Non-functional
Priority	Must

Use case IDs	UC-P3B-1
Rationale	Define the vehicle surface damage categories that are of interest
Description	ASSIST-IoT shall be able to classify potential defects on a vehicle's exterior to one of the below categories: 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 reflection 9. miscellaneous defects (any defect other than the above, e.g., missing mirror or antenna)
Acceptance criteria	Provide the detection confidence level for each category
Identified by	**Source**
TWOTRONIC	Partner's expertise

Requirement	
Name	Critical Damage Identification Time
Identifier	R-P3B-19
Category	Non- functional
Priority	Should
Use case IDs	UC-P3B-1
Rationale	The professional driver of a commercial vehicle has to be automatically notified that their vehicle is roadworthy before they drive their vehicle away from the vehicle scanner.
Description	ASSIST-IoT shall inform the driver of a commercial vehicle (van, light truck) about a safety critical damage within 30-60 seconds from scanning. This would additionally warn the driver, to not leave the parking premises of the logistic distribution centre without an additional manual check of his van about drive safety.
Acceptance criteria	The vehicle does not leave the premises with safety-critical damage.
Identified by	**Source**
TWOTRONIC	Partner's expertise

6.8. Requirements summary

At this time the project has about **66** requirements: **3**7 functional requirements, **29** non-functional requirements; 6 of them are common for all the pilots. However, since requirements identifications is an iterative process that takes place throughout the duration of the project, existing requirements may be improved or new ones may be added (next version of this deliverable is expected in month 18). As we are using an agile and iterative methodology, we can add new requirements without interfering with what has already been defined.

Concerning the requirements priority, approximately three quarters are mandatory. This is because at first we have identified the essential features and functionalities that, the different products, must have. The main sources of data we have taken into account when defining the requirements have been the stakeholders' needs and the partner's expertise. 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 first six months of the project. So far, the information flow between Tasks 3.2 and 3.3 and other tasks and work packages has been primarily one way. T3.1 has offered insights to existing knowledge and expertise while the identified business scenarios, use cases and requirements were constantly feeding the developments in T3.5 and subsequently WP4 and WP5. As the project progresses the requirements will be iteratively revised several times, in order to evolve and prioritise them based on feedback from the pilot deployments and Open Calls.