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

D8.3 – Final Evaluation Report

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Authors

Name	Partner	e-mail
Alejandro Fornes	P01 UPV	alforlea@upv.es
Ignacio Lacalle	P01 UPV	iglaub@upv.es
Carlos Guardiola	P01 UPV	carguaga@upv.es
Francisco Mahedero	P01 UPV	framabio@upv.es
Eduardo Garro	P02 PRO	egarro@prodevelop.es
Piotr Sowiński	P03 SRIPAS	piotr.sowinski@ibspan.waw.pl
Karolina Bogacka	P03 SRIPAS	karolina.bogacka@ibspan.waw.pl
Evripidis Tzionas	P04 CERTH	tzionasev@iti.gr
Anastasia Blitsi	P04 CERTH	akblitsi@iti.gr
Vaios Koumaras	P06 INFOLYSIS	vkoumaras@infolysis.gr
Vaslileios Mavrikakis	P06 INFOLYSIS	vmavrikakis@infolysis.gr
Theodore Papadopoulos	P06 INFOLYSIS	tpapadopoulos@infolysis.gr
Monika Kobus	P07 CIOP-PIB	mokob@ciop.lodz.pl
Witold Olczak	P08 MOW	w.olczak@mostostal.waw.pl
Angira Singh	P09 NEWAYS	Angira.Singh@newayselectronics.com
Nasia Balakera	P10 ICCS	nasia.balakera@iccs.gr
Fotios Konstantinidis	P10 ICCS	fotios.konstantinidis@iccs.gr
Tina Katika	P10 ICCS	tina.katika@iccs.gr
Tom Papaioannou	P10 ICCS	thomas.papaioannou@iccs.gr
Klaus Schusteritz	P12 FORD-WERKE	kschust4@ford.com
Rafael Bornés	P13 S21SEC	rborne@s21sec.com
Lambis Tassakos	P14 TWOT	lambis.tassakos@gmail.com
Jaroslaw Legierski	P15 OPL	jaroslaw.legierski@orange.com
Zbigniew Kopertowski	P15 OPL	zbigniew.kopertowski@orange.com

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Executive Summary

This Final evaluation report is written within the context of WP8 – Evaluation and Assessment of **ASSIST-IoT** project, under Grant Agreement No. 957258. Deliverable D8.3 finalizes the KPI reporting, initiated in D8.1 and continued in D8.2, and reports the rest of activities stemming from WP8.

KPIs were initially divided into five different dimensions of assessment. Those included exploitation, impact, pilots, technology as well as ethical, societal, gender and legal evaluation. These dimensions were then further subdivided into fields that group together related Key Performance Indicators (KPIs). With regards to the actual evaluation, they were divided in three parts: technical, pilot-related and process-related (i.e., business, impact, dissemination, communication or ethical-related). In this deliverable, information already available in D8.2 is arranged in a common templated structure, aiming at providing a unified way for al KPIs and completing their formalization. All this information is presented in Section 3. Specifically, a total of x KPIs are here reported.

Besides, D8.3 goes beyond KPI formalization, gathering also different efforts performed mainly in the scope of T8.4. First, the transferability analysis is presented in Section 2. It includes the methodology description itself, the gathering of transferability results from the resulting project KERs (presented in the annex), the analysis of the surveys related to the adoption barriers and technological acceptance, feedback from adopters (i.e., Open Callers) and links to relevant documentation. Finally, Section 4 presents a list of relevant research lines to continue the efforts of the ASSIST-IoT action, focusing on the future direction of the Next-Generation Internet of Things (IoT).

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List of acronyms

Acronym	Explanation
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
AWS	Amazon Web Services
BLE	Bluetooth Low Energy
BIM	Building Information Modelling
CAN	Controller Area Network
GCP	Google Cloud Platform
CHE	Container Handling Equipment
CLI	Command Line Interface
CNF	Cloud-native Network Functions
CPU	Central Processing Unit
CV	Computer Vision
DLT	Distributed Ledger Technology
EDB	Edge Data Broker
EDR	Endpoint Detection and Response
EoT	Ease of Transferability
EU	European Union
FL	Federated Learning
GDPR	General Data Protection Regulation
GWEN	Gateway/Edge Node
HPA	Horizontal Pod Autoscaling
HRB	Horizon Results Booster
HSO	Health and Safety Officer
HW	Hardware
IdM	Identity Manager
IE	Innovation Elements
IFC	International Foundation Class
IoT	Internet of Things
IP	Internet Protocol
IPR	Intellectual Property Rights
JSON	JavaScript Object Notation
KER	Key Experience Indicator
KPI	Key Performance Indicator
KVI	Key Value Items
LTSE	Long-Term Storage Enabler
ML	Machine Learning
MQTT	Message Queuing Telemetry Transport
MR	Mixed Reality
NG-IoT	Next Generation IoT
OPEX	Long-term Operational Expenditures
OS	Operative System
OSH	Occupational Safety and Health
PCAP	Packet Capture

PCM	Power-train Control Module
PCT	Potential Contribution to Transferability
PPE	Personal Protective Equipment
PUD	Performance and Usage Diagnosis
RIA	Research and Innovation Actions
RoI	Return of Investment
ROS	Robot Operating System
RTG	Rubber-tyred gantry
RTT	Round-trip Time
SD-WAN	Software-defined Wide-Area Networking
SDN	Software-defined Networking
SIEM	Security Information and Event Manager
SIM	Subscriber Identity Module
SOC	Security Operations Center
SUS	System Usability Scale
SW	Software
TA	Transferability Analysis
TCP	Transmission Control Protocol
TIDE	Transport Innovation Deployment for Europe
TOS	Terminal Operating System
TPR	True Positive Rate
UC	Use Case
UDP	User Datagram Protocol
UWB	Ultra-Wideband
UX	User Experience
VNF	Virtual Network Functions
VPN	Virtual Private Network
VR	Virtual Reality

1. About this document

This deliverable is the last report from WP8, finalizing the activities initiated in D8.1 & D8.2 with respect to the identification and initial reporting of the project KPIs, as well as the implementation of the transferability strategy of the project, continuing the roadmap devised in D8.1.

1.1. Deliverable context

Keywords	Lead Editor
Objectives	D8.2 contributes to **all objectives** set for ASSIST-IoT by defining quantitative and qualitative KPIs for all the KVIs envisioned, as well as the rest of identified KPIs for the action.
Work plan	D8.3 is directly linked with T8.2, T8.3 and T8.4, as it gathers all the indicators gathered within those tasks, as well as the transferability efforts and surveys carried out under the scope of T8.4. Additionally, it follows the strategy envisioned at T8.1.
Milestones	Deliverable D8.3 is indirectly linked to milestone MS8 feedback, concluding the efforts provided in the previous deliverables of the WP.
Deliverables	This deliverable is virtually linked to all the rest of the action, as it evaluates several of its facets: architecture (WP2), use cases, legal and regulatory framework and requirements (WP3), technical (WP4, WP5) and integrated (WP6) outcomes, pilot implementation (WP7), as well as impact and outreach (WP9). Key linked deliverables are D3.3, D3.5, D4.3, D5.5, D7.4, D9.4, D9.7 & D9.8 (apart from D8.1 & D8.2 as previous iterations).

1.2. Outcomes of the deliverable

D8.3 is one of the lengthiest project deliverables. This is due to the following factors:

- More than 120 KPIs have been reported, with significant success considering the initial targets (3 targets not accomplished and one not yet measured).
- The of the surveys shared, to gather barriers for implementation, technological acceptance and feedback from adopters.
- The KERs' transferability scores are included, consisting on several questions following AIOTI's methodology.
- The presentation of further research lines stemming from the project, and that could be chase after the project finalization.

1.3. Lessons learnt

Given the large amount of assets evaluated, more than one line could be presented for each of them (plus the insights from the surveys and feedback from adopters – pilots and open callers). Among the different assets, the project selected to highlight the following:

- Administrative and financial are the main barriers for implementing the ASSIST-IoT as any other novel technological proposition.
- Ease of deployment, configuration and usability are the key elements for using the developed tools. Any difficulty on these aspects is a major barrier in the short-term.
- Documentation level of the project is good overall, but has room for further improvement.
- Some security-related KPIs were targeting too high values for this kind of action, not (uniquely) focused on enablers of its vertical. Thus, targets could not be met.

- The project has been executed over 42 months. Novel technologies and paradigms have been emerging over that time, thus, the project has dedicated some effort in reporting further research lines to improve the outcomes after the action, aligning with them.

1.4. Deviation and corrective actions

Some deviations occurred while implementing this deliverable and that are worth mentioning. These are summarized in the following list:

- Since former leader (P08-NEWAYS) had to devote more effort than expected in developing the GWEN, a new leadership (P01-UPV) was agreed to prevent any potential deviation.
- The reporting of KPIs in the previous deliverable lack of some coherence among them, thus a template has been designed to unify their reporting to a certain extent.
- One of the KPIs was eliminated due to it low relation with the action by its original definition (KPI 4.8.4), and a new one has been added for Pilot 3B (KPI 2.4.5). This is expected considering the large number of KPIs.
- Given the large reporting needs and aiming at reducing the load over the project partners, the transferability analysis has been carried out only over the KERs, not over the Innovation elements nor the enablers.
- The market share could not be completed in time. It required higher effort than expected and then project partners agreed to complete it in the following weeks.
- One project KER did not provide two of its business-related templates in time, which affected the computation of one of the KPIs. These templates will be available in the following days.

2. ASSIST-IoT transferability analysis

2.1. ASSIST-IoT as a transferable technology

Transferability of the result outcomes has been a core feature of the project. Technology transfer is "the movement of data, designs, inventions, materials, software, technical knowledge or trade secrets from one organisation to another or from one purpose to another. The technology transfer process is guided by the policies, procedures and values of each organisation involved in the process"[1]. In the project scope, it refers to all the design and implementation choices that allow implementing ASSIST-IoT architecture or specific outcomes (e.g., enablers, pilot-specific software) to verticals beyond those leveraged in the project. With that in mind, ASSIST-IoT:

1. Provided a Reference Architecture, vertical-agnostic, so that NGIoT systems can be adopted by different verticals. It includes several views to:
    - Understand the features that might be involved (*functional*), as well as the properties and cross-cutting functions (*verticals*),
    - Provide the baseline requirements of the computing elements supporting the system (*node*),
    - Describe how a system is developed (*development*), instantiated and operated (*deployment*),
    - Understand how data flows and should be managed in a given system (*data*).
2. Developed (D4.3, D5.5) and released enablers are almost all open-source (mainly Apache 2.0 license), considering the following common aspects:
    - Are mostly domain-agnostic (only 1 exception with the MR-enabler),
    - Packaged as Helm charts to be deployable on any K8s-based virtualized infrastructure (except 3 motivated encapsulation exceptions),
    - Set of pre-configurable values to tailor them for the operational environment,
    - Published in open code, Docker images and Helm chart repositories.
3. Prepared some guidelines for preparing the computing and virtualized environment, as well as a set of scripts for easing this process.
4. Validated the technological proposition in pilots, inviting 3rd-party open callers to further test the ecosystem and enablers (as well as integrating their own solution) in the project pilots.
5. Promoted the outcomes in relevant communities, and explored jointly with the EC's Horizon Result Booster the exploitability of the project KERs.

2.1.1. Innovation Elements

The following table gathers the Innovation Elements identified so far by the ASSIST-IoT Consortium. It should be considered that some of these elements are directly mapped to enablers, while others are aggrupation of them and some additional components to deliver a domain-specific functionality:

Table 1. ASSIST-IoT innovation elements

IE id	IE name	IE type	Task item(s)	Partners involved	Access conditions
IE-01	TruckGUI app	SW Platform	T7.1	PRO	Yearly license
IE-02	UWB Geofencing	HW / SW Platform	T7.1	PRO	On request
IE-03	Multiwireless ROS	HW / SW Platform	T7.1, T4.2	UPV, KONE	On request
IE-04	eGuided ROS	SW Platform	T7.1, T4.4	PRO	On request
IE-05	Workers safety system	SW Platform	T7.2	MOW, SRIPAS	On request

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[1] TWI, "What is technology transfer? (definition and examples)", Available at: https://www.twi-global.com/technical-knowledge/faqs/what-is-technology-transfer

IE-06	MR-based inspection support system	SW source code	T4.4	ICCS	On request
IE-07	In-Service emission diagnostic	HW / SW Platform	T7.3	FORD, UPV	TBD
IE-08	Enhanced scanner	SW Platform	T7.3	TWOT, CERTH, SRIPAS	On request
IE-09	GWEN	HW	T4.1	NEW	On request
IE-10	ASSIST-IoT service deployment orchestration (ASDO)	SW source code	T4.2	UPV	Open source
IE-11	FL System	SW Platform	T5.2	PRO, SRIPAS	Open source
IE-12	Enhanced Security Center	SW Platform	T5.3	S21SEC	On request
IE-13	ASSIST-IoT Horizontal Autoscaling (ASHA)	SW Platform	T5.1	UPV	Open source
IE-14	Edge data broker	SW source code	T4.3	ICCS	On request
IE-15	Enhanced Blockchain as a Service	SW source code	T5.4	CERTH	On request

2.1.2. Main contributions and publications

Some key deliverables for further transfer are D3.7 for understanding the reference architecture, D4.3 & D5.5 with the documentation of the enablers developed, and D6.6 with information practical information to prepare an environment to make use of ASSIST-IoT platform and manageability tools, and D6.7 with a set of resources for packaging enablers and making them ready to be managed by the smart orchestrator:

Table 2. ASSIST-IoT relevant links

Asset	Link
Deliverables	https://assist-iot.eu/deliverables/
Publications	https://assist-iot.eu/publications/
Enablers' code	https://github.com/assist-iot
Enablers' Docker images	https://hub.docker.com/search?q=assistiot
Enablers' Helm charts	https://artifacthub.io/packages/search?ts_query_web=assist-iot&sort=relevance&page=1
Enablers' documentation	https://assist-iot-enablers-documentation.readthedocs.io/en/latest/index.html

2.2. Analysis of relevant transferability analysis methodologies

This section gathers outcomes from previous Transferability Analysis (TA) methodologies, as inspiration for preparing a proper evaluation for the ASSIST-IoT project, described afterwards in Section 2.2.3. Particularly, the TIDE, DocksTheFuture, ELIPTIC and AIOTI approaches are briefly presented in the following subsections.

2.2.1. TIDE approach

An **initial methodology identified** to be considered in ASSIST-IoT is **extracted from the European project TIDE,** and essentially answers to the following question: "*What are the steps to follow if I want to transfer successfully any of the ASSIST-IoT assets in my business?*".

Transferability is the process of verifying the chances of successfully implementing a measure that has been previously implemented in a pioneer use-case to an adopting use-case at an operational or implementation level.

This process involves analysing various factors that influence the potential for successful implementation, drawing lessons from the experiences of the pioneer use-case. By using a transferability methodology, there is an opportunity to learn from previous implementation experiences, enabling better exploitation of opportunities and avoiding mistakes.

The TIDE project aimed to enhance the transfer of innovative measures by refining and incorporating well-proven methodologies into an accessible Transferability Handbook. This handbook was created through a comprehensive review of transferability methods available in scientific literature, practitioners' guidelines, and handbooks. Additionally, a workshop was conducted in Brussels to contribute to the development of this handbook.

Figure 1. TIDE methodology schema[2]

STEP 1: *"Mission statement/objectives and scoping"*

The first step in a transferability assessment is to establish a clearly defined mission statement (or clear objectives) and a realistic scope for the measure. This ensures that any potential misunderstandings during the subsequent transferability and implementation processes are avoided. It is crucial for the adopter to fully comprehend and agree with the objectives and scope of the measure before proceeding with the remaining transferability steps

STEP 2: *"Clarification of the impacts of the measure"*

The identification and quantification of the impacts of a measure are crucial for justifying and providing supporting evidence to consider its implementation by a potential adopting use-case. It is important to recognize that these impacts may vary depending on the specific measure being analyzed for potential transferability.

STEP 3: *"Identification of up-scaling/down-scaling need"*

It is crucial to ascertain whether scaling (up-scaling or down-scaling) of the measure is necessary. If scaling is indeed required, it is essential to carefully consider the potential implications of such scaling during the subsequent transferability assessment steps. This consideration is contingent on various context conditions, primarily the implementation size of the adopter use-case in comparison to the pioneer use-case.

STEP 4: *"Identification of the main components and characteristics"*

In this step, the main factors (referred to here as components) that can contribute to the success or failure of a measure are identified, allowing for the assessment of their relevance to transferability. These factors encompass policy, finance, stakeholder involvement, technical requirements, demographic considerations, as well as institutional and legal frameworks, among others. These components are further categorized into sub-categories (termed here as characteristics) relevant to transferability. The identification of components and characteristics of a measure in the context of transferability draws upon the experiences of the pioneer use-case.

STEP 5: *"Identify the level of importance of the characteristics"*

In this step, the relative level of importance (high/medium/low) for each characteristic is judged from the viewpoint of the adopter use-case. The experience of the pioneer use-case and input from experts in the field

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[2] Source: European project TIDE, available at: https://cordis.europa.eu/project/id/313979/reporting/fr

are valuable in this process. The selected level of importance for each characteristic should be supported by accompanying comments.

STEP 6: *"Assessment of the characteristics in the context of the adopter use-case"*

This assessment is subjective, influenced by the ease or difficulty experienced during the implementation of the measure in the pioneer use-case, but adaptable based on potential modifications for the adopter use-case. A thorough discussion with both use-cases (pioneer and adopter) as well as domain experts is likely necessary for this step. If the assessment is conducted in a group setting, an anonymous scoring approach could be effective.

STEP 7: *"Conclusions"*

The final step of the transferability assessment involves drawing conclusions about the potential for transferability by considering the identified factors and their corresponding assessment values. This should encompass discussions on all key success factors and key barriers for transferring the measure. Additionally, it should include a discussion of the mitigating actions that could overcome these key barriers. Based on these discussions, concluding remarks on the chances of successful transferability should be provided.

From this handbook, **ASSIST-IoT will take the schema presented in Figure 1** and adapt it for the NGIoT ecosystem.

2.2.2. DocksTheFuture TA approach

The "DocksTheFuture" (DtF) project, with its vision for the Port of the Future for 2030, places a strong emphasis on the concept of TA. This process is crucial for ensuring that innovative concepts (IC) developed in specific port contexts can be adapted and implemented in various other port environments, thereby maximizing their impact and utility.

Its objective was to facilitate the uptake and application of innovative concepts in different port contexts. It involves moving these concepts from niche applications to mainstream use, thereby increasing their impact and reach. The analysis requires a thorough understanding of the transfer objectives, which includes identifying risks, challenges, constraints, barriers, and success factors that could affect the implementation of a new concept in different port contexts.

Their methodology follows the **NICHES+ 6-Step Methodology**, developed by POLIS, which is tailored to the specific needs of Port of the Future (PoF) projects. This approach, known as the "PoF TA Methodology", is essential for guiding the transfer process of innovative concepts. The methodology starts with an initial high-level appraisal (TA-score) assessing two aspects: innovativeness and transferability. The key is to transfer an innovative concept, originally applied in a specific situation, to different environments. The analysis is based on identifying issues, particularly success factors and barriers, assessing the practicality of implementation in different port contexts, and evaluating the potential for peering with other ports to share resources and knowledge. Another key aspect of the TA methodology is the "**TA-Index**". This index is derived from a comprehensive assessment of the project using the PoF TA Methodology, which includes evaluating various measured indexes, constraints, success factors, and risk management strategies relevant to transferring solutions to other targeted ports.

In DtF, the methodology is particularly effective in Research and Innovation Actions (RIA), where port peering is used to achieve better outcomes across multiple ports. While maintaining its core features, the methodology is adapted to meet the specific requirements of port environments. This adaptation involves focusing on transferability while addressing port-specific needs and guidelines. The methodology differentiates between potential contribution to transferability (PCT) and ease of transferability (EoT), focusing on developing port-specific risk assessment and management approaches. Three scenarios were foreseen: (i) multi-port participation projects, involving collaboration in living labs or pilot projects; (ii) the "CHAMPION" approach, where experienced ports (donor ports) offer guidance to adaptor ports; and (iii) port peering, in which ports voluntarily collaborate, combining resources throughout the project lifecycle.

In conclusion, the Transferability Analysis in DocksTheFuture represents a comprehensive approach to adapting and implementing innovative concepts across various port environments. It relies on a modified version of the NICHES+ methodology, tailored to the specific needs of ports, focusing on collaborative efforts and effective project management to facilitate the transfer of innovations, thereby enhancing their utility and impact in the maritime sector. **ASSIST-IoT takes the concept of TA-Index**, from their proposition, although computed (and actually meaning) slightly different as the ecosystems in which it applies are not comparable. Other aspects that are taken from this methodology are:

- The identification of the issues, and particularly the barriers that will affect the implementation of a system based on ASSIST-IoT in a particular context.
- The identification of a need of transferability strategy.

2.2.3. ELIPTIC

The ELIPTIC project aimed at developing new use concepts and business cases to optimise existing electric infrastructure and rolling stock, saving both money and energy. This project had strong piloting activities, analysing 23 different use cases focusing on uptake and exploitation. For that reason, ELIPTIC approached transferability based on the results and findings of the demonstrators themselves, as well as a set of feasibility studies. The project designed a 6-step approach, described below, has been adapted for the ELIPTIC use cases transferability:

Step 1 - Selection of candidate ELIPTIC Use Cases (EUCs)

Step 2 - Cluster of origin cities

Step 3 - Selection of target cities

Step 4 - Cluster of target cities

Step 5 – Transferability exercise

Step 6 – Assessment of transferability

Step 1 - Selection of candidate EUCs

The EUCs selection for transfer was based on the EUC's progress and results as well as possible barriers occurred during the implementation phase assessment. The assessment outcome was that there are no bad examples, even if not optimal performance level was reached. Therefore, all EUCs qualified for being considered for the further transfer becoming "origin cities.

Step 2 - Cluster of origin cities

Within the step, the cities were characterized utilizing selected variables. The variables identify the context needed by the target city to receive a given measure typical of a given origin city. The variables were ascribed to the physical, the institutional and the socio-economic domains. The cluster of EUCs as origin cities was established.

Step 3 - Selection of target cities

The target cities should be qualitatively close to the origin cities considering metropolitan/urban areas, dominant transit mode and similar in terms of the feasibility of operations associated to the measure to transfer. In general, the biggest is amount of the candidate cities, the more appropriate will be the choice. Two types of target cities were considered: the twinning cities, as close to EUCs per definition, and untwined cities.

Step 4 - Cluster of target cities

In the step the final election is carried out by comparing the origin cities with the candidate cities. The options for clustering the final cities are horizontal (comparable cities also from different nations) vs. vertical (within national boundaries scale up to national levels) and real (no matter the scale of transferability, the variables will allow to identify real cities where the UCs can be transferred) vs. hypothetical (profiling "ideal" cities where the measures can be transferred). The process resulted into an interesting mix of vertical and horizontal choices.

Step 5 – Transferability exercise

Transferability exercise is based on the assessment of the transferability as technical feasibility and the strategic opportunity. The study of transferability technical feasibility means to define some thresholds as limits for transferability, whilst transferability as strategic opportunity means to define possible goals to motivate the transfer of the EUCs measures to the target contexts. For a given target city planned to successfully implement a given measure from the EUCs, the requirement was to meet the threshold values for the considered KPIs in the technical and strategic fields. In the ELIPTIC project the transfer exercise was based on the quantitative data coming from tests or on qualitative assessment according to surveys. In particular, KPIs for the demonstrator and SWOT narrative for the feasibility studies were used. A questionnaire was developed to collect the data from the responders. Multiple test sessions were run.

Step 6 – Assessment of transferability

In this step the visions and results were compared and critically assessed.

Transferability exercise - insides

After established methodology, selection of the target cities and collection of the EUCs results, the transferability exercise started. The key activities within the transferability exercise were:

- Preparation of the questionnaire tool
- Questionnaire submission to the participants
- Preparation of the calculation spreadsheets
- Results analysis and elaboration

The developed questionnaire included results from KPIs and the narrative from the SWOT analysis, addressed all clusters of technological concepts, allowed to analyse preferences according to the strategic opportunity options (i.e., the visions) and assess the technical feasibility (i.e., threshold values). From the user side in was easy to fill and supported the fast data process. The questionnaire draft was presented to the project partner for the tests. The second and final questionnaire after including the test feedback was developed in Qualtrics Platform. The collected data were passed into Ms Excel for further processing.

Considering the former, ELIPTIC had strong piloting activities, analysing 23 different use cases focusing on uptake and exploitation. For that reason, its approached transferability based on the results and findings of the demonstrators themselves, as well as a set of feasibility studies. ELIPTIC presented a **questionnaire** as an exercise for quantifying the transferability of a particular solution. ASSIST-IoT cannot consider the same questions, as the ecosystem is different, however, it is inspired by this project from its approach. In particular, as it will be seen in the following subsection, ASSIST-IoT will distribute a survey among adopters (namely, pilots and Open Callers) to gather insights about its current transferability and usability.

2.2.4. AIOTI Replicability and Scalability Assessment (RSA) Tool

As part of the research and innovation actions of the Alliance for IoT and Edge Computing Innovation (AIOTI), a task force on Replicability and Scalability was created. The Replicability and Scalability initiative has the objective to facilitate the re-usage of IoT and Edge computing use cases and solutions developed in European funded projects. A number of projects are developing and experimenting use cases and solutions that could be advantageously replicated in other locations in order to avoid reinventing the wheel syndrome. For that purpose, the **Replicability and Sustainability AIOTI Task Force** has decided to work on a tool and a set of guidelines to assess and foster the replicability and scalability of project results, maximizing their impact, facilitating their uptake and bring them to the market. Moreover, this initiative is aimed to encourage innovation and stimulate cooperation among European, national, regional and local actors. Particularly, this task force aims at:

1. Providing criteria and guidelines to be taken into consideration when we talk about Replicability and Scalability in an EU R&I Project, starting from LSPs (especially in IoT domain and 5GPPP Pilot projects) experiences.
2. Providing a "Replicability and Scalability Assessment Tool" to increase project efficiency and maximise the impact of project results, in line with the EU Commission expectations.
3. Facilitating emerging of Innovation Ecosystems in EU and their interconnection.

The ASSIST-IoT project will make use of this tool developed by the AIOTI for characterising the replicability of the outcomes of the project.

2.3. Methodology and results

2.3.1. Methodology

In first place, the methodology considers the **DocksTheFuture approach**, numerically characterizing the transferability of the solutions provided and, also, identifying the different barriers that may affect this adoption. DocksTheFuture focused on port environments; thus, in ASSIST-IoT, the index is computed in a very different way. Particularly, being adapted to the particularities and characteristics of NGIoT, the ASSIST-IoT methodology quantifies the transferability capabilities of the innovative elements considering the **AIOTI's replicability and Scalability Assessment (RSA) Tool**. Dedicated surveys for identifying the (administrative, financial, ethical, technical, geographical, legal, etc.) barriers are also considered.

The second aspect of the ASSIST-IoT methodology is about the **adaptation of the TIDE methodology** for the specific characteristic of NGIoT environments. This methodology defines a set of steps to facilitate the implementation of innovations in smart city context. The following steps are envisioned for NGIoT ecosystems:

STEP 1: "*Business scenarios and use cases involved*". Before starting to assess a potential technological adoption, it is key to understand the ecosystem in which it will work. This includes simple use case diagrams identifying primary "actors" and processes that form each system, including involved actors (i.e., persons, devices or digital entities), pre-requirements, assumptions and/or pre-conditions; and flow of events between actors, and sequences of interactions focusing on differences from current operations. It is crucial for the adopter to fully comprehend and agree with the objectives and scope of the measure before proceeding with the remaining transferability steps.

STEP 2: "*Clarification of expected impacts of the measure*". The second step entails to understand which are the expected outcomes of the innovation that will be applied, in technical, social, economic and any other relevant aspect for the business scenario. Enough evidence should be provided, linking these impacts with the expected features brought by the NGIoT system.

STEP 3: "*Identification of requirements*". This step goes beyond the former, moving towards a formalization of their expectations. Requirements should be clear, complete, consistent and time-bounded. Technical and business needs need to be gathered, and how they are expected to address associated process improvements, organizational changes and policy development be managed. Requirements and business analysis will help to initially assess and refine action coverage, identifying existing gaps (technical, functional and organisational) to fulfil the operational concept, approach and goals.

STEP 4: "*Identification of the enablers and their characteristics*". In this step, a first effort in envisioning a NGIoT system is made, assessing first which features are desired to meet the identified requirements, and mapping them with actual enablers from the horizontal and vertical planes. It is key to select those that are really needed and avoid aiming at having an overloaded system.

STEP 5: "*Identify the level of importance of the enablers and their features"*. Once enablers are selected, a dedicated plan is required. This entails identifying the provisioning, development, integration and validation activities, overall envisioning an implementation plan. Custom developments might be needed, and this additional effort must be accounted for, as in the end, the offered enablers are pilot-agnostic so they have to be used and configured accordingly.

STEP 6: "*Conclusions*". Once the strategy is clear, a final assessment of roles in the end-to-end process needs to be made, analysing the potential risk factors that may appear during the technological adoption. Contingency plans must be always considered to overcome these barriers. Based on these discussions, concluding remarks on the chances of successful transferability should be provided.

Finally, following the practical piloting approach considered by ELIPTIC, the methodology finally considers a third step, feedback, collected by a set of surveys, this among the real adopters of the ASSIST-IoT proposition (i.e., platform, enablers, etc.). This entails the gathering of a set of questions from real users in piloting activities and open callers, thus obtaining subjective numbers that can help identify additional issues that may arise before, during and after its adoption. To sum up, the project methodology is expressed in the following diagram:

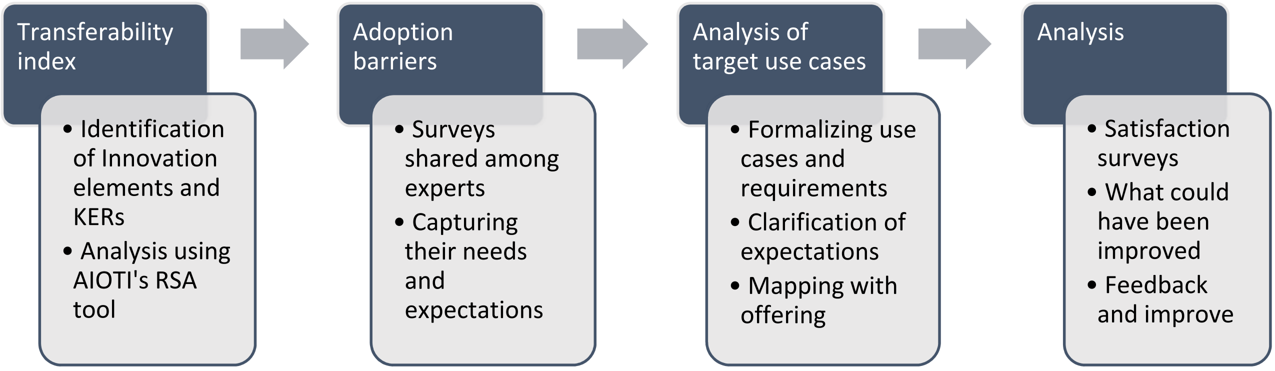


Figure 2. Steps of the ASSIST-IoT transferability methodology

2.3.2. Assessment of the results of ASSIST-IoT

2.3.2.1. Transferability index

The Key Exploitable Results (KERs) of the project have been characterized considering the replicability and scalability assessment tools of AIOTI (see Annex A). Particular results can be seen in the following table:

Table 3. Replicability and scalability scores from ASSIST-IoT's KERs

#	KER	Score	Detected flaws
1	TrackGUI app	45/80	Some effort to make data management more secure could be included. Missing extended documentation, and presenting difficulties to be implemented by any entity not being the KER owner.
2	Workers safety system	55/80	This is one of the more complete solution, tackling correctly several aspects of the questionnaire, thanks to its holistic design from multiple perspectives. Still, it is a concept that needs further validation for its maturity to be introduced in the market.
3	In-service emission diagnostic	40/80	Solution to be further documented and validated by real users. Difficult to install and maintain without expert support. Room for improvement in the management of data. Strategy for commercialization pending to expand.
4	Enhanced scanner	49/80	Technically it is quite mature, with some room for improvement with respect to data quality measurements, if desired. Further documentation is required for its long-term sustainability.
5	GWEN	41,25/80	Effort towards exploitation required. Further testing and validation with real stakeholders needed.
6	Enhanced security center	47/80	Main drawback encountered was about data. Although the used tools and techniques should work properly, data erasure and cypher techniques would be of special interest for long-term scalability and sustainability.
7	ASSIST-IoT platform	50/80	Data model to be standardized/use existing ones. Further validation on industrial environments pending. Data resilience and consistency mechanisms to be integrated. More work towards further commercialization pending. Improvement of documentation would be desirable.

These KERs are some examples of technologies developed from the project, being particularly the assets with higher exploitation possibilities. In any case, the rest of Innovation Elements listed in 2.1.1 could also have been analysed and, in any case, are part of them. Overall, results show quite acceptable levels of acceptability, with logical room for improvement as the project is a Research and Innovation Action (RIA) and thus additional efforts are needed in order to bring them to the real market.

2.3.2.2. Survey #1: Barriers for implementation

A questionnaire was developed in the framework of task T8.4 of ASSIST-IoT project, containing a set of questions related to heterogeneous fields in order to understand the **adoption and implementation barriers** of NGIoT solutions (i.e., administrative, political, financial, technological, geographical, cultural related barriers/drivers). T8.4 relies on the exposed information on the developed deliverables of the project (https://assist-iot.eu) and spreads this questionnaire to selected experts and stakeholders with technical background to gain knowledge on such barriers and drivers. The questionnaire is structured in five parts, starting with a profiling chapter to understand the responder background, followed by some sub-parts corresponding to the features that characterize the adoption barriers. The aims of the survey are:

- To collect experts' and stakeholders' opinions on the relevance of each barrier and specific aspect, to feed back the technical and exploitation approaches of the results of ASSIST-IoT.
- To understand the different views of the barriers depending on the respondent profiles.
- If necessary, to map additional barriers which had not been considered. This questionnaire is the first of a series of three surveys that are planned to be exerted by T8.4 of ASSIST-IoT.

PROFILING AND MISCELLANEOUS

The survey was answered by 25 people, devoting an average time of ~29 minutes. 48% came from academia and research, 32% from SMEs, 12% from large Industrial companies, 4% from service provider and 4% from Non-profit organizations (NGOs). Their technical expertise is summarised in the following figure:

Figure 3. Technical expertise responders

Among the repliers, 64% have real expertise working with IoT, and the same number was aware of the term NGIoT. Among the key features demanded by adopters for full-fledged IoT systems, prioritization was on (i) ease of installation and use, (ii) scalability and growth possibilities – thus (iii) open source, (iv) usability of data and (v) interoperability with existing systems, as can be seen in Figure 4 below.

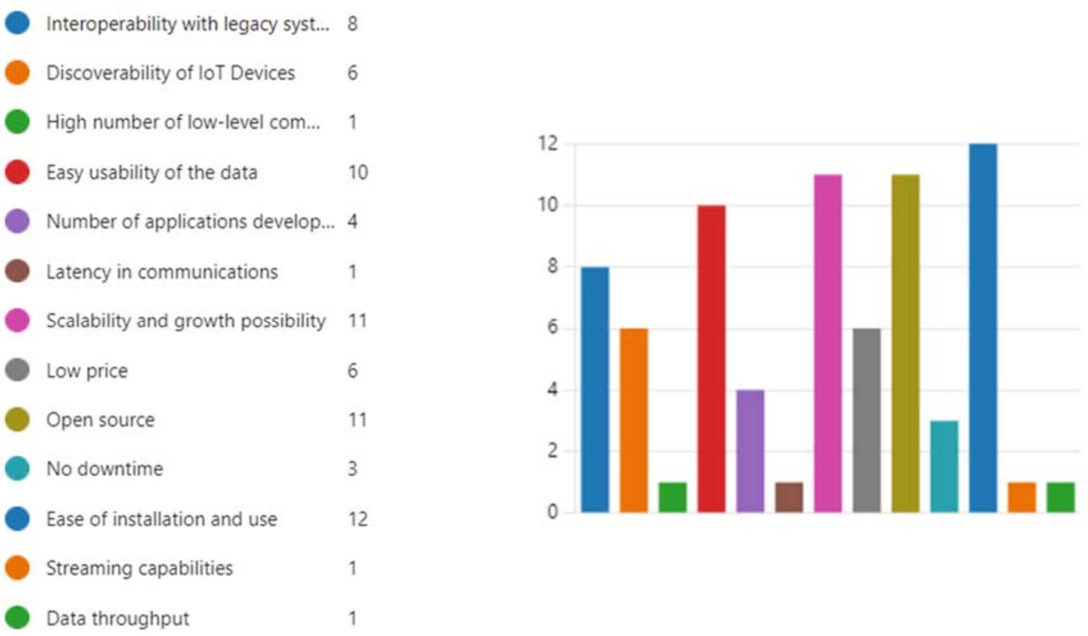


Figure 4. Importance of full-fledged IoT systems

This can be summarized as users wanting to have systems that are easy to use and can be tailored for their particular ecosystems. Besides, regarding NGIoT, responders prioritized (i) distributed orchestration of workloads, (ii) ubiquitous access, (iii) agile DevOps methodologies, distributed learning and AI as key features, all in all obtaining higher variety in this case (see Figure 5).

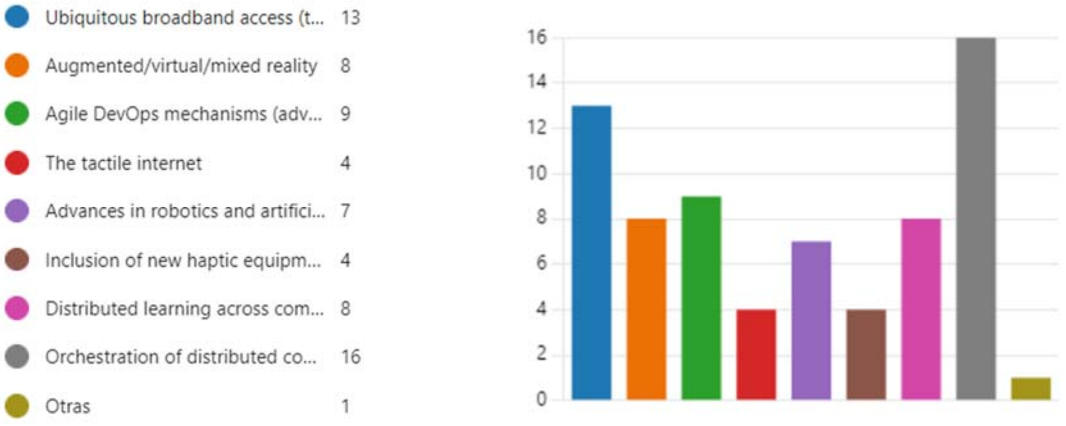


Figure 5. Relevant features of NGIoT

Among the different barriers, responders foresaw administrative, financial, technological and internal barriers as the most critical ones for a NGIoT system adoption, rather than cultural, political and geographical. The following questions delves in some of these barriers.

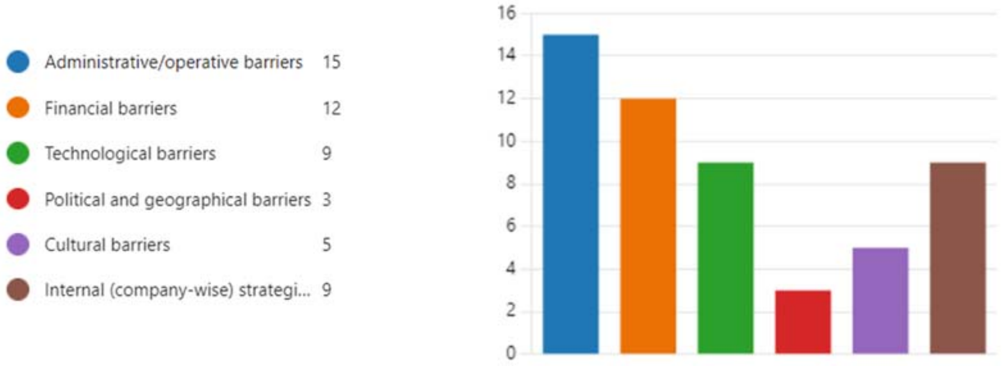


Figure 6. Barriers to adopt modern solutions based on IoT

ADMINISTRATIVE, OPERATIVE AND FINANCIAL BARRIERS

The following questions were distributed regarding administrative barriers, with the answers obtained below. Some of the most important barriers were i) the high investment required for unclear Return of Investment (RoI), (ii) limited short-time payback expectations and (iii) lack of funds or access to finance; on the contrary, less importance was given to (i) the salaries of skilled staff, (ii) the volatility of the trends in the NGIoT sector and (iii) the lack of trust of NGIoT EU providers. To sum up, financial issues have been more critical than operative or administrative ones.

Figure 7. Answers to administrative, operative and financial barriers

POLITICAL, GEOGRAPHICAL AND CULTURAL BARRIERS

In this classification:

- 72% of the responders were not fully aware if the current/ongoing regulation in the cloud, edge and AI areas in Europe;
- 64% were not aware of the existence of tax incentives for the adoption of edge to cloud systems (4% answered that "yes" and 32 that "no");
- 52% against 28% think that regulation to address energy crisis will influence (for better or worse) in the choice of adopting cloud/edge NGIoT systems, while 20% did not have any opinion.
- And with respect on the environmental crisis, the number was raised to 64%, with 16% answering as no and 20% without expressing their opinion.

With respect to where they believe that EU ranks in terms of edge computing market in comparison to other world competitors: EEUU, China, India, South-America, Africa, Other Asian markets. *Rank 1 (BEST) to 7 (WORST)*, most responders placed EU in third and even fourth place.

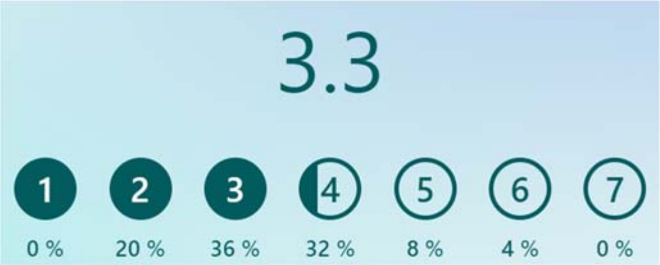


Figure 8. Rank of EU in the edge computing market

Among other data (1 min, 6 max), responders think mostly that current and future political relations at the international level can influence European companies to adopt European NGIoT products rather than other world competitors'-based products.

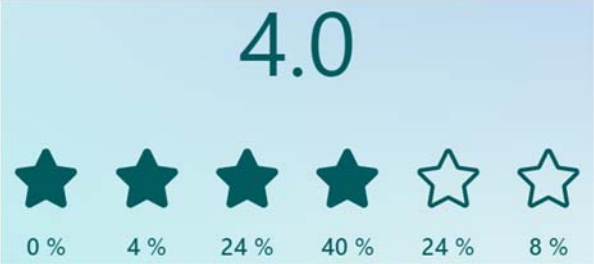


Figure 9. Influence of political relations to adopt European NGIoT products

On the same scale, they consider that blockchain has low pervasiveness and widespread in their countries (2.3), while they consider that AI (3.2), orchestration (3.3) and especially cybersecurity technologies (3.6) have larger adoption.

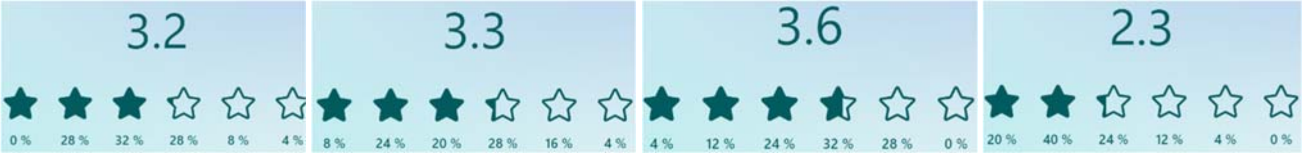


Figure 10. Pervasiveness and widespread adoption in respective countries of AI, orchestration, cybersecurity and blockchain (from right to left)

About the importance of associated barriers, most of the options had significant levels of importance for the responders, arguably being the existence of attack surfaces for cybersecurity the option that was less important for them (we consider that it might be due to the "technical" nature of the responders). On the contrary, privacy concerns were the ranked as most important.

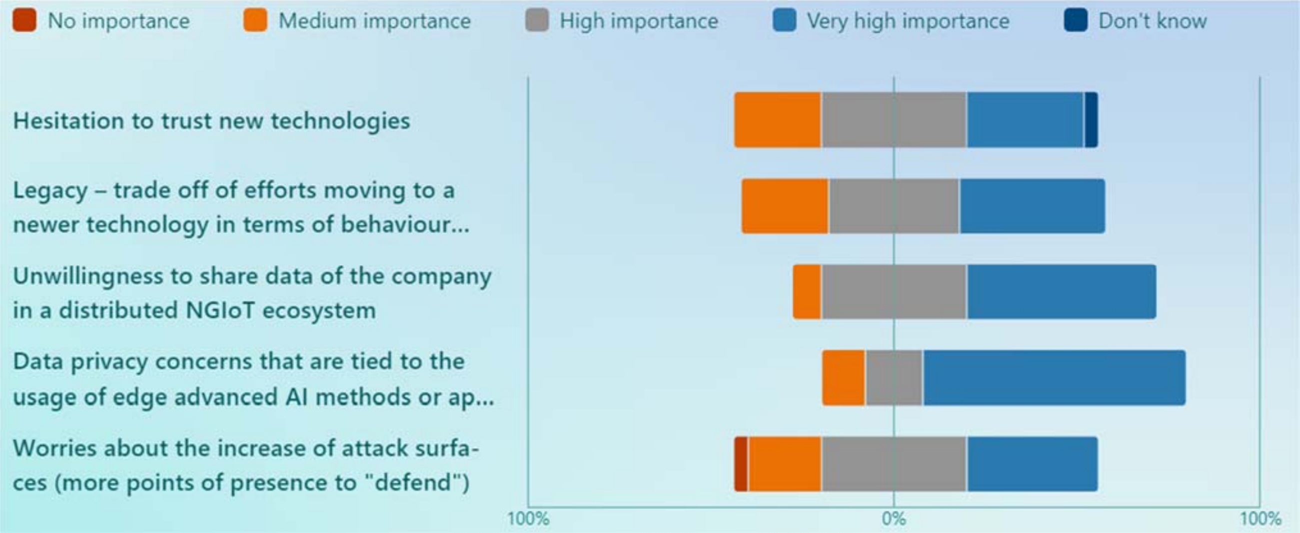


Figure 11. Answers to political, geographical and cultural barriers

MISCELLANEOUS

Additional questions were shared for further profiling the responders as well as gather additional numbers beyond the barriers mentioned. Among them,

- 76% answered that their entity does not host any application making use of NGIoT architectures;
- Around half of them (52%) do not consider IoT critical for their business applications or processes;
- Feel that this paradigm is relevant for operation (42%) and innovation (36%) areas, but less for management (12%), selling (6%) and human resources (2%);
- Consider that a hybrid (48%) approach between private cloud (24%), public cloud (24%) and on-premises (12%) deployments are better for deploying NGIoT systems, with 4% not answering;

Finally, responder believe that better control of the scattered applications of the continuum, cost savings and modernization of the monitoring and computing fabrics of the company (Figure 12) are the key factors of implementing NGIoT technologies.

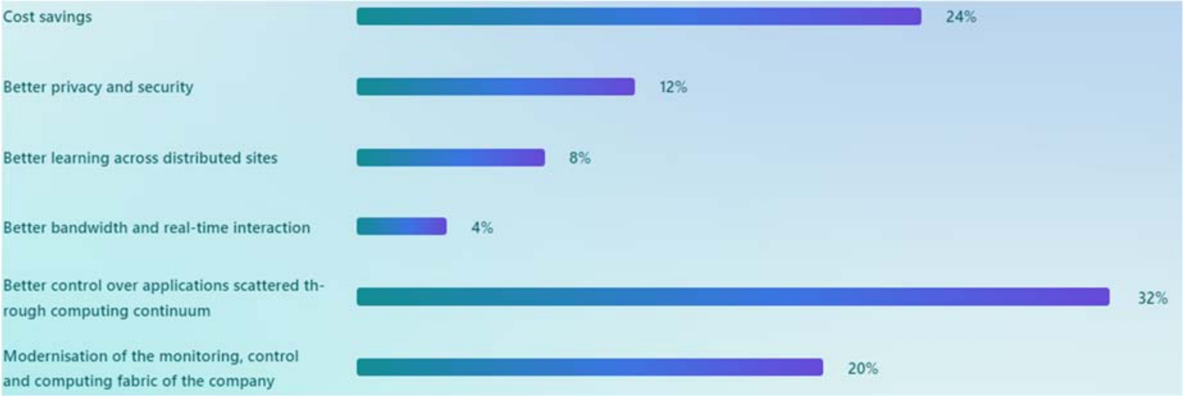


Figure 12. Key factors of implementing NGIoT technologies

2.3.2.3. Survey #2: Technological acceptance and expectations

The questionnaire was structured in 3 parts, starting with a profiling chapter to understand the responders' background, followed by two sections to retrieve feedback about the technical decisions adopted by the project. Particularly, the aims of the survey are:

- To collect technical experts' opinions on the technical approaches followed by ASSIST-IoT.
- To know which might be the most relevant/"appealing" outcomes produced by the project. This questionnaire is the second of a series of surveys that are planned to be exerted by T8.4.

PROFILING AND MISCELLANEOUS

The survey was answered by 34 people. 65% came from academia and research, 24% from SMEs, 6% from large Industrial companies, 3% from service provider and 3% from Non-profit organizations (NGOs). Among them, 65% had real experience with K8s-based system, either self-managed or hosted by a hyperscaler (AWS, GCP, Azure, etc.). Their technical expertise is summarised in the following figure:

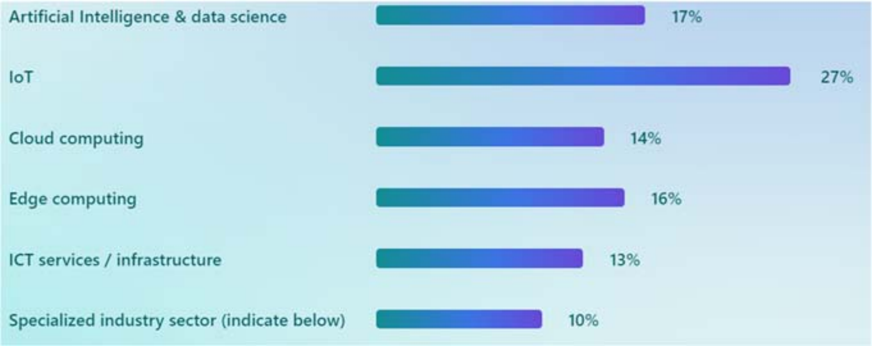


Figure 13. Technical expertise responders

Responders identified the most beneficial aspects of NGIoT, prioritizing having good installation and configuration guidelines, well-defined interfaces and baseline technologies among the rest of the options:

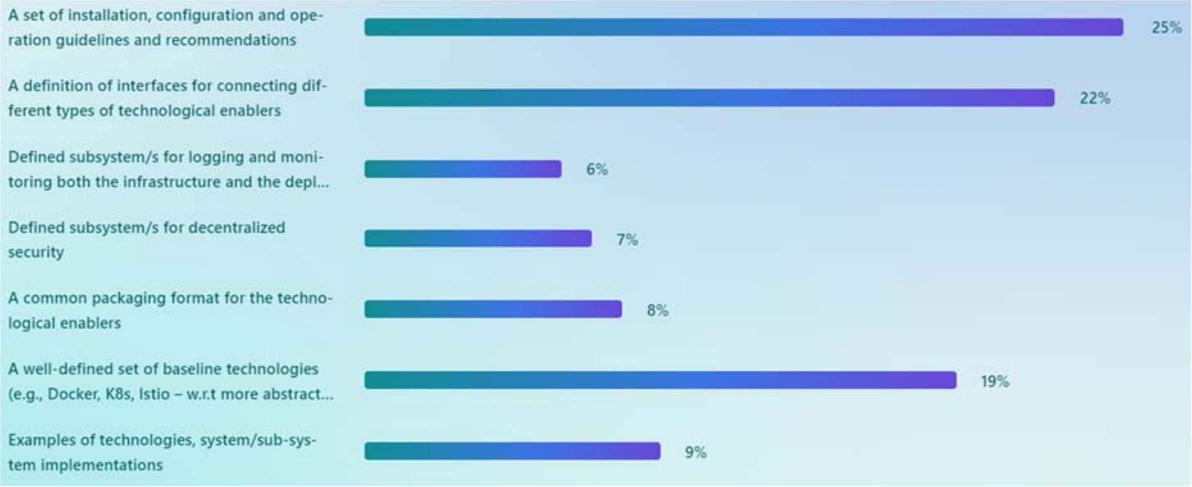


Figure 14. Beneficial aspects of a Reference Architecture for Next-Generation IoT

They also rate the importance of different aspects related to microservices and containers. While they saw beneficial the resiliency mechanisms, surprisingly not high importance was given to the possibility of working with external teams, or the integration of DevSecOps processes, as can be seen in the figure below:

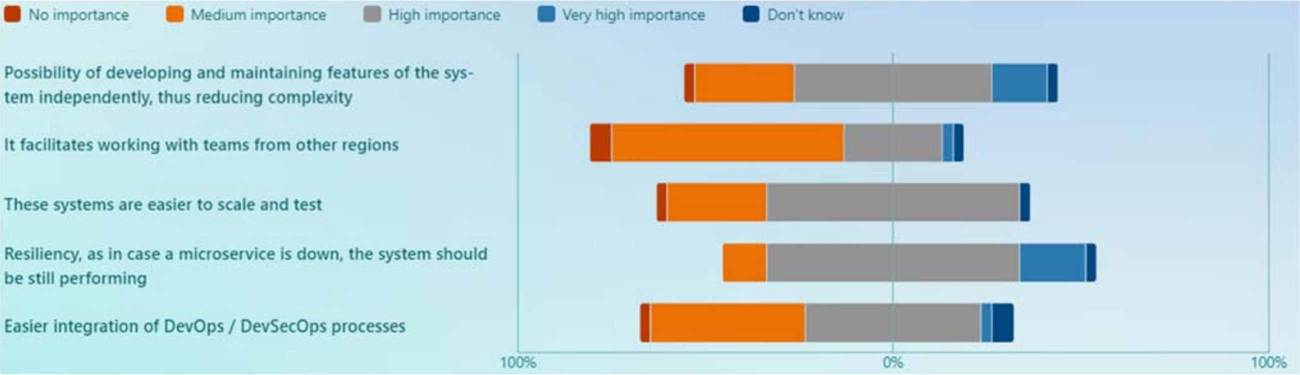


Figure 15. Aspects related to microservices and containers

With respect to the most challenging aspects of distributed (IoT-edge-fog-cloud) computing systems, (i) the management of connectivity and data interoperability among workloads, (ii) having strong self-healing mechanisms against failures and (iii) the configuration of data pipelines were the most selected options:

Figure 16. Challenging aspects of distributed IoT-edge-fog-cloud computing systems

With regards to the enablers in which adopters are more interested in, workloads orchestration, data management and cybersecurity enablers were the most liked ones, still, the rest of the options were demanded to a greater or lesser extent:

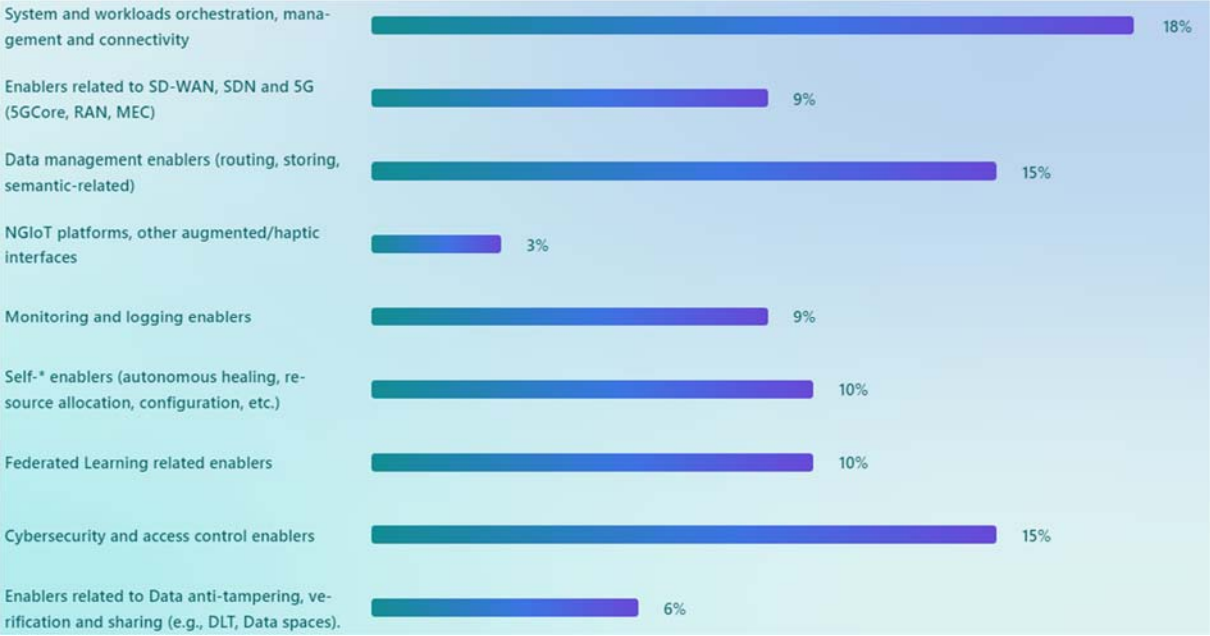


Figure 17. Technological enablers for NGIoT demanded

Particularly, on the field of self-* services (i.e., autonomous enablers, supporting the main system), less importance was given to self-context and self-configuration and surprisingly, to self-resource provisioning. On the contrary, self-healing was the most demanded aspect, as well as self-monitoring and notifications, as can be seen in the figure below:

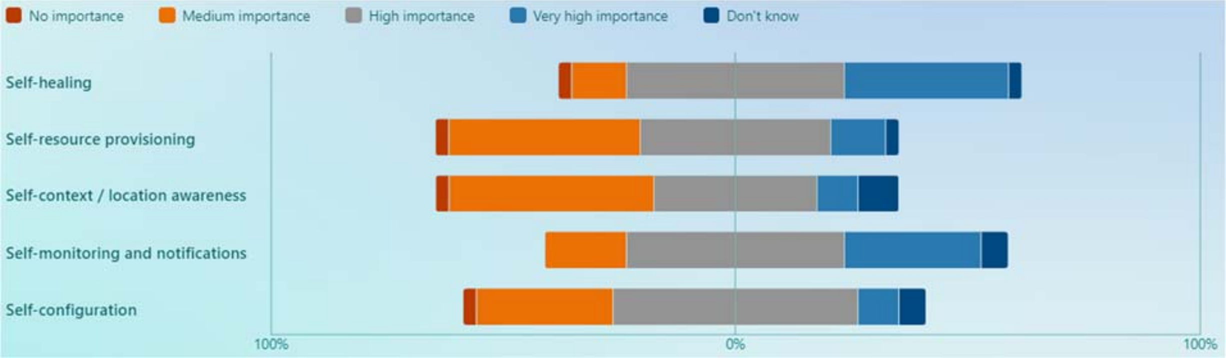


Figure 18. Importance of self- enablers*

On the hardware side, the project has implemented its own Gateway/Edge Node (GWEN), consisting of processing and storage power as well as (i) wired (Ethernet, RS232/485, CAN & CAN FD, USB; (ii) wireless (WiFi, Bluetooth and 3G/4G/5G); and (iii) UWB interfaces for localisation purposes. Users were more interested on the pre-installed software rather than its expandibility and, especially, the use of Yocto:

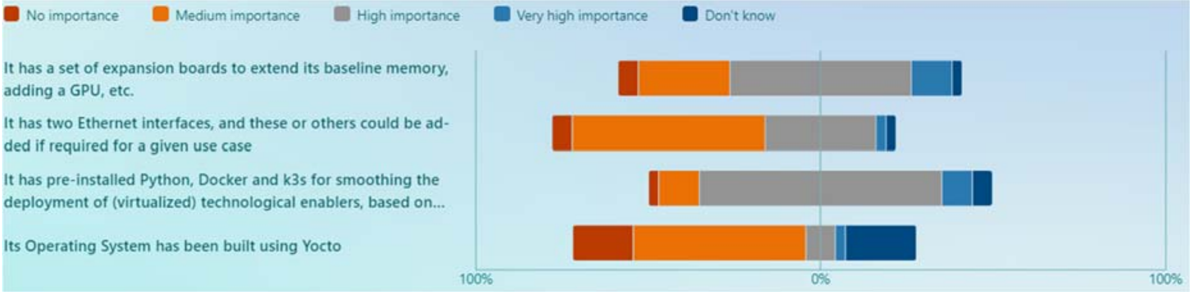
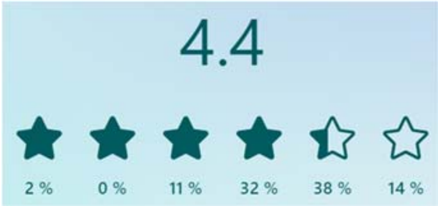
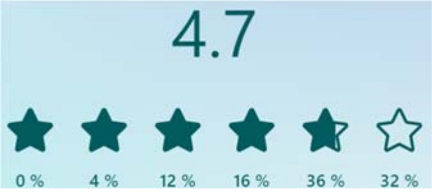


Figure 19. Importance of ASSIST-IoT's GWEN features

Among other aspects:



- In a rank from 1 to 6, responders agreed to leverage Cloud Native concepts for the edge-cloud continuum (i.e., based on microservices, containers/Wasm, Service mesh, K8s, DevOps), with proper adaptations.
- 52% did not express any opinion with respect to gRPC vs REST becoming prominent for managing communication between microservices, showcasing its relatively low pervasiveness among the community. 41% sees it a possibility, while only 5% do not think so.
- 61% of responders were not aware of the WebAssembly (Wasm) standard. 44% of them expect it to take significant market from the container-based paradigm while 5% do not think so.
- On the contrary, DLT is more well-known, having in this case a 35% of responders not aware of this family of technologies. 70% of respondents see it beneficial for ensuring the validity of registered logs/data in novel systems (against 23% who do not know, and 5% who answered as no).



- According by responders, 73% of them are aware of colleagues leveraging it for coding, seeing it very beneficial (4.7/6). The same number expects its use for DevOps processes (testing, building, deploying, monitoring, etc.).
- Finally, on a rank from 1 to 6, responders believe that they or they customers could benefit from augmented/virtual/mixed/haptic interfaces (AR/VR glasses, haptic controls/gloves, holograms, etc.), getting a value of 4/6.

2.3.2.4. Use cases and requirements

This section presents a follow up of the steps mentioned, including resources available.

STEP 1: "*Business scenarios and use cases involved*" -> Available in D3.3.

STEP 2: "*Clarification of expected impacts of the measure*". -> Available in D8.1 (Section 4.2).

STEP 3: "*Identification of requirements*" -> Available in D3.3.

STEP 4: "*Identification of the enablers and their characteristics*" -> Available in D7.1.

STEP 5: "*Identify the level of importance of the enablers and their features*" -> Refined during beginning of implementations in D7.2 & D7.3.

STEP 6: "*Conclusions*" -> Feedback from pilots (see questionnaire results from Sections 3.2, 3.3 and 3.4) and open callers, available below.

2.3.2.5. Feedback

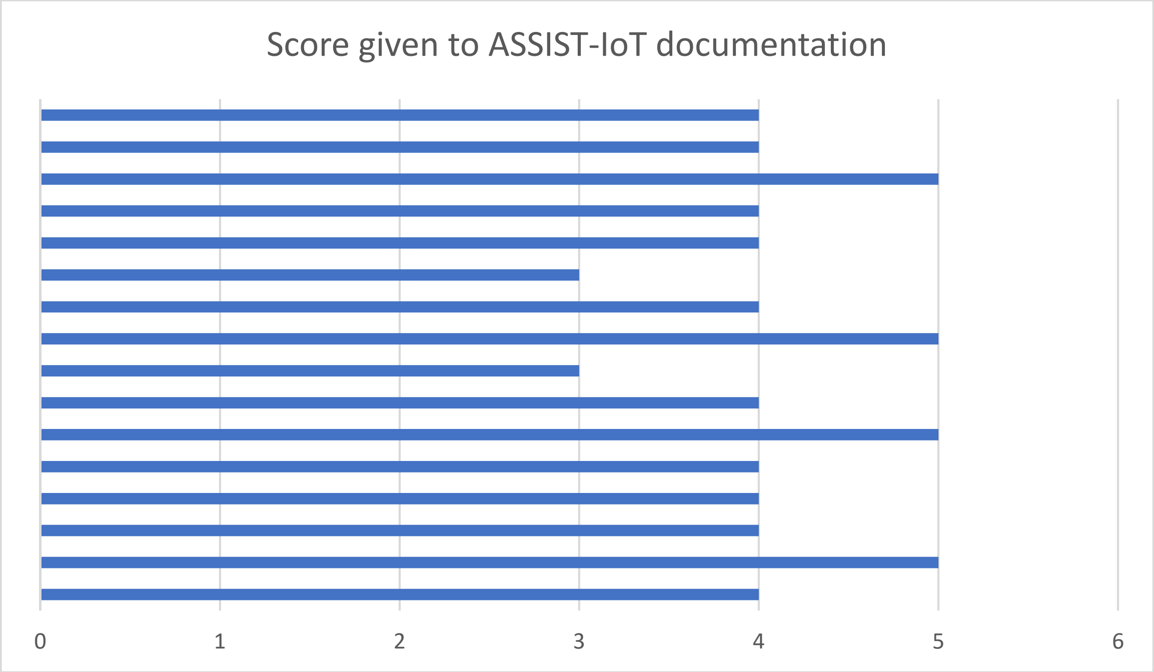
This sections summarizes the feedback that has been received from Open Call participants. In general, some of them express their suggestion to enhance the **documentation of the enablers**, as that is a key adoption barrier and can discourage further pervasiveness of the project results:

- "*Documentation should be updated from the beginning and contain more detailed info. It was updated during the project with more images and new information - now it is more useful; each enabler's details should contain its development state, related documentation, documentation date, and documentation version*".
- *"It would be helpful to have the payload formatting in a column at the REST API endpoints section"*.
- *"In some cases, additional information about the deployment of the components could be improved"*.
- *"A set of tutorial guides could be very useful. With concrete examples explained with step by step command (like posts in medium which conduct a step-by-step example of using a certain technology) that can be repeated in a local environment. If the enabler has different application cases where it is*

used differently, support each of these with such a guide. I think this would help a lot encouraging third parties to make the step of trying the enablers*”.

- *“We plan to work on Federated Learning enablers. We would like to have more documentation related to the configurations required to have the different services connected together (if not readily available by installing the Helm packages on the same K8s cluster), more details on API payloads, and some procedures to test that the installation is working properly”.*
- *“A more complete description of the Multilink Enabler would be desirable”.*
- *“It is well structured. Some sections need to be completed but overall it is nice”.*
- *“Provide for more components some "Hello world" tutorials, to facilitate the first step for using them”.*

Out of the gathered responses (16), the average score given to documentation is 4.1/5



With respect to the deliverables of the project, in general they were quite happy with the level of the project:

- *“Relevant information used for the architecture definition”.*
- *“It was useful to know the general structure of the project and the way the different functionality was deployed”.*
- *“The documentation was easily accessible and complete at a very technical level that made the preparation of the proposal easier”.*
- *“Highly detailed”.*
- *“All the documentation is well structured and can be easily understood”.*
- *“When preparing the proposal, we found the available deliverables good enough to get an idea of how the overall ASSIST-IoT architecture looked like and what were how we were expected to interoperate with its components”.*
- *“The description of the data and the scanner setup for the Pilot 3B is very good, with the exception of a few issues. Due to the large image size and the substantial number of images, it is not feasible to provide a solution that will run efficiently on a Jetson. To address this, we propose to provide a containerized OpenAPI enabler designed to run on Pilot 3B’s edge device which is very much the same and probably fits better to Pilot 3B as it removes the communication overhead between the jetson and the edge node”.*
- *“It was OK”.*
- *“The deliverables about the reference architecture were useful”.*

- *"Most of the information required was made available through the documentation. Discussions with partners helped clarify few things".*
- *"I found the documentation in your deliverables to be clear, comprehensive, and well-organized".*
- *"I found it satisfactory".*
- *"We think deliverables were moderately useful to us. They did not contain all the aspects necessary for us to correctly interpret architecture".*
- *"They were good quality deliverables. However, there were quite high number of information. The online documentation, everything in one place is a much better option".*
- *"At a good level".*
- *"Good".*
- *"The information in the deliverables was helpful when preparing the proposal".*

Another question that was raised to them was about "how different did they feel about the technical scope of ASSIST-IoT enablers and architecture comparing to now and when they were writing your proposal". It can help understand if their assumptions/expectations were right, or if further details should have been provided. The answers can be seen below. All in all, adopters were quite aligned with the proposition from the beginning, but still recognized the advancements carried out during the months they were part of the project, with some few cases in which their expectations were not the correct ones, showing room for improvement.

- *"The technical scope seems to be ambitious; at the end of the project we are more confident that the scope is possible to execute".*
- *"Now it is more clear how enablers work and the kind of service they can offer to reduce the amount of work necessary to cover certain tasks (instead of self-implementing them)".*
- *"The enablers were well documented, which enabled us to start the development before the enablers were fully ready. Once the enablers got complete, we had very few issues achieving a full integration".*
- *"Reached the initial expectations".*
- *"We gained a lot of helpful knowledge for the future regarding the cloud (Helm, Kubernetes) and the overall project architecture".*
- *"Nothing to remark".*
- *"We liked the many examples provided in the documentation and there are lots of enablers that can be integrated".*
- *"Now we have a much clearer understanding".*
- *"It is the same".*
- *"I think the architecture contains a pretty complete list of components. It also contains the layers of the things to cloud computing continuum. It seems, however, that the enablers are implemented for those layers where sufficient hardware capacities are available to run Kubernetes components".*
- *"Difficult to compare, it was almost a year ago. But the documentation was already helpful".*
- *"I believe that the technical scope of ASSIST-IoT enablers and architecture has evolved and improved since I wrote the proposal, demonstrating a positive development".*
- *"Considering our project scope, we expected the FL enablers to be ready at this point, but still one of them is still not ready and the project is very close to the end".*
- *"We misunderstood the functionality of enablers (Multi-Link enabler) when writing the proposal, which is why we had to make several corrections".*
- *"Our understanding about the ASSIST-IoT before and after the proposal remained nearly the same. However, after having interacted closer with the project's participants, we have now better understanding of it. But it still requires some further exploration. In particular, we lack some concrete use cases that we could work on".*
- *"Now, everything is clearer".*
- *"The same".*

- *"In terms of design, the ASSIST-IoT enablers and architecture I think they were pretty stable, but the status of the on-going implementation for some of the enablers were not clear from the available documentation (however, such documentation can probably not easily be provided while a component is under development or evaluation)".*

The following logical question was to how they managed to fulfil the unexpected gaps they found, between the promised scope of the project and actual status. In such cases, they value the help provided by the ASSIST-IoT members to overcome such possible issues.

- *"Regarding VAE: the initial state was not developed as we were expecting; to solve this problem we decide to improve the enabler structure".*
- *"There were some enablers and functions not available at the beginning of the project execution, but later they were provided. It is understandable, given we were within the first open call".*
- *"Technically, we were able to integrate as expected. Small issues within the implementation of the enablers were targeted very fast and solutions came promptly. Having frequent meetings with our point of contact in the pilot also made the integration process of our project much easier".*
- *"Strong interaction with and support from Pilot Host".*
- *"We researched any possible solution and after discussion with the partners of the ASSIST-IoT, we agreed to choose the one that seemed more relevant to the project's goals".*
- *"Not applicable".*
- *"We did not find any unexpected gaps".*
- *"We constantly trying to meet ASSIT-IoT Technical scope. In terms of technology stack we are aware of what is needed but given the very specific nature of the Pilot we are facing some issues due to the massive data size".*
- *"Contacting with the enablers providers".*
- *"We regularly inform the ASSIST-IoT team about our progress and in our meetings we discuss options and solutions for any gap that may appear".*
- *"For now, the only technical requirement we are missing is the ability to provide vehicle 2 vehicle direct communications. We fill the gap by emulating such a link with Android device 2 device link".*
- *"We may need, for the FL scope, to focus more on theoretical documentation about the integration rather than actual implementation".*
- *"We had to adapt our scenarios to take into consideration our updated understanding of what the functionality that the enablers offer".*
- *"We had some delays for obtaining some sample data, but it was not critical, we are progressing as planned. We may need to work on with the project team on some concrete use cases, the main ones and some alternatives in order to mitigate in terms of risks of not being able to fulfil the gaps for the main use cases".*
- *"With collaborative work with Pilot 3B and ASSIST-IoT partners".*
- *"Bilateral telcos".*
- *"I think we could solve any difficulties that we faced along the project development".*

As final questions, from 0 to 5, they found the level of the public GitLab repository acceptable (3,58/5), and their accessibility as good (4/5).

With respect to the project pilot's and stakeholders, different surveys can be found in the KPI section (e.g., KPIs 4.4.3, 1.1.3, 1.1.5 and 1.1.6), apart from pilot-specific. Insights can be found there, but as general comments, adopters are satisfied with the technologies considered, the human interfaces developed/leveraged and the end-to-end systems implemented, but request further effort on their usability (ease of use) and optimized integrations.

3. KPIs

This section gathers the technical, pilot-related and process-related KPIs of the action. Aiming at giving a more "unified" view with respect to the previous deliverables, a template has been prepared to be filled by all responsible. It includes three parts: a summary of the KPI, its measurement methodology and a subsection of results and outlooks about them.

KPI X.X.X – Name

Table 4. Summary of KPI X.X.X

Name					
Description	What is the KPI about. Avoid over explaining.				
Motivation	Why is it important to have/mention as KPI (added value).				
Initial target		**Score***		**Achieved**	Yes/No
Rationale target selection	Why the target number was selected. Try not to exceed 4-5 lines of text, unless needed.				
Measurement period					
Partner/s responsible					

*** In case of several measurements, averaged.**

Measurement methodology

Test/measurement procedure (what and where do we have to measure). Suggested to include a list of **steps**.

Include involved **actors**, **enablers**, and **data sources.**

Include how it is measured (tools, formulas, models, etc.). It can be also based on expert judgement, questionnaires, existing methodologies and other references. Regardless of the case, justify it.

Specify how the baseline is computed, in the cases needed.

Results and outlook

Reporting as tables is not required in all cases. Here are some notes that have been considered during their reporting:

- Table 5 (or similar ones) applies for technical ones in which different measurements are required to come up with a statistically significant value (e.g., a value of latency cannot be measured just once to be significant). A well-though previous methodology is needed in such kind of cases, considering also depicting the environment, equipment, etc. considered to characterize it.

Table 5. Result of KPI X.X.X

Times measured	Mean	Unit	Standard deviation

- Table 6 is the preferred way for reporting questionnaires/surveys.

Table 6. Survey results of KPI X.X.X

Topic	Mean value*

*** Options go from x (lower result) to y (higher result).**

- When the KPI figure is a value that comes up considering the sum of some or many items, Table 7 (considering small adaptations) is the one to use.

Table 7. Results of KPI X.X.X

Item	**Justification**
…	
Total: x	

- Besides, it may be that justifying a KPI figure with a paragraph (or some) is enough in some cases, for instance, for justifying a boolean (true/false).
- Since some information might be available in concurrent deliverables (e.g., D7.4, WP9 ones), supporting material can be referenced to them to avoid repeating information.

Results are accompanied by an explanation assessing the KPI outcomes (if accomplish the original expectations; if exceed them, if not and why, how it could have been improved, etc.).

3.1. Summary of KPIs

Table 8. Summary of reported KPIs

Dimension	**Field**	**KPI**	**Target/score**
Exploitation	Stakeholders and 3rd-parties engagement	1.1.1 - Stakeholders/innovators expressing interest of willing to join the project or to adopt ASSIST-IoT *(KVI 7.2)*	>10 / 74
		1.1.2 - External adopters	25 / 25
		1.1.3 - Satisfaction of tactile applications *(KVI 5.1)*	85% / 86,2%
		1.1.4 - IoT pillar institutions involved	12 / 14
		1.1.5 - System usability scale	70% / 73,9%
		1.1.6 - Technology acceptance	80% / 84,0%
	Business models	1.2.1 - Target customers	500 / >1.999
		1.2.2 - Business plans for exploitable assets *(KVI 7.1)*	100% / 100%
		1.2.3 - Total addressable markets	10k / >400k
		1.2.4 - Innovative business models *(KVI 8.2)*	> 4 / 3
		1.2.5 - Technological advantage	10-15% / 34%
		1.2.6 - Diversification	8 / 8
	Exploitation of products	1.3.1 - IPRs	≥5 / >7
		1.3.2 - Revenue growth *(KVI 8.3.1)*	15-25% / ~125 %
		1.3.3 - Market share *(KVI 8.3.2)*	15% / NA
		1.3.4 - Return of Investment (RoI)	5-10% / > 83%
		1.3.5 - Architecture made available *(KVI 1.1)*	True / True
		1.3.6 - Conformance to new techs	100% / 100%
		1.3.7 - New verticals identified *(KVI 6.2)*	≥3 / 5
		1.3.8 - Collaborating IoT Security Projects	10 / 12

Pilots	Port automation pilot	2.1.1 – Trucks turnaround time	5% reduction / 8.38%
		2.1.2 - CHE fleet dispatching	30% increase / 31.2%
		2.1.3 - Yard equipment workforce	20% increase / 29.45%
		2.1.4 - Yard accidents	80% reduction / 100%
		2.1.5 - Remote wireless bandwidth	> 60 Mbps / 21 Mbps (max)
		2.1.6 - Remote wireless latency	< 20 ms / <28 ms
		2.1.7 - Proximity range	10 m / 17.8 m
		2.1.8 - Redundant access networks	≥2 / 2
		2.1.9 - New human-to-machine interfaces	≥3 / 3
	Smart Safety of workers Pilot	2.2.1 - Workers alerts	5% / 3.98%
		2.2.2 - OSH hazards detected	10 / 11
		2.2.3 - Hazard detection time	50% / 94.39%
		2.2.4 - User acceptance	75% / 84%
		2.2.5 - Notification and alerting	90% / 100%
		2.2.6 - Reporting	90% / 100%
		2.2.7 - BIM manipulation	9 degrees of freedom / 9
		2.2.8 - Near-miss fall from a height	85% / 98%
		2.2.9 - Worker alert latency	1.5 s / 0.747 s
		2.2.10 - OSH manager notification latency	5 s / 0.657 s
	Vehicle in-service emission diagnostics	2.3.1 - Series recall reduction	50% reduction / 50% (estimated)
		2.3.2 - Development time for diagnostic software updates	50% reduction / 50% (estimated)
		2.3.3 - Number of data channels measured in parallel	≥200 / 382
		2.3.4 - Available connectivity channels provided by ASSIST-IoT	7 / 7
		2.3.5 - Time to update a PCM calibration on the Edge, after a vehicle was offline	< 1 h / < 5 m
		2.3.6 - Number of Drivelets, which can be stored on a GWEN for later download	≥100 / 24.000
		2.3.7 - Server capacity to manage and monitor vehicle fleet	≥200 / 38.736
	Vehicle exterior condition inspection and documentation	2.4.1 - Detected defects	40-60% recognition rate / 40-67%
		2.4.2 - Vehicle inspection elapsed time	10 min saving per vehicle / 10-15 min
		2.4.3 - Revenues for repairing services	+10% revenue / 5000€ month (estimated)
		2.4.4 - Minimised dataset to be uploaded	50% less / 93-97%
		2.4.5 - Deliver vehicle images to the user in time, after vehicle (new)	5 m / 32,11 s
	Overall pilots' implementation	2.5.1 - Architecture integrated in lab and real conditions *(KVI 1.2)*	True / True
		2.5.2 - AI-driven pilots *(KVI 4.1)*	> 5 / 11
		2.5.3 - Successful pilots' implementation *(KVI 6.1)*	>95% / 100%
Impact	Standardization	3.1.1 - Internationally recognized standards supported in ASSIST-IoT solutions	40 / 53

		3.1.2 - Communications to modify/improve existing standards used in ASSIST-IoT	5 / 7
		3.1.3 - Recommendations in relevant SDO's and initiatives	10 / 25
		3.1.4 - SDOs and pre-normative initiatives engaged.	40 / 42
		3.1.5 - Identified standards related to ASSIST-IoT activities	120 / 154
	Dissemination	3.2.1 - Number of scientific publications	38 / 39
		3.2.2 - European IoT Platforms compatible and connected to ASSIST-IoT modules	4 / 4
		3.2.3 - Letters of interest to adopt ASSIST-IoT technologies	2 / 2
		3.2.4 - Research actions including one or several modules developed on ASSIST-IoT	2 / 5
		3.2.5 - Industrial actions including one or several modules developed on ASSIST-IoT	2 / 3
		3.2.6 - Cybersecurity fairs/congresses attended	8 / 9
	Communication	3.3.1 - Communication and community building activities organised	12 / 17
		3.3.2 - Subscribers to ASSIST-IoT communication channels and related activities	2000 / 11.405
		3.3.3 - Online communications (news, posts, articles)	600 / 1.976
		3.3.4 - Online traffic attracted (website, social media)	50.000/ 29.4153
		3.3.5 - Participation in external IoT Communities	25 / 87
		3.3.6 - IoT related organisations *(KVI 8.1.3)*	10 / >30
		3.3.7 - Joining communities *(KVI 8.1.2)*	20 / >27
		3.3.8 - Professionals engaged for impact *(KVI 8.1.1)*	2.000 / 2.208
		3.3.9 - External Professionals involved	80 / 150
Technology	Device and edge plane	4.1.1 - CPU load of GWEN processes	<75% / <32%
		4.1.2 - Memory usage of GWEN processes	<75% / <47%
	Smart network and control plane	4.2.1 - VNFs achieved for improving network *(KVI 2.1.1)*	6 / 8
		4.2.2 - AI models achieved for improving network *(KVI 2.1.2)*	3 / 5
		4.2.3 - Percentage of network connections being improved *(KVI 2.2)*	20% / 32%
		4.2.4 - Hosts connected to VPN k8s clusters	8 / 100
		4.2.5 - Messages classified	500 / 20.000
	Data management plane	4.3.1 - Streaming Annotation Latency	10 ms / 7 ms
		4.3.2 - Streaming Translation Latency	10 ms / 10 ms
		4.3.3 - Streaming Annotation Clients Number	10 / 20
		4.3.4 - Streaming Translation Clients Number	4 /4
		4.3.5 - Semantic Repository File Size Support	5 GB / 10 GB
	Applications and services plane	4.4.1 - Human-centric components *(KVI 5.2)*	9 / 10
		4.4.2 - Human-centric UCs per pilot *(KVI 6.3)*	12 / 15
		4.4.3 - UX usability	70% / 77,14%
	Self-*	4.5.1 - Number of autonomous decisions while executing pilots	>5 / 5

		4.5.2 - Number of components/resources involved in self-* process	>5 / 7
	FL	4.6.1 - Distributed AI costs *(KVI 4.2)*	50% / 63%
		4.6.2 - FL users	10 / 10
		4.6.3 - FL models	2 / 10
		4.6.4 - FL use cases	2 / 3
	Cybersecurity	4.7.1 - Users covered by ASSIST-IoT security	20.000 / 30.158
		4.7.2 - Pervasiveness of user coverage by security enablers	75 % / 99,95%
		4.7.3 - Correct identification attempt ratio	75 % / 81,33%
		4.7.4 - Validated authorization request ratio	40 % / 85,25%
		4.7.5 - Detected alerts per hour	<10 events / 4 alerts
	DLT	4.8.1 - Automated accountability of interactions /communications performed (defining responsible) *(KVI 3.1)*	85% / 100%
		4.8.2 - Data governance services supported by IoT-enabled DLT *(KVI 3.2)*	10 / 12
		4.8.3 - Availability of FL ML local models' collection	1 / 1
		~~4.8.4 - Decrease in training dataset biases~~	NA
		4.8.5 - Number of use cases successfully tested with the DLT registry enabler	1 / 1
		4.8.6 - Number of use cases successfully tested with the DLT integrity verification enabler	1 / 2
	Manageability	4.9.1 - Enablers deployed through interface	60 / 61
		4.9.2 - Service topologies and enablers	4 / 4
		4.9.3 - Configuration parameters	50 / 66
Ethical, societal, gender and legal evaluation	Legal issues	5.1.1 - Regulation adherence	3 / >5
		5.1.2 - Legalisation assessment	>75% / 100%
	Holistic innovation	5.2.1 - Worktime - Time Saving	>75% / 99%
		5.2.2 - Human-centred innovations	>75% / 98%
	User work time/life impact	5.3.1 - Threat on the labour demand	>75% / 96%
	Targeted social groups	5.4.1 - Life - Social inclusion	>75% / 94%
		5.4.2 - Gender equality	>75% / 98%
	Trusted, safe, secure IoT environment promotion	5.5.1 - Security and privacy institutions engaged	20 / 26
		5.5.2 - Security, privacy, trust and accountability specific publications	12 / 4
	Community engagement	5.6.1 - Minority groups inclusion	>75% / 86%
		5.6.2 - Accessibility	>75% / 82%

3.2. Technical evaluation of ASSIST-IoT

3.2.1. Selected KPIs

3.2.2. Data collection and measurement

3.2.2.1. KPI 4.1.1 – CPU load of GWEN

Table 9. Summary of KPI 4.1.1

Name	**CPU load of GWEN**				
Description	During normal operation the CPU of the GWEN must not operate at full load. Some headroom must remain for unforeseen tasks or future upgrades.				
Motivation	To validate design estimations measurements must be taken to assure CPU load during normal operation. Common design estimations are generally too low, therefore headroom must be built in.				
Initial target	< 75%	**Score***	< 32%	**Achieved**	Yes
Rationale target selection	To assure lifetime and flexibility towards system changes the load shall not be higher than 75% for the whole processor (containing 4 cores and a co-processor)				
Measurement period	Last phase of pilot trials				
Partner/s responsible	NEWAYS				

Measurement methodology

Measurements will take place once the enablers and the pilot-specific software is completely deployed in the pilots. To capture the metric, this methodology will be followed:

- One-week time frame collection, per pilot in which the GWEN is deployed.
- 4 times per day a timeframe shall be measured for a duration of 15 minutes.
- This measurement shall form be analysed to give an average value of the load. The PUD enabler will be used to that end, modifying the periodicity of the metrics gathering.
- After 1 week all average values shall be combined into a grant total average which is the final KPI value.

Results and outlook

Results vary depending on the pilot scenario, as well as the board functionality used. While it was possible to overload CPU cores by message saturation, it was noted that during operation the CPU load never exceeded **32% on average**. This can perhaps be explained by the fact that not all available GWEN functionalities were used simultaneously during testing, that the number of messages that passes though the channels was chosen not to overwhelm the GWEN and therefore the resource requirements for the applications remained below design expectations.

3.2.2.1. KPI 4.1.2 – Memory usage of GWEN processes

Table 10. Summary of KPI 4.1.2

Name	**Memory usage of GWEN processes**
Description	During normal operation the memory (RAM) of the GWEN must not operate at full load. Some headroom must remain for unforeseen tasks or future upgrades.

Motivation	To validate design estimations measurements must be taken to assure memory usage during normal operation. Common design estimations are generally too low, therefore headroom must be built in.				
Initial target	< 75%	**Score***	< 47%	**Achieved**	Yes
Rationale target selection	To assure lifetime and flexibility towards system changes the usage shall not be higher than 75% usage.				
Measurement period	Last phase of pilot trials				
Partner/s responsible	NEWAYS				

Measurement methodology

- One-week time frame collection, per pilot in which the GWEN is deployed.
- 4 times per day a timeframe shall be measured for a duration of 15 minutes.
- This measurement shall form be analysed to give an average value of the load. The PUD enabler will be used to that end, modifying the periodicity of the metrics gathering.
- After 1 week all average values shall be combined into a grant total average which is the final KPI value.

Results and outlook

The board functionalities used within the pilot scenarios influenced mutual resource use. Although it was possible to overload the internal memory due to message saturation. It was noted that memory usage during operation never exceeded 47% on average. This can perhaps be explained by the fact that not all available GWEN functionalities were used simultaneously during testing, that the number of messages that passes though the channels was chosen not to overwhelm the GWEN (otherwise, the internal buffer would eventually overflow) and therefore the resource requirements for the applications remained below design expectations.

3.2.2.2. KPI 4.2.1 – VNFs achieved for improving network (KVI 2.1.1)

Table 11. Summary of KPI 4.2.1

Name	**VNFs achieved for improving network**				
Description	This KPI aims at recording how many VNFs/CNFs have been achieved in the project for improving performance and network reconfiguration and other network tasks. This is an automatic result of the outcomes of T4.2, especially the smart orchestrator that will be able to deploy NFs in diverse ecosystems.				
Motivation	The goal of this KPI is to illustrate that the orchestrator is actually functional in the network area, improving the network performance in different ways (bandwidth, availability, speed, etc.). The usage of these functions is rather specific (in contrast with application functions). They can only be applied to particular environments and setups, overseen by specialised, skilful teams.				
Initial target	6	**Score***	8	**Achieved**	Yes
Rationale target selection	This number was defined during the proposal phase and confirmed in the GA signature. It is a balanced number between number of contributions and effort.				
Measurement period	Task 4.2 execution				
Partner/s responsible	UPV				

Measurement methodology

Apart from identifying and developing the enablers that will perform such actions, the validation of this KPI will entail testing such enablers in at least one of the pilot premises and validate that their basic features are working as expected. A summary of procedure for measuring this KPI is:

- Identification of VNFs/CNFs, in the form of enablers, that have been achieved in the scope of T4.2.
- Having a functional, packaged version of all these enablers (M36 at the latest).
- Having the computing premises of the pilots provisioned. Currently, Pilot 3A has it ready.
- Each one of the enablers will be tested in pilot premises (at least, in one). SDN and SD-WAN-related enablers will be tested in OPL/UPV premises, but as SDN infrastructure is not available in pilots, they will be validated in laboratory conditions; multi-link in Pilot 1; and the Smart orchestrator in all pilots.
- The features specified in D4.2 will be checked, and it will be fulfilled if they have been accomplished.

Results and outlook

Table 12. List of VNFs implemented

Item	**Justification**
The Smart orchestrator	Enables the lifecycle management of rest of enablers. It considers some scheduling policies to automatically deploy them based on user preferences (e.g., reduction of latency – close to source, more available RAM/CPU, fully usage of them). Validated in all pilots.
The 3 enablers from the SDN stack	The SDN controller, the auto-configurable network enabler and the traffic classification enabler, which work together in SDN-enabled networks to control the networking equipment, selecting the optimal routing policies based on the type of traffic, among other parameters. Validated in lab conditions (see Michał Berliński et al. article[3], developed with the support of the project)
The multi-link enabler	Eases the combination of networking interfaces, at layer 2 level, to work as a single, logical one, with real-time reliability mechanisms. Validated in lab conditions and with PROUD-5G open caller, considering 5G as one of the supported networks.
The 2 SD-WAN enablers	Considering the SD-WAN enabler and the WAN acceleration enabler, which provide security (i.e., via tunnels and firewalls) for connecting delocalised managed networks. Validated in lab conditions.
The VPN enabler	Eases the setup of VPN servers to establish secure tunnels between external devices and network sites, to be managed via APIs. Validated in P3B to access to the infrastructure, via VPN tunnels.
Total: 8	

3.2.2.3. KPI 4.2.2 – AI models achieved for improving network (KVI 2.1.2)

Table 13. Summary of KPI 4.2.2

Name	**AI models achieved for improving network**
Description	ASSIST-IoT has committed to deliver a “smart orchestrator”. Naturally, for an orchestrator to be called “smart”, it needs to rely on certain intelligence to deploy the functions in the edge-cloud ecosystem. One of the goals of ASSIST-IoT is to realise such “intelligence” by leveraging some AI models to allow the orchestrator to select the most optimal spot in the deployment (in the available clusters) in such a way that both the

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[3] Michał Berliński, Mateusz Rasmus, Zbigniew Kopertowski, Stanisław Kozdrowski, Ant Colony algorithms application for telco networks performance with multi-criteria optimization, IEEE SoftCOM 2023 International Conference on Software, Telecommunications and Computer Networks, 21-23 September 2023, Split, Croatia.

	network and the function's purposes are maximised. Other AI models might be considered for other network purposes.				
Motivation	There might be business scenarios in which several clusters are available, with different processing/storage capabilities; or services having particular requirements in terms of e.g., latency. This KPI aims at ensuring that different policies have been implemented to automatically allocate such services in the managed continuum.				
Initial target	3	**Score***	5	**Achieved**	Yes
Rationale target selection	This number was defined during the proposal phase and confirmed in the GA signature. Number considered as a proof of concept for giving adopters enough options depending on their specific scenarios, to prevent arbitrary decisions.				
Measurement period	1/09/2023 – 30/11/2023				
Partner/s responsible	UPV				

Measurement methodology

The methodology will be the following: (i) trained AI models leveraged by the smart orchestrator listed and described; (ii) other AI models from other enablers that improve directly or indirectly the network, listed and described.

Results and outlook

Table 14. AI models achieved for the network

#	Model	Description
1 – Smart orchestrator	Cluster with most resources	The model selects the cluster with more resources available, and that is expected to have enough resources over time.
2 – Smart orchestrator	Cluster with enough resources	The model selects the cluster with enough resources available, and that is expected to have enough resources over time.
3 – Smart orchestrator	Edge cluster	The smart orchestrator selects the cluster with nodes closer to the edge, expected to have enough resources over time.
4 – Auto-configurable network enabler	SDN intent-based routing	Optimises the flow distribution (traffic load) over an SDN-enabled network to minimize traffic lost and latencies
5 – Resource provisioning enabler	Time-series forecast	Determines the expected resource utilization of resources to up/down-scale enablers resources (i.e., pods) in advance
Total: 5		

3.2.2.4. KPI 4.2.3 – Percentage of network connections being improved (KVI 2.2)

Table 15. Summary of KPI 4.2.3

Name	**Percentage of network connections being improved**
Description	Auto-configurable network enabler is optimising the traffic load distribution (throughput) over the SDN network (flows re-routing) to obtain improved QoS parameters for the overall network (data losses, data transfer latency). KPI measures the percentage of connections (links) that QoS parameters were improved in the specified SDN network topology.

Motivation	To show the advantages of traffic load optimisation in the network and QoS parameters improvement for different IoT applications.				
Initial target	20%	**Score***	32%	**Achieved**	Yes
Rationale target selection	Target was set arbitrary based on similar solutions performances.				
Measurement period	M36				
Partner/s responsible	OPL				

Measurement methodology

To measure number of improved network connections in terms of QoS parameters, the continuous monitoring of all links and flows in the network is implemented using rt-sFlow for packet losses and ping-based mechanisms for latency parameter. After the generated traffic load changes (different distribution scenarios), the AI-based auto-configurable network mechanism optimising the flow distribution (traffic load) over the network. After changes in the routing of flows the new QoS parameters are measured. Then, compare initial QoS parameters value with current one we obtain the number of the improved connections. Measuring this for different traffic load generation scenarios we can have average value of improved network connections.

Results and outlook

Initial QoS parameters for each link (data losses and latency) were measured. After the traffic load generation according to the specified scenario the new QoS parameters were measured after 30 sec. Then comparing these values, the percentage number of improved connections in average was 32% for given network load scenarios. Depends on the scenario the improvement can differ, so we calculated average value from different traffic load cases applied in the network experiments.

3.2.2.5. KPI 4.2.4 – Hosts connected to VPN k8s clusters

Table 16. Summary of KPI 4.2.4

Name	**Hosts connected to VPN K8s clusters**				
Description	A VPN server (encapsulated as an ASSIST-IoT enabler following the packaging and releasing methodology set out in deliverable D6.4) allows the access to a node or device (in the case of ASSIST-IoT, to a Kubernetes -or equivalent- cluster) from a different network to the site's private network using a public network (e.g., the Internet) or a non-trusted private network. In practical terms, this enabler allows an external host (device, computer, server…) to join ASSIST-IoT deployment's network via the connection using a VPN that is served by a k8s cluster that is part of the environment of the site.				
Motivation	The goal with this KPI is to illustrate the functionality (and that it actually meets its objective, and it is used in real life) in the pilots of the project, considering 8 hosts connecting to K8s clusters of ASSIST-IoT as the target KPI. This will be measured transversally across all pilots and will be reported by the end of WP7 and WP8.				
Initial target	8	**Score***	100	**Achieved**	Yes
Rationale target selection	The initial target was a bit conservative. Reason is to ensure enough throughput of the connected clients.				
Measurement period	Last trimester of 2023				
Partner/s responsible	UPV				

Measurement methodology

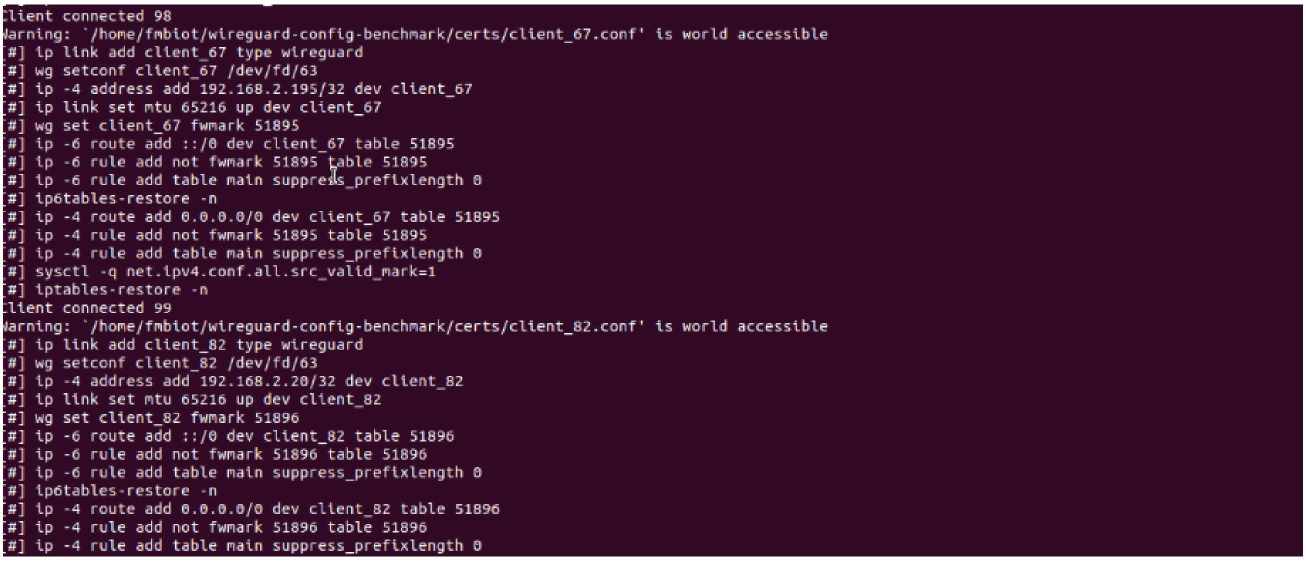
Being a generic enabler that can work regardless of the pilot, it will be validated only in one of the pilots' infrastructures (Pilot 3A). The number selected may not seem that ambitious, still, the number is not that representative as it depends on the expected traffic (see outlook below). A summary of procedure for measuring this KPI is the following:

1. The VPN enabler will be deployed via the Smart orchestration in one of the clusters of the pilot.
2. The number of clients will be evaluated considering a VPN test client, to simulate connected devices.

To measure this number of clients, a script has been created to automate the generation of corresponding client configurations. Another script establishes connections to the VPN enabler and displays the connection output.

Results and outlook

As developed considering Wireguard technology, it is expected that such number can be easily achieved, theoretically up to 2^{16} with IPv4 (i.e., 65536). It should be highlighted that the throughput per client is reduced when additional ones are added, especially if they have to forward/receive traffic from the VPN server. This limitation depends heavily on the traffic it has to handle, as it can range from handling all (including from/towards the Internet, and from which type), or just K8s signalling, as it may be in ASSIST-IoT-based implementations. The simulator considered achieved a total number of 100 connected clients.



```
lient connected 98
arning: `/home/fmbiot/wireguard-config-benchmark/certs/client_67.conf' is world accessible
[#] ip link add client_67 type wireguard
[#] wg setconf client_67 /dev/fd/63
[#] ip -4 address add 192.168.2.195/32 dev client_67
[#] ip link set mtu 65216 up dev client_67
[#] wg set client_67 fwmark 51895
[#] ip -6 route add ::/0 dev client_67 table 51895
[#] ip -6 rule add not fwmark 51895 table 51895
[#] ip -6 rule add table main suppress_prefixlength 0
[#] ip6tables-restore -n
[#] ip -4 route add 0.0.0.0/0 dev client_67 table 51895
[#] ip -4 rule add not fwmark 51895 table 51895
[#] ip -4 rule add table main suppress_prefixlength 0
[#] sysctl -q net.ipv4.conf.all.src_valid_mark=1
[#] iptables-restore -n
lient connected 99
arning: `/home/fmbiot/wireguard-config-benchmark/certs/client_82.conf' is world accessible
[#] ip link add client_82 type wireguard
[#] wg setconf client_82 /dev/fd/63
[#] ip -4 address add 192.168.2.20/32 dev client_82
[#] ip link set mtu 65216 up dev client_82
[#] wg set client_82 fwmark 51896
[#] ip -6 route add ::/0 dev client_82 table 51896
[#] ip -6 rule add not fwmark 51896 table 51896
[#] ip -6 rule add table main suppress_prefixlength 0
[#] ip6tables-restore -n
[#] ip -4 route add 0.0.0.0/0 dev client_82 table 51896
[#] ip -4 rule add not fwmark 51896 table 51896
[#] ip -4 rule add table main suppress_prefixlength 0
```

Figure 20. Logs of the clients successfully connected

The number of clients has been limited both by the resources available on the enabler and by the limit on the number of clients that can be created via the API within the same subnet. By adjusting this and increasing the resources, much higher figures can be achieved, as mentioned earlier.

3.2.2.6. KPI 4.2.5 – Messages classified

Table 17. Summary of KPI 4.2.5

Name	**Messages classified**				
Description	The traffic classification enabler classifies network traffic into a number of classes types (e.g., email, VoIP, video streaming), which can be used for network profiling or later traffic shaping operations like prioritization in SDN and/or SD-WAN networks, among others. This KPI is related to the number of messages, or traffic packets, ingested in the aforementioned enabler for classification purposes.				
Motivation	This KPI was included within task T8.2 to ensure that the enabler was tested and validated during the project and have a preliminary estimation of its performance.				
Initial target	500 messages	**Score**	20.000 messages	**Achieved**	Yes

Rationale target selection	The expected KPI selected is 500 (i.e., entries of .pcap files), to have a representative number without hindering the rest of development and validation activities.
Measurement period	5/11/23 – 20/12/23
Partner/s responsible	UPV

Measurement methodology

This KPI will be obtained considering both traffic from pilot implementations (specifically, 1 & 3a) and in-lab. The following procedure will be followed:

0. The traffic classification model will be trained in laboratory conditions, with several applications and grouped in types of traffic.
1. A traffic sniffer will be installed on a computer node where such traffic will pass through.
2. Once the use case associated with such use case is about to happen, the sniffer will be manually started, capturing traffic from the (suitable) network interfaces in .pcap format.
    - At least 3 tests of the use case will be monitored.
3. The sniffer will be stopped, and then the generated. pcap files will be processed offline consuming the API of the traffic classification enabler.
4. The packets of each file (which can contain hundreds or thousands of them) will be classified. The class with more representation among the packets will be main result.
5. The following outputs will be generated: inference time (related to the resources of the K8s cluster, to be included) and application class result.
6. Once the measurement campaign is finished, the total number of processed messages will be computed.

Results and outlook

The number of **messages classified** has been of 20000, exceeding by far the original target (500). Since data involved are quite large (especially for image and video transmissions), the number of packets involved in a traffic burst is quite high. The results obtained per pilot are depicted in Table 18. Aiming at giving figures about the performance of the enabler, additional information besides plain number of messages classified is given:

Table 18. Complementary information of KPI 4.2.5

Packets measured	Target class	Output class	Latency (per packet / total)
4000	Video life stream	Streaming	10.21 ms/packet
4000	VoIP call	VoIP	9.92 ms/packet
4000	FTP	File transfer	10.07 ms/packet
4000	Torrent download	Torrent	9.96 ms/packet
4000	Video recorded stream	Chat	10.25 ms/packet

Latencies were quite high for traffic classification. Still, they were executed without GPU, so latencies are expected to be reduced by a factor of ~100 if graphic processing were used. It should be reminded that a 100% of packets from one single class, even if it is the target one, is not expected. This is due to different factors, including network discovery, signalling and the possible presence of traffic from other applications. The overall number of packets classified could have been increased easily, by fine-tuning the training of the model to the target scenario. However, this KPI was included to ensure that a minimum number of messages were classified with pilot data. In any case, thanks to setting up this campaign, it became clear that classifying a single packet does not make much sense, but rather a group of them.

3.2.2.7. KPI 4.3.1 – Streaming Annotation Latency

Table 19. Summary of KPI 4.3.1

Name	**Streaming Annotation Latency**				
Description	The Semantic Annotation Enabler transforms messages that pass through its annotation channels that use a streaming broker. This KPI measures the amount of time it takes for a message to be processed, independently of the network conditions.				
Motivation	The process of annotation introduces latency, which may be important in time-sensitive IoT applications.				
Initial target	10 ms	**Score***	7 ms	**Achieved**	Yes
Rationale target selection	The number was chosen arbitrarily to target 100 messages per second.				
Measurement period	1/03/2023 – 30/03/2023				
Partner/s responsible	SRIPAS				

Measurement methodology

Streaming annotation is a process that depends on many factors, including network throughput, message size, and annotation configuration file size. The annotation core is a component that connects to a broker, which interfaces with clients, and passes messages to the core. To isolate the performance of the annotator itself, the message processing latency is measured. This latency is defined as the amount of time it takes to process a single message (averaged over a period of time) at the core component, without taking into account broker throughput. Even though the annotator is designed to support high volume of small messages, the latency will be tested with messages of small and medium size, to stretch the limits of the simulation. Measurements will be taken over 1 minute of constant message output from the broker, with the target of average processing latency less than 10ms per message.

Results and outlook

Message processing latency after initial was measured to be 7ms on average, with minimum of around 0,9ms and maximum of 50ms. 90% of messages are processed with latency below 10ms. It was observed, that the annotation core gets more efficient when processing a message that was already processed before, so the messages were randomised for the test.

3.2.2.8. KPI 4.3.2 – Streaming Translation Latency

Table 20. Summary of KPI 4.3.2

Name	**Streaming Translation Latency**				
Description	The Semantic Translation Enabler transforms messages that pass through its annotation channels that use a streaming broker. This KPI measures the amount of time it takes for a message to be processed, independently of the network conditions.				
Motivation	The process of translation introduces latency, which may be important in time-sensitive IoT applications.				
Initial target	10 ms	**Score***	10 ms	**Achieved**	Yes
Rationale target selection	The number was chosen arbitrarily to target 100 messages per second.				
Measurement period	1/03/2023 – 30/03/2023				

Partner/s responsible	SRIPAS

Measurement methodology

Just like in the case of streaming annotation (see KPI.4.3.1 above), measurement of streaming translation latency was performed at the core component to isolate it from networking conditions and broker performance. Latency, defined as time needed to process a single message was measured as average over 1 minute of constant small and medium message streaming with target of less than 10 ms per message.

Results and outlook

Average message processing latency after initial tests was measured to be 10ms with minimum of 5ms and maximum of 100ms. 90% of messages are processed with latency below 35ms. Alignment and message size make a big impact on processing speed, with large alignments (1000 cells) taking significantly longer, than smaller or medium ones (<100 cells). Message and alignment size in ASSIST-IoT pilots is small, following the general principle observed in IoT, of high number of small messages, rather than large messages that are sent less often.

3.2.2.9. KPI 4.3.3 – Streaming Annotation Clients Number

Table 21. Summary of KPI 4.3.3

Name	**Streaming Annotation Clients Number**				
Description	The Streaming Annotation Enabler supports parallel execution of multiple annotation channels, which may be used by multiple clients. This KPI measures the number of clients that is supported in parallel (i.e. at the same time).				
Motivation	The streaming architecture is designed to support many clients, that may join or leave, making the number variable. IoT applications often require support for multiple clients.				
Initial target	10	**Score***	20	**Achieved**	Yes
Rationale target selection	Given that each annotation channel corresponds to a kind of message semantics that should be annotated, 10 channels was deemed more than enough to cover ASSIST-IoT use cases.				
Measurement period	1/03/2023 – 30/03/2023				
Partner/s responsible	SRIPAS				

Measurement methodology

A single streaming annotator is designed to support multiple streaming channels. Performance of supported client parallelism was measured by creating a number of annotation channels, and scaling the number up, until resources on the test machine are saturated. Because the number of clients per channel is scaled on the level of the broker, each channel will have just one sender and receiver. Adding more clients per channel is supported but would make the simulation more dependent on performance of the broker, and not the streaming annotation core. A conservative target is placed at 10 parallel channels, as that is the expected maximum number of channels in a single real-world deployment, that will be realistically required.

Results and outlook

The annotation streamer is able to easily support 20 parallel channels on a desktop machine with 2 logical CPU cores. Pilot deployments on the GWEN were measured to support 10 channels without saturating the resources. Note that the number of messages that passes though the channels was chosen not to overwhelm the machine. This means that the processing time for a message was lower than the frequency of messages. Otherwise, the internal buffer would eventually overflow. In practice, if the messages are not processed fast enough, buffer overflow becomes the main factor in resource saturation. Thus, the channel resource saturation was measured at maximum message throughput before having to use the buffer. Note, that idle channels (channels, that don't have messaging passing through them) have negligible effect on performance.

3.2.2.10. KPI 4.3.4 – Streaming Translation Clients Number

Table 22. Summary of KPI 4.3.4

Name	**Streaming Translation Clients Number**				
Description	The Streaming Translation Enabler supports parallel execution of multiple annotation channels, which may be used by multiple clients. This KPI measures the number of clients that is supported in parallel (i.e. at the same time).				
Motivation	The streaming architecture is designed to support many clients, that may join or leave, making the number variable. IoT applications often require support for multiple clients.				
Initial target	4	**Score***	4	**Achieved**	Yes
Rationale target selection	A translation channel can support big annotation files, that represent a large chunk of semantics of an IoT ontology. Even though technically one annotation file may model an entire ontology, it is more practical and manageable to split it into multiple files. Based on the needs of ASSIST-IoT pilots, 4 parallel channels were chosen as a practical target.				
Measurement period	1/03/2023 – 30/03/2023				
Partner/s responsible	SRIPAS				

Measurement methodology

Just like the streaming annotator (see KPI.4.3.3 above), streaming semantic translator can support a number of channels in parallel, with performance concerns dependent on the same factors, as in the case of streaming annotation. Despite similar dependency on streaming brokers, the core components and internal processing infrastructure of the streaming translator and annotator are very different, so KPIs have to be measured separately. Supported client parallelism of the streaming translator was measured as maximum number of channels with one consumer and one producer per channel, before saturation of resources.

Results and outlook

The tests reveal that resource saturation is highly hardware dependent. For 4 CPU cores and configured parallelism of 4, the streaming translator easily supports 4 parallel channels that are constantly busy. In such cases network saturation occurs before local resource saturation. Constant saturation of channels is defined as a never ending stream of messages, where processing of a new message starts as soon as the previous one finishes. In practice (e.g. in testing messages in the pilots) constant saturation never occurs. Even under constant saturation, more channels may be supported. It should be noted, however, that (if allowed) the streaming translator will saturate CPU usage, and a constant CPU load will increase temperatures and, in general, prevent full efficiency in CPU performance in the long term. When not under constant saturation 32 active channels were working on 4 CPU cores. Idle channels (channels, that don't have messaging passing through them) have negligible effect on performance.

3.2.2.11. KPI 4.3.5 – Semantic Repository File Size Support

Table 23. Summary of KPI 4.3.5

Name	**Semantic Repository File Size Support**
Description	Maximal supported size of a versioned data model stored in the repository, measured per versioned file i.e., a single version of a model, not all versions together. Latency of basic operations (download, retrieval of metadata) should not be significantly different (<20%-

	time difference) than average for smaller files. In this context, latency excludes network speed, and counts only processing time after upload, or before download.				
Motivation	In some real-life applications, the support for large files is needed. For example, in the Smart Safety of Workers Pilot, there is a need to upload large (~100MB) BIM files to the enabler.				
Initial target	5 GB	**Score***	10 GB	**Achieved**	Yes
Rationale target selection	5GB is a large enough file size to cause problems for unoptimized software that inefficiently handles the incoming/outgoing data.				
Measurement period	1/03/2023 – 30/03/2023				
Partner/s responsible	SRIPAS				

Measurement methodology

The measurement was performed using a external software that uploaded and downloaded the test files to the Semantic Repository enabler. The Semantic Repository enabler was extended to include nanotime-based time measurements for the relevant latencies. The latencies were then exposed via a custom endpoint of the enabler as a JSON file. The test procedure was as follows:

- Start the Semantic Repository enabler.
- Repeat 50 times:
  - Upload a 100 kB file.
  - Retrieve the file’s metadata.
  - Download the file.
  - Delete the file from the enabler.
- Gather the latency measurements from the metrics endpoint.
- Restart the Semantic Repository enabler.
- Repeat 50 times:
  - Upload a 10 GB file.
  - Retrieve the file’s metadata.
  - Download the file.
  - Delete the file from the enabler.
- Gather the latency measurements from the metrics endpoint.

Results and outlook

Table 24. Result of the tests over the Semantic Repository File Size Support

File size	Operation	Measurements	Median	IQR	Unit
100 kB	Download	50	1.2914	0.204	ms
	Get metadata	50	1.2736	0.072	ms
10 GB	Download	50	1.2916	0.250	ms
	Get metadata	50	1.2849	0.273	ms

The conducted experiments show that for 10 GB files the median download response latency grew by ~0.02%, and the median metadata response latency grew by ~0.89%. In both cases the increase is negligible. This result was expected, as the Semantic Repository handles files in a streaming manner, and therefore file size should have no impact on its operation.

3.2.2.12.KPI 4.4.1 – Human-centric components (KVI 5.2)

Table 25. Summary of KPI 4.4.1

Name	**Human-centric components**				
Description	This KPI is focused on quantifying the different ASSIST-IoT human-centric enablers that the project will develop.				
Motivation	This KPI will provide a quantifiable impact in the quality of work/life of end-users with project pilots deployments.				
Initial target	9	**Score***	10	**Achieved**	Yes
Rationale target selection	As a KVI, it was selected in the proposal and approved by the European Commission evaluators. The reasoning was to provide >=2 human-centric enablers per pilot.				
Measurement period	After every successful execution of any pilot trial (there are 9 trials in the project)				
Partner/s responsible	PRO				

Measurement methodology

KPI partner responsible requests the list of human-centric enablers deployed and tested to every pilot trial owner. To be completed via template shared with them.

Results and outlook

The following human-centric interfaces have been tested in the project's pilots:

- Pilot 1: 2x Web applications, 1x CV service on top of regular video streams.
- Pilot 2: 1x smartwatch custom interface, 1x MR googles with pilot-specific dashboard.
- Pilot 3A: 1x Web application, 1x MR glasses that makes use of 1xCV service.
- Pilot 3B: 1x Web application for the data collection, 1x Web application for the FL management.

Thus, 10 human-centric components have been deployed in the project lifetime. These are the base for facilitating the interaction of humans with the ASSIST-IoT system, facilitating the realization of use cases that can be of interest for real-life scenarios, as the ones of the project (see next KPI).

3.2.2.13. KPI 4.4.2 – Human-centric UCs per pilot (KVI 6.3)

Table 26. Summary of KPI 4.4.2

Name	**Human-centric UCs per pilot**				
Description	This KPI will identify the number of ASSIST-IoT use cases that make full or partial use of some of the human-centric NGI technologies developed in the project (listed in the previous KPI.4.4.1)				
Motivation	Human-centric components provide meaningful tasks that can be done by humans without requiring big ICT-related knowledge.				
Initial target	12 (3 per pilot)	**Score***	15	**Achieved**	Yes
Rationale target selection	As a KVI, it was selected in the proposal and approved by the European Commission evaluators. The reasoning was to provide >=1 human-centric use case per pilot.				
Measurement period	After the last execution of pilot trials				
Partner/s responsible	PRO				

Measurement methodology

KPI partner responsible requests the list of human-centric use cases deployed and tested to every pilot trial owner. To be completed via template shared with them.

Results and outlook

The following 15 ASSIST-IoT use cases make use of different human-centric enablers of the project. That shows a good level of interaction between the humans and the deployed systems, thanks to their interactions with the ASSIST-IoT enablers. In the future, this list could be enhanced with use cases making use of novel human-centric components, thanks to the interfaces exposed by the system (mainly via OpenAPI and EDB).

- **Pilot 1**:
    1. UC-P1-3 Asset location management
    2. UC-P1-4 Truck identification and authentication
    3. UC-P1-5 RTG truck alignment
    4. UC-P1-7 Target visualization during RTG operation
- **Pilot 2:**
    5. UC-P2-1 Workers' health and safety assurance
    6. UC-P2-2 Geofencing boundaries enforcement
    7. UC-P2-3 Construction site access control
    8. UC-P2-4 Detection of falls and immobility
    9. UC-P2-5: Safe navigation instruction
    10. UC-P2-6: Health and safety inspection support.
- **Pilot 3A**:
    11. UC-P3A-1 Fleet in-service emissions verification
    12. UC-P3A-2 Vehicle's non-conformance causes identification
    13. UC-P3A-3 Updating the diagnostics methods pool.
- **Pilot 3B**:
    14. UC-P3B-1 Vehicle's exterior condition documentation & visualisation
    15. UC-P3B-2 Exterior defects detection support.

3.2.2.14. KPI 4.4.3 – UX usability

Table 27. Summary of KPI 4.4.3

Name	**UX usability**				
Description	This KPI indicates how difficult it will be to operate with the ASSIST-IoT GUIs.				
Motivation	Usability is important because if users do not obtain the goals they expect from a service or product, they will eventually abandon ASSIST-IoT system, and choose other IoT architecture competitors.				
Initial target	>70% (>3.5/5)	**Score***	77,14%	**Achieved**	Yes
Rationale target selection	Ideally, the number should be close to 100%. However, being a research project, usability is not the main focus, but still some minimum is required to later on foster their use and devote effort to improve these interfaces.				
Measurement period	After the last execution of pilot trials				

Partner/s responsible	PRO

Measurement methodology

A System Usability Scale (SUS) questionnaire, which offers a quick and effective way to evaluate the usability of products and/or designs, has been used for the evaluation of this KPI. The list of questions to form part of the SUS questionnaire are presented below, and were extracted from John Brooke's article[4].

1. *I would like to use this system frequently.*
2. *I have found the system unnecessarily complex.*
3. *I think the system was easy to use.*
4. *I would need the support of a technical person to be able to use this system.*
5. *I found the various functions in this system were well integrated.*
6. *I think there was too much inconsistency in this system.*
7. *I would imagine that most people would learn to use this system very quickly.*
8. *I found the system very cumbersome to use.*
9. *I have felt very confident using the system.*
10. *I have needed to learn a lot of things before I could get going with this system.*

A minimum of 5 members per pilot are requested to answer these questions, from 0-5. The overall score is computed considering that "negative questions" are inverted (i.e., 2, 4, 6, 8, 10), as lower scores are the desired ones.

Results and outlook

20 different end-users filled in the questionnaire, providing a quantitative value between 1 (strongly disagree) and 5 (strongly agree). The KPI was considered successful if **the score is greater than 70% (3.5/5)**. As one can see, a 77,14% was obtained, showing a good level of usability according to the users of the different interfaces of the systems deployed. More specific numbers about specific outcomes are reported in further KPIs, being KPI 1.1.3 (Section 3.4.2.3) the most interesting one for granular data.

Table 28. Survey results of ASSIST-IoT's UX usability

Topic	Mean value*
I would like to use this system frequently	4.58
I have found the system unnecessarily complex	1.32 (3.68)
I think the system was easy to use	3.79
I would need the support of a technical person to be able to use this system	2.05 (2.95)
I found the various functions in this system were well integrated	4.26
I think there was too much inconsistency in this system	1.32 (3.68)
I would imagine that most people would learn to use this system very quickly	4.10
I found the system very cumbersome to use	1.05 (3.95)
I have felt very confident using the system	4.26
I have needed to learn a lot of things before I could get going with this system	1.68 (3.32)
Mean	3,86 (77,14%)

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[4] Brooke, John. (1995). SUS: A quick and dirty usability scale. Usability Eval. Ind. 189.

3.2.2.15. KPI 4.5.1 – Number of autonomous decisions taken while executing pilots (KVI-4.2)

Table 29. Summary of KPI 4.5.1

Name	**Number of autonomous decisions taken while executing pilots**				
Description	Self-* Enablers can take autonomous decisions. Such decisions do not involve human operators.				
Motivation	This KPI is useful to measure the number of autonomous decisions supported by the developed enablers, in the scope of the pilots. Of interest to measure their success.				
Initial target	>5	**Score***	5*	**Achieved**	Yes/No
Rationale target selection	To ensure that a minimum number of actions have been automated with self-* components, and validated in pilots' premises				
Measurement period	Last month of the project (M41), gathering overall figures.				
Partner/s responsible	SRIPAS				

Measurement methodology

The methodology is straightforward. A template to be completed will be distributed among pilots, to check which enablers have been deployed. Knowing which enablers have been leveraged form the self-* vertical, their related decisions can be obtained, as well as the resources involved (see also next KPI).

Results and outlook

The following enablers have been deployed, considering the following self-* characteristics:

- Resource monitoring, which is capable of scale-in/out computing resources before potential traffic increase or decrease.
- Self-healing, which is capable of restarting failing devices.
- Self-location processing enabler, which transforms location data from different sources and is capable to publish through the EDB in case of specific events.
- Smart orchestrator, although not in the self-* classification, has dedicated logic to decide the deployment place of workloads (i.e., enablers) in the managed infrastructure.
- AI-based fall-arrest automatic detection and alerting, reported, along with the location and the identity of the worker, in order to be further investigate.

The two missing self-* enablers were not considered as any of the project's use cases easily fit with their features. For that reason, other leveraged enablers with self-* capabilities have been reported.

3.2.2.16. KPI 4.5.2 – Number of resources involved in self-* processes

Table 30. Summary of KPI 4.5.2

Name	**Number of resources involved in self-* processes**				
Description	Resource is a "Thing" in Internet of Things. It may vary from physical device to a software component. This KPI will track how many such Things (excluding Self-* Enabler's internal components) will participate in autonomous decision taking or be influenced by such decisions.				
Motivation	Why is it important to have/mention as KPI (added value)				
Initial target	>5	**Score***	7	**Achieved**	Yes

Rationale target selection	To ensure that a minimum number of actions have been automated with self-* components, and validated in pilots premises
Measurement period	Last month of the project (M41), gathering overall figures.
Partner/s responsible	SRIPAS

Measurement methodology

The methodology is the same as the previous KPI. A template to be completed will be distributed among pilots, to check which enablers have been deployed. Knowing which enablers have been leveraged form the self-* vertical, their related decisions can be obtained, as well as the resources involved (see also next KPI).

Results and outlook

The resources involved by each of the aforementioned enablers are:

- Resource monitoring: K8s' HPA, monitoring metrics (from PUD).
- Self-healing: Host processes, (indirectly) K8s self-healing.
- Self-location: UWB data, EDB, OSH manager interface.
- Smart orchestrator: K8s API, monitoring metrics (from PUD).
- AI-based fall-arrest detection and response: UWB data, OSH manager interface.

3.2.2.17. KPI 4.6.1 – Distributed AI costs (KVI 4.2)

Table 31. Summary of KPI 4.6.1

Name	**Distributed AI costs**				
Description	This KPI will evaluate the reduction of AI costs from traditional cloud-based systems versus custom-edge distributed AI solutions.				
Motivation	Different factors have to be considered in order to create working and exploitable AI-based software solutions. One of these factors (if not the most relevant) is the cost of AI infrastructure, i.e., AI-based ASSIST-IoT services should be as much affordable as possible.				
Initial target	50%	**Score***	63%	**Achieved**	Yes
Rationale target selection	This KPI was identified in the proposal and approved by the European Commission evaluators. The reasoning was to reduce the cost of AI solutions by half in order to boost their use beyond project's lifetime.				
Measurement period	After the final identification of ML models and dataset sizes used in the pilots of the project.				
Partner/s responsible	PRO				

Measurement methodology

A theoretical and empirical study for the situation before and after Pilot 3B model training is considered as a realistic example, given the business expertise of the project partner TWOT. Both approaches (before and after using the ASSIST-IoT FL) are consisting of the edge and the cloud components.

On the one hand, before ASSIST-IoT, all the data were transferred to the cloud for processing and storage. Only temporarily storage was used additionally in the edge for the scans (only for a few days' operation). On the other hand, With the FL approach of the ASSIST-IoT, there are no needs to send the scans with the high-resolution colour pictures to the cloud for neither for the training nor for the surface-inspection. Both operations are performed locally.

The analysis was split across three different aspects of the AI-training & the operational execution of the AI-inference machine to produce the AI-proposals of the surface inspection: (i) Processing and (ii) data storage costs include all the necessary infrastructure associated with the business cases of this hybrid architecture. (iii) Communication costs mostly include the cost of delivering the necessary image data from the edge nodes to the cloud system. For the Pilot 3B both mobile networks as well as stationary high-speed networks are used.

Results and outlook

1. **Processing cost (typical time market consideration of 3 years)**
   a) **Before ASSIST-IoT:**
   - *local computing*: let us define for the standard case "100%" with typical costs, about 5.000€ for an industrial computer, assuming 5 years' amortisation time: 1.000€/year. *additional costs:* (note: additional costs like power consumption etc. are here not considered*)*: setup costs (5% of the investment costs: 250€), plus yearly maintenance costs (5% of the investment costs: 250€, for 3 years = 750€).
   - *cloud computing*: let us define for the standard case for a typical scanner application "100%" with typical costs about 1.500€/month (i.e., 18.000€/year), assuming 3 years' operation: 54.000€.
   - *Total processing costs*: CAPEX: 5.250 € once + OPEX / year: (250€ + 250€ + 18.000€) = 18.500€/year = 55.500€ for 3 years. CAPEX+OPEX = **60.750€** for 3 years.

   b) **After ASSIST-IoT:**
   - *local computing*: 40% on the top of the previous one, so in total 140% (mostly for a robust graphic subsystem with typical costs about 2.000 €), i.e. in total with the main computer: 7.000 €, assuming 3 years' amortisation time: 2.333 €/year). *additional costs*: setup costs (5% of the invest costs: 350€) + yearly maintenance costs (5% of the invest costs: 350€, for 3 years = 1.050€)
   - *cloud computing*: let us define for the standard case of a few supported scanners: 100% (typical costs, about 500€ / month, i.e., 6.000€/year, assuming 3 years' operation: 18.000€).
   - *Total processing costs*: CAPEX: 7.350 € + OPEX / year: (350€ + 6.000 €) = 6.350€/year. CAPEX+OPEX for 3 years = **19.050€**.
2. **Data storage cost (typical time market consideration of 3 years)**
   a) **Before ASSIST-IoT:**
   - *local computing*: included in the computer.
   - *cloud computing*: included in the cloud services costs

   b) **After ASSIST-IoT:**
   - *local computing*: additional long-term storage subsystem for the scan data needed for local reviewing and FL-training, typical costs about. **2.500€**.
   - *cloud computing*: included in the cloud services costs.
3. **Communication cost**
   - **Before ASSIST-IoT:** *One garage performs 150 scans per day (every scan about 100-150 pictures),* generating 200 MB per scan, and leading to the need of sending to the cloud up to 22 GB/day data volume. Since scans are not carried out in a regular basis, there are peaks and downfalls, and the garage should guarantee the proper functioning at early times in the day (two cars scanned per minute). Thus, the garage sends to the cloud server **400 MB/minute**, which leads to approximately an uplink bandwidth requirement of 60 Mbps. This requirement is supported by premium 4G subscriptions at the cost of 200€/month, or 2.400€/year, i.e., for 3 years it would go up to **7.200€.**
   - **After ASSIST-IoT:** Thanks to the FL system of the project, the inspection takes places on the edge. Therefore, there is no need to send all the pictures of the scans to the cloud, as the ML training is performed on-site. Thus, only the model updates represented as JSON files of **5 MB per week** (plus a small set of the scanned images used for documentation purposes) is sent to the FL training collector allocated at the cloud environment. This will instead require a basic 4G subscription, at the cost of 100€/month, or 1.200 €/year, i.e., for 3 years it would go up to **3.600€**.

The summary of all above considerations leads to the following costs overview (for 3 years' operation). **Before ASSIST-IoT - costs: 60.750€ + 0€ + 7.200€= 67.950€; After ASSIST-IoT - costs: 19.050€ + 2.500€ + 3.600€ = <u>25.250€.</u>** This results in a difference of **42.700€, <u>which can be translated to 63% of savings.</u>**

3.2.2.18. KPI 4.6.2 – FL users

Table 32. Summary of KPI 4.6.2

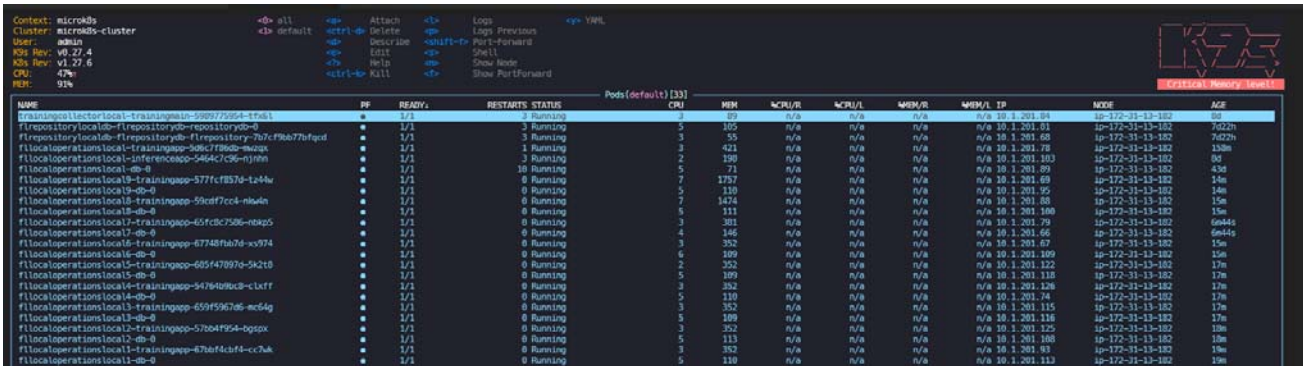
Name	**FL users**				
Description	This KPI quantifies how many simultaneous users can be involved in a common ML model training through the FL system of the project.				
Motivation	This KPI aims at demonstrating the scalability capabilities of the ASSIST-IoT FL system				
Initial target	10	**Score***	10	**Achieved**	Yes
Rationale target selection	The target of 10 simultaneous users/clients involved in the FL system was agreed internally, channels, as that is the expected maximum number of users in a single real-world deployment, that will be realistically required.				
Measurement period	Several tests have been performed along the FL development stages. As long as new features were incorporated, they were tested with at least 10 clients involved in the training.				
Partner/s responsible	PRO				

Measurement methodology

1. A minimum of 10 available clients are set up in the initial configuration fields from the GUI that connects with the FL Orchestrator.
2. Then, as long as the number of connected clients (i.e., websocket clients with their IP addresses and ports) are below 10, the FL Orchestrator enforce to stop the training and the tests were considered a failure.

Results and outlook

The FL suite has been tested in laboratory conditions with multiple users, in order to validate its scalability capabilities. Particularly, the system has been tested with 10 users (this is, ten instances of the FL Local Operations enablers). A picture of the connected clients can be seen in the following snapshot, which makes use of K9s User Interface. They could be used for training local models correctly, which then were combined via the FL training collector and which result was shared with these instances to enable inference processes.



```
Context: microk8s                <0> all       <a>        Attach     <l>         Logs              <y> YAML
Cluster: microk8s-cluster        <1> default   <ctrl-d>   Delete     <p>         Logs Previous
User:    admin                                 <d>        Describe   <shift-f>   Port-Forward
K9s Rev: v0.27.4                               <e>        Edit       <s>         Shell
K8s Rev: v1.27.6                               <?>        Help       <n>         Show Node
CPU:     47%                                   <ctrl-k>   Kill       <f>         Show PortForward
MEM:     91%                                                                                       Critical Memory level!

                                                                         Pods(default)[33]
NAME                                                            PF  READY↓  RESTARTS STATUS   CPU   MEM  %CPU/R  %CPU/L  %MEM/R  %MEM/L IP            NODE               AGE
trainingcollectorlocal-trainingmain-5989775954-tfx6l            ●   1/1            3 Running    3    89     n/a     n/a     n/a     n/a 10.1.201.84   ip-172-31-13-182   8d
flrepositorylocaldb-flrepositorydb-repositorydb-0               ●   1/1            3 Running    5   105     n/a     n/a     n/a     n/a 10.1.201.81   ip-172-31-13-182   7d22h
flrepositorylocaldb-flrepositorydb-flrepository-7b7cf9bb77bfqcd ●   1/1            3 Running    3    55     n/a     n/a     n/a     n/a 10.1.201.68   ip-172-31-13-182   7d22h
fllocaloperationslocal-trainingapp-5d6c7f86db-mwzqx             ●   1/1            1 Running    3   421     n/a     n/a     n/a     n/a 10.1.201.78   ip-172-31-13-182   150m
fllocaloperationslocal-inferenceapp-5464c7c96-njnhn             ●   1/1            3 Running    2   190     n/a     n/a     n/a     n/a 10.1.201.103  ip-172-31-13-182   8d
fllocaloperationslocal-db-0                                     ●   1/1           10 Running    5    71     n/a     n/a     n/a     n/a 10.1.201.89   ip-172-31-13-182   43d
fllocaloperationslocal9-trainingapp-577fcf857d-tz44w            ●   1/1            0 Running    7  1757     n/a     n/a     n/a     n/a 10.1.201.69   ip-172-31-13-182   14m
fllocaloperationslocal9-db-0                                    ●   1/1            0 Running    5   110     n/a     n/a     n/a     n/a 10.1.201.95   ip-172-31-13-182   14m
fllocaloperationslocal8-trainingapp-59cdf7cc4-nkw4n             ●   1/1            0 Running    7  1474     n/a     n/a     n/a     n/a 10.1.201.88   ip-172-31-13-182   15m
fllocaloperationslocal8-db-0                                    ●   1/1            0 Running    5   111     n/a     n/a     n/a     n/a 10.1.201.100  ip-172-31-13-182   15m
fllocaloperationslocal7-trainingapp-65fc8c7586-nbkp5            ●   1/1            0 Running    3   381     n/a     n/a     n/a     n/a 10.1.201.79   ip-172-31-13-182   6m44s
fllocaloperationslocal7-db-0                                    ●   1/1            0 Running    4   146     n/a     n/a     n/a     n/a 10.1.201.66   ip-172-31-13-182   6m44s
fllocaloperationslocal6-trainingapp-67748fbb7d-xs974            ●   1/1            0 Running    3   352     n/a     n/a     n/a     n/a 10.1.201.67   ip-172-31-13-182   15m
fllocaloperationslocal6-db-0                                    ●   1/1            0 Running    6   109     n/a     n/a     n/a     n/a 10.1.201.109  ip-172-31-13-182   15m
fllocaloperationslocal5-trainingapp-605f47097d-5k2t8            ●   1/1            0 Running    2   352     n/a     n/a     n/a     n/a 10.1.201.122  ip-172-31-13-182   17m
fllocaloperationslocal5-db-0                                    ●   1/1            0 Running    5   109     n/a     n/a     n/a     n/a 10.1.201.118  ip-172-31-13-182   17m
fllocaloperationslocal4-trainingapp-54764b9bc8-clxff            ●   1/1            0 Running    3   352     n/a     n/a     n/a     n/a 10.1.201.126  ip-172-31-13-182   17m
fllocaloperationslocal4-db-0                                    ●   1/1            0 Running    5   110     n/a     n/a     n/a     n/a 10.1.201.74   ip-172-31-13-182   17m
fllocaloperationslocal3-trainingapp-659f5967d6-mc64g            ●   1/1            0 Running    3   352     n/a     n/a     n/a     n/a 10.1.201.115  ip-172-31-13-182   17m
fllocaloperationslocal3-db-0                                    ●   1/1            0 Running    5   109     n/a     n/a     n/a     n/a 10.1.201.116  ip-172-31-13-182   17m
fllocaloperationslocal2-trainingapp-57bb4f954-bgspx             ●   1/1            0 Running    3   352     n/a     n/a     n/a     n/a 10.1.201.125  ip-172-31-13-182   18m
fllocaloperationslocal2-db-0                                    ●   1/1            0 Running    5   113     n/a     n/a     n/a     n/a 10.1.201.108  ip-172-31-13-182   18m
fllocaloperationslocal1-trainingapp-67bbf4cbf4-cc7wk            ●   1/1            0 Running    3   352     n/a     n/a     n/a     n/a 10.1.201.93   ip-172-31-13-182   19m
fllocaloperationslocal1-db-0                                    ●   1/1            0 Running    5   110     n/a     n/a     n/a     n/a 10.1.201.113  ip-172-31-13-182   19m
```

Figure 21. Snapshot of K9s showing 10 Local operations enablers correctly connected

3.2.2.19. KPI 4.6.3 – ML models

Table 33. Summary of KPI 4.6.3

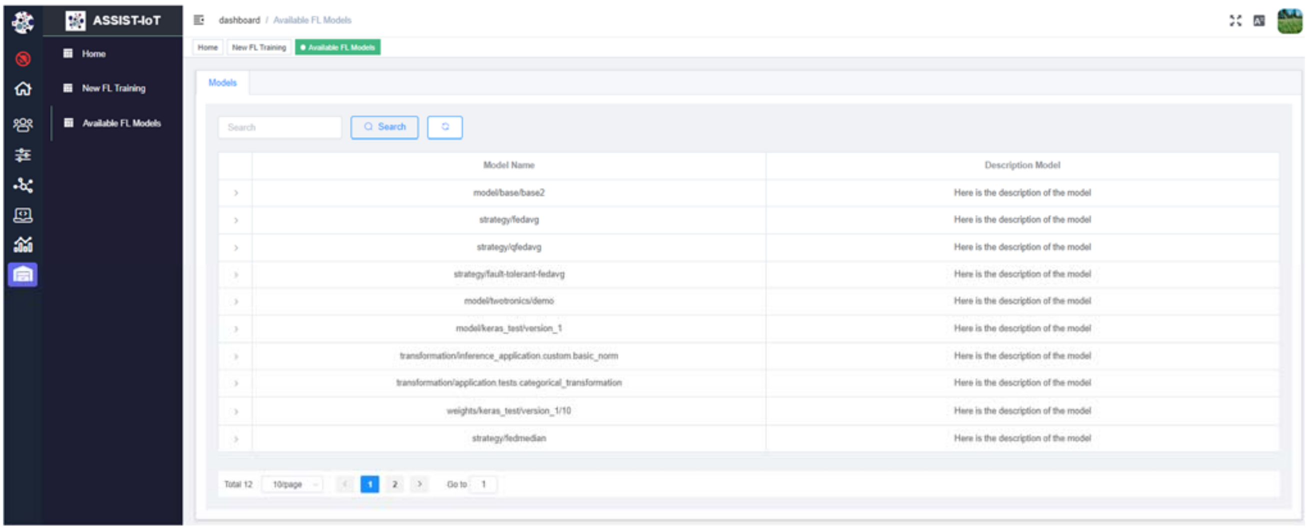
Name	**ML models**				
Description	This KPI evaluates the support of how many pre-trained ML models (e.g., Keras, Tensorflow, or scikit-learn) by the ASSIST-IoT FL system.				
Motivation	Another pillar of ASSIST-IoT FL system is to be able to support several ML models				
Initial target	2	**Score***	10	**Achieved**	Yes
Rationale target selection	It was internally agreed that at least a regression model and a classification model will be supported, given that they are the two most commonly used models in the scientific environment.				
Measurement period	Several tests have been performed along the FL development stages. As long as new features were incorporated, the two ML models were tested.				
Partner/s responsible	PRO				

Measurement methodology

1. The supported ML models for the ASSIST-IoT FL system are stored in the FL Repository.
2. We connect to the corresponding models collection of this enabler and quantify the stored documents/entries.
3. As long as 2 or more documents were stored, the KPI was considered fulfilled.
4. Furthermore, FL training tests with the different stored models in the FL repository are carried out in order to guarantee that they are actual working models.

Results and outlook

The FL suite was fully used on Pilot 3B, using all its components. Additionally, this pilot had different delocalized sites belonging to different stakeholders, thus being a good use case for validate the suite and the models developed. The following figure presented the models used in P3B and hosted by the FL repository enabler, providing different alternatives that can be used for training. A total of 10 models have been used. Although Open Callers have made use of it, this information has not been requested to them.



Model Name	Description Model
model/base/base2	Here is the description of the model
strategy/fedavg	Here is the description of the model
strategy/qfedavg	Here is the description of the model
strategy/fault-tolerant-fedavg	Here is the description of the model
model/twotronics/demo	Here is the description of the model
model/keras_test/version_1	Here is the description of the model
transformation/inference_application.custom.basic_norm	Here is the description of the model
transformation/application.tests.categorical_transformation	Here is the description of the model
weights/keras_test/version_1/10	Here is the description of the model
strategy/fedmedian	Here is the description of the model

Figure 22. FL models in Pilot 3B

3.2.2.20. KPI 4.6.4 – FL use cases

Table 34. Summary of KPI 4.6.4

Name	**FL use cases**				
Description	This KPI evaluates the number of use cases of ASSIST-IoT pilots that have made use and successfully tested the ASSIST-IoT FL system (either with simulations in laboratory or with real-time demonstrations on their industrial premises).				
Motivation	There are many reasons why the classic centralized machine learning approach does not work for a large number of highly important real-world use cases. Those reasons include Regulations (GDPR), user preference (users do not want their data leaves their device ever), and/or data volume (lack of budget for high-processing infrastructure to process and store training data). ASSIST-IoT FL system expected to reverse these limitations, enabling more private and less-consuming ML training.				
Initial target	2	**Score***	3	**Achieved**	Yes
Rationale target selection	The reasoning was to provide more than one use case in the project, in order to be tested in at least two different environments.				
Measurement period	After the last execution of pilot and open call trials				
Partner/s responsible	PRO				

Measurement methodology

KPI partner responsible requests the list of human-centric use cases deployed and tested to every pilot trial owner.

Results and outlook

The following ASSIST-IoT use case as well as 2 open calls have made use of the FL system of the project.

- **Pilot 3B** UC-P3B-2 Exterior defects detection support.
- **Open Call** IoTLORAMesh
- **Open Call** HazardMiner

It became clear during the project execution that P3B was the one in which the system could be of more advantage, even considering its multi-stakeholder environment. Its specific conditions make it optimal for its deployment and its long-term success.

It should be also mentioned that Pilot 2's UC-P2-4 (Detection of falls and immobility) could also take great advantage of it. At this moment, it already leverages some of the FL components of the stack, particularly the FL Local Operations; however, having a single construction site, the models used could not be trained with data from other environments/stakeholders – it could have been simulated or validated in lab though, but not in the pilot itself. In any case, the Open Caller HazardMiner achieved something similar for their own models, proving its potential.

3.2.2.21. KPI 4.7.1 – Users covered by security of ASSIST-IoT

Table 35. Summary of KPI 4.7.1

Name	**Users covered by security of ASSIST-IoT**
Description	This KPI measures the potential number of users that could be covered by implementing ASSIST-IoT security / privacy methods
Motivation	To validate that that the systems can support all the users needed by any kind of application in any market.

Initial target	20.000 users	**Score***	30.158 users	**Achieved**	Yes
Rationale target selection	To ensure that the systems can be used in any use case and market and grow up without any updating the services and making the solution available for long time.				
Measurement period	During pilots' trials execution				
Partner/s responsible	S21Sec				

Measurement methodology

The total amount of users covered by the security enablers will not be quantified, but an estimation of the maximum number of users can be made:

- From Pilot 1, the following information will be requested:
    1. How many cranes are in Malta Freeport?
    2. How many trucks can a crane unload/load per hour?
    3. How many hours a day is working a crane?
    4. How many crane operators are working in Malta Freeport?
- From Pilot 2, the following information will be requested:
    1. How many users will wear IoT devices in the construction site?
    2. How many operators will work remotely?
- From Pilot 3A, the following information will be requested:
    1. How many cars are sold as average per year by brand?
    2. How many admin operators are working or expected to work in?
- From Pilot 3B, the following information will be requested:
    1. How many users will be in each tunnel?
    2. How many tunnels will be per garage?
    3. How many operators will work remotely?
    4. Will the end costumers have access to the systems?
    5. If so, how many users per day or month or year are estimated to use the pilot?

The way of **estimate the number of users** will be the following:

Pilot 1:

a. Question 2 answer will be multiplied per the answer to question 3.
b. The result of the previous point will be multiplied per the answer to question 1.
c. Finally, the result of the previous point will be added to the answer to question 4.

Pilot 2:

a. We will add the result of both answers

Pilot 3A:

a. We will take into account the 3% of the answer to question 1.
b. The result of previous point will be added to the answer of question 2.

Pilot 3B:

a. We will multiply the user numbers per the number of tunnels.
b. We will add the previous result to the number of operators.
c. If end users will have access to the system, we will take the number of users of one year and add it to the final result.

Results and outlook

The answers to the questions proposed in the previous section have been the following ones:

- From Pilot 1, the following information will be requested:
    1. How many cranes are in Malta Freeport? -> 20 Ship-to-Shore cranes, and 59 Rubber-Tyred-Gantry cranes
    2. How many trucks can a crane unload/load per hour? -> N/A
    3. How many hours a day is working a crane? -> The operations are 24/7, QCs and RTGs work according to work load, therefore, a particular crane can work for 4 hours or 3 whole days, there is no pattern to this.
    4. How many crane operators are working in Malta Freeport? -> The operations are 24/7, QCs and RTGs work according to work load, therefore, a particular crane can work for 4 hours or 3 whole days, there is no pattern to this.
- From Pilot 2, the following information will be requested:
    1. How many users will wear IoT devices in the construction site? -> 10
    2. How many operators will work remotely? -> 3
- From Pilot 3A, the following information will be requested:
    1. How many cars are sold as average per year by brand? -> 1.000.000 cars
    2. How many admin operators are working or expected to work in? -> 50 people
- From Pilot 3B, the following information will be requested:
    1. How many users will be in each tunnel? -> 4
    2. How many tunnels will be per garage? -> 1
    3. How many operators will work remotely? -> 8
    4. Will the end costumers have access to the systems? -> no
    5. If so, how many users per day or month or year are estimated to use the pilot? -> No need to answer

Pilot 1: (4 hours x 20 cranes) + 3 (operators/day) = 83 users

Pilot 2: 10 users + 3 operators = 13 users

Pilot 3A: 1.000.000 cars x 0,03 (3%) + 50 = 30.050 users

Pilot 3B: 4 tunnel x 1 garage + 8 operators = 12 users

Total => Pilot 1 + Pilot 2 + Pilot 3A + Pilot 3B = 83 + 13 + 30.050 + 12 = **30.158 users**

This result shows that the project is ready to support a large scale of users that provides significant data. Regarding the pilots in the project this result is been estimated to get an approach and get a result that the systems should support in case of a large-scale pilots. Regarding the result makes really important to have robust tools deployed, as the ones that has been implemented in the project, to ensure that the systems is able to run in almost any environment.

3.2.2.22. KPI 4.7.2 – Pervasiveness of user coverage by security enablers

Table 36. Summary of KPI 4.7.2

Name	**Pervasiveness of user coverage by security enablers**				
Description	This KPI measures the coverage of users implementing the security and privacy methods				
Motivation	The goal of the KPI is to illustrate that the cybersecurity is important and get added value to the services.				
Initial target	75%	**Score***	99,95%	**Achieved**	Yes
Rationale target selection	The 75% of people covered by cybersecurity enablers is a good way to ensure that almost all people can access the system in secure way.				

Measurement period	During the pilots' trials execution
Partner/s responsible	S21Sec

Measurement methodology

Each pilot has reported to S21Sec the total amount of cybersecurity enablers that they have implemented, and calculating the ratio with the following formula:

$$\frac{user\ covered\ in\ the\ pilots\ by\ cybersecurity\ enablers}{total\ estimated\ user} \times 100$$

Results and outlook

Pervasiveness = (30145/30158) * 100 = 99,95%

The result above has been taken from the total user estimated in the previous KPI and considered the pilots that have implemented the cybersecurity enablers. In this project, the pilots that has implemented the cybersecurity enablers has been the Pilot 1, Pilot 3A and Pilot 3B. Results shows that almost all the user are covered by the cybersecurity enablers, warrantying the maximum protection against different event that can be achieved in the networks.

3.2.2.23. KPI 4.7.3 – Correct identification attempt ratio

Table 37. Summary of KPI 4.7.3

<table>
<tr><td>Name</td><td colspan="5">Correct identification attempt ratio</td></tr>
<tr><td>Description</td><td colspan="5">This KPI measures the flow of identification requests as they are being processed by the system.</td></tr>
<tr><td>Motivation</td><td colspan="5">This KPI was included to ensure that the enabler was tested and validated during the project and the methodology below involves how to measure it properly.</td></tr>
<tr><td>Initial target</td><td>75%</td><td>Score*</td><td>81,33</td><td>Achieved</td><td>Yes</td></tr>
<tr><td>Rationale target selection</td><td colspan="5">The score will comply with the project KPI if the 75% of the request are successful. Less could reference some kind of attack of misconfiguration.</td></tr>
<tr><td>Measurement period</td><td colspan="5">During the pilots' trials execution</td></tr>
<tr><td>Partner/s responsible</td><td colspan="5">S21Sec</td></tr>
</table>

Measurement methodology

From IDM enabler, the total number of login attempts and the total number of correct login have to be taken, considering all the measurement period. It will be evaluated with the following formula:

$$\frac{total\ number\ of\ correct\ login}{total\ number\ of\ login\ attempts} \times 100$$

Results and outlook

The result of the project (**81,33%**, see figure below) is the average of the pilots that implements the identification enabler. These results show that during the trials execution the users were able to type their username and password properly and the tools implemented where use-friendly and easy to use.

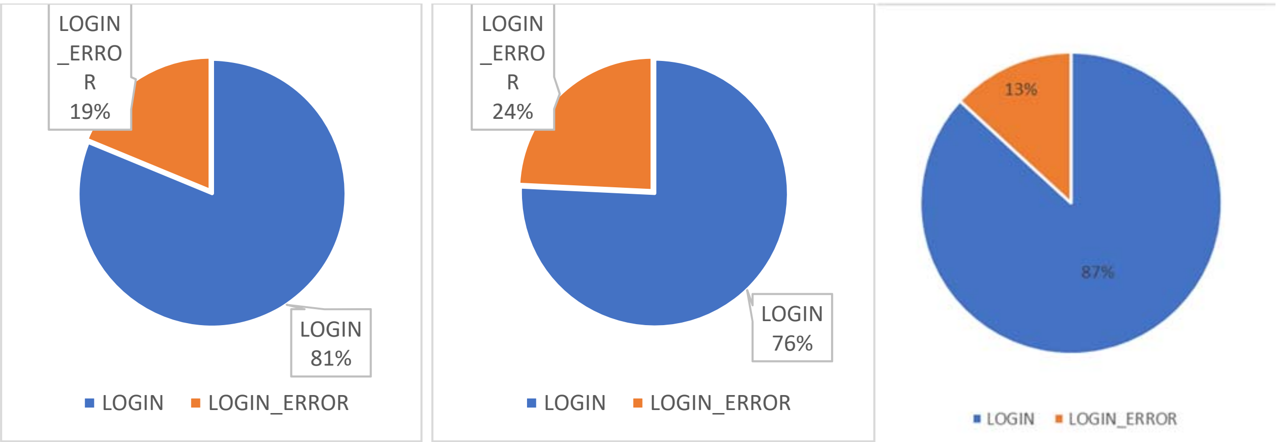


Figure 23. Correct login ratios: Pilot 1 (left), pilot 3A (center), Pilot 3B (right)

3.2.2.24.KPI 4.7.4 – Validated authorization request ratio

Table 38. Summary of KPI 4.7.4

Name	**Validated authorization request ratio**				
Description	This KPI measures the flow of decision-making requests processed by the system				
Motivation	This KPI was included to ensure that the enabler was tested and validated during the project and the methodology below involves how to measure it properly				
Initial target	40%	**Score***	85,25%	**Achieved**	Yes
Rationale target selection	The score will comply with the project KPI if the 40% of the request are successful. Less could reference some kind of attack of misconfiguration.				
Measurement period	During the pilots' trials execution				
Partner/s responsible	S21Sec				

Measurement methodology

From Authorization enabler it is taken the total number of authorization requests and the total number of successful requests. The taken data will be from all the measurement period. It will be evaluated with the following formula:

$$\frac{total\ number\ of\ successful\ requets}{total\ number\ of\ authorization\ requets} \times 100$$

Results and outlook

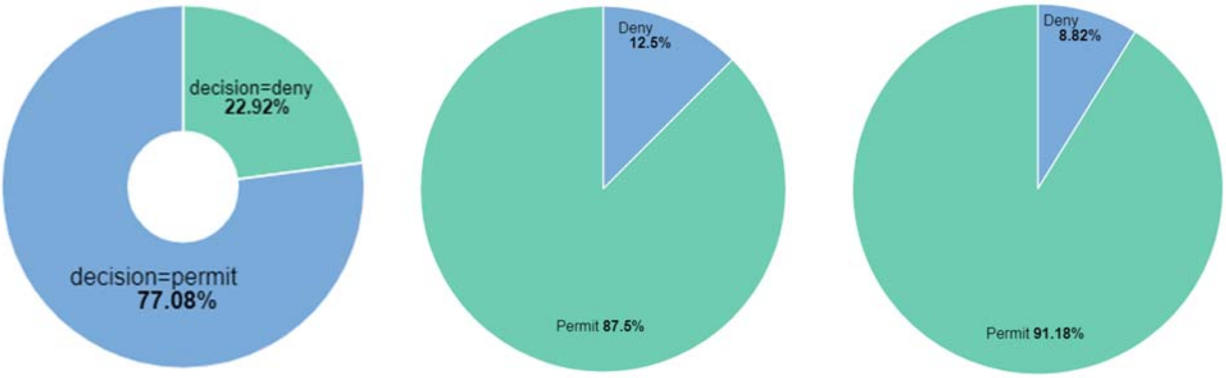


Figure 24. Authorization ratios: Pilot 1 (left), pilot 3A (center), Pilot 3B (right)

The result of the project (**85,25%**, see figure above), as in the previous KPI, is the average of the authorization success rules of each pilot. These results show that the users requested services, options or any other data that they were supposed to get and only in a few cases the users request for services, data or options that they should not have to get. The result also shows that the tools were properly configured and there were not many unauthorized access attempts.

3.2.2.25. KPI 4.7.5 – Detected alerts per hour

Table 39. Summary of KPI 4.7.5

Name	**Detected alerts per hour**				
Description	This KPI measures the number of incorrect situations that require visibility detected on the network				
Motivation	This KPI was included to ensure that the enabler was tested and validated during the project and the methodology below involves how to measure it properly				
Initial target	<10 alerts/hour	**Score***	4 alerts/hour	**Achieved**	Yes
Rationale target selection	The score will comply with the project KPI if less than 10 events/hour are detected. More could reference some kind of attack of misconfiguration.				
Measurement period	During the pilots' trials execution				
Partner/s responsible	S21Sec				

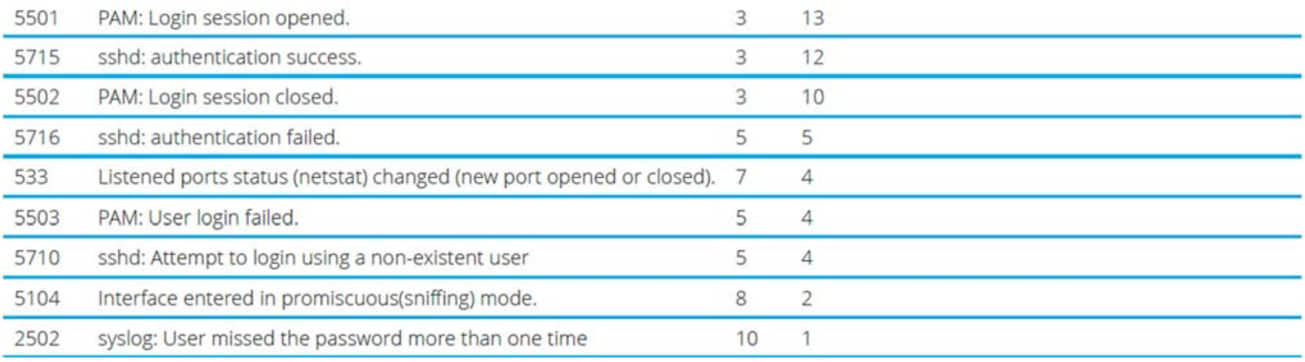
Measurement methodology

From the cybersecurity monitoring enabler, the total cybersecurity incident number will be taken (above level 7), that are alerts send to the incident response tool. The data will be from all the measurement period, and they will be evaluated by the following formula:

$$\frac{total\ number\ of\ incidents\ in\ a\ day}{(Total\ number\ of\ hours)}$$

Results and outlook

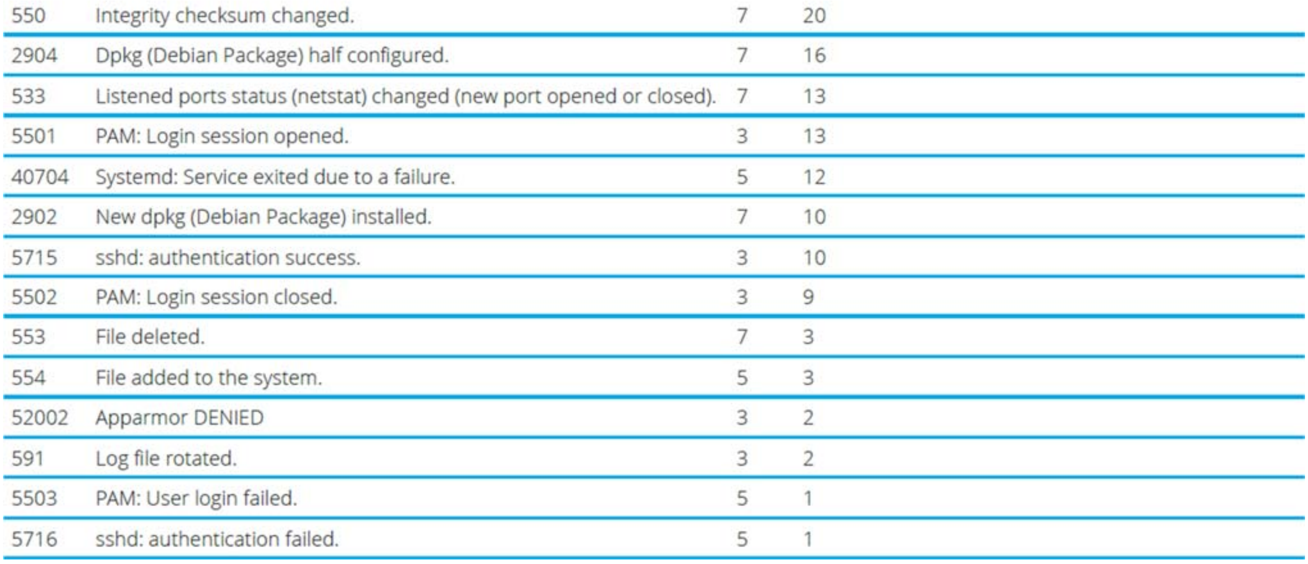
The following image shows the events detected in 2 hours in Pilot 1:



5501	PAM: Login session opened.	3	13
5715	sshd: authentication success.	3	12
5502	PAM: Login session closed.	3	10
5716	sshd: authentication failed.	5	5
533	Listened ports status (netstat) changed (new port opened or closed).	7	4
5503	PAM: User login failed.	5	4
5710	sshd: Attempt to login using a non-existent user	5	4
5104	Interface entered in promiscuous(sniffing) mode.	8	2
2502	syslog: User missed the password more than one time	10	1

Figure 25. Pilot 1 events list

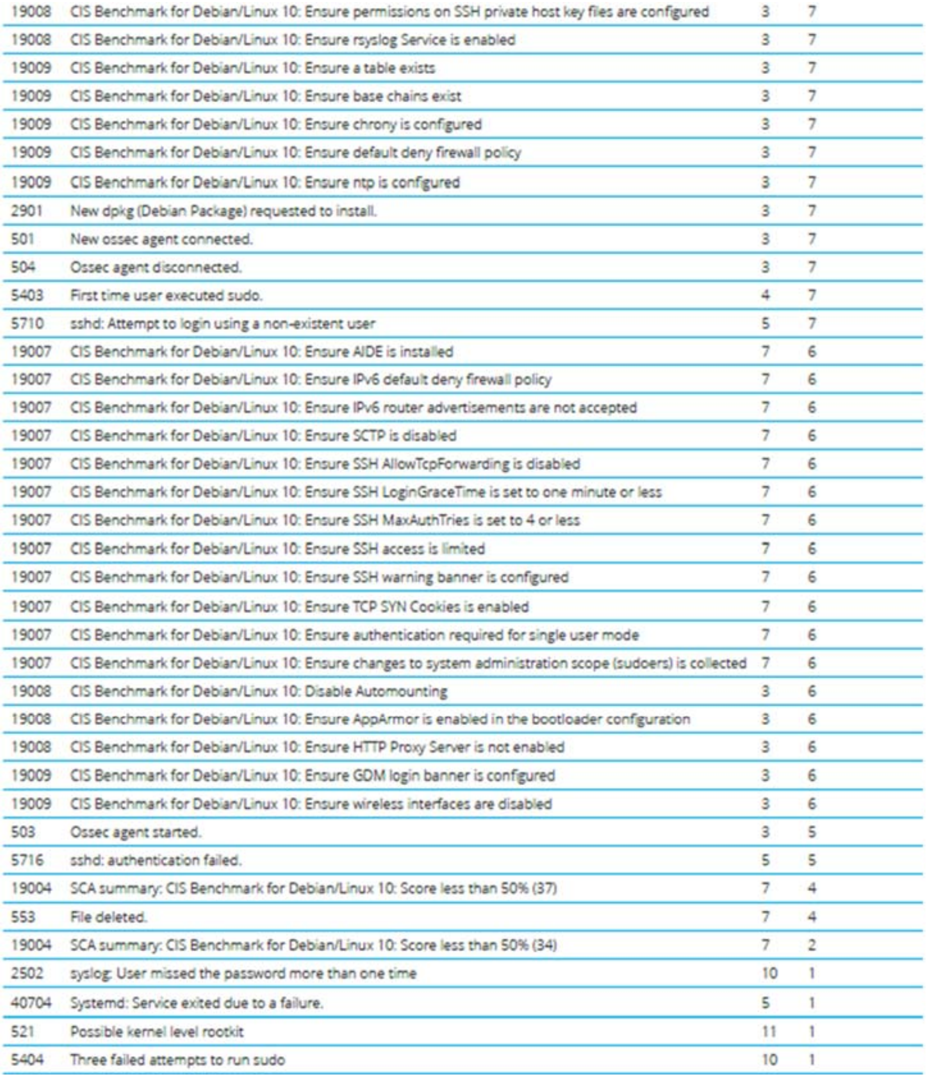
The following image shows the events detected in 24 hours in Pilot 3A:



550	Integrity checksum changed.	7	20
2904	Dpkg (Debian Package) half configured.	7	16
533	Listened ports status (netstat) changed (new port opened or closed).	7	13
5501	PAM: Login session opened.	3	13
40704	Systemd: Service exited due to a failure.	5	12
2902	New dpkg (Debian Package) installed.	7	10
5715	sshd: authentication success.	3	10
5502	PAM: Login session closed.	3	9
553	File deleted.	7	3
554	File added to the system.	5	3
52002	Apparmor DENIED	3	2
591	Log file rotated.	3	2
5503	PAM: User login failed.	5	1
5716	sshd: authentication failed.	5	1

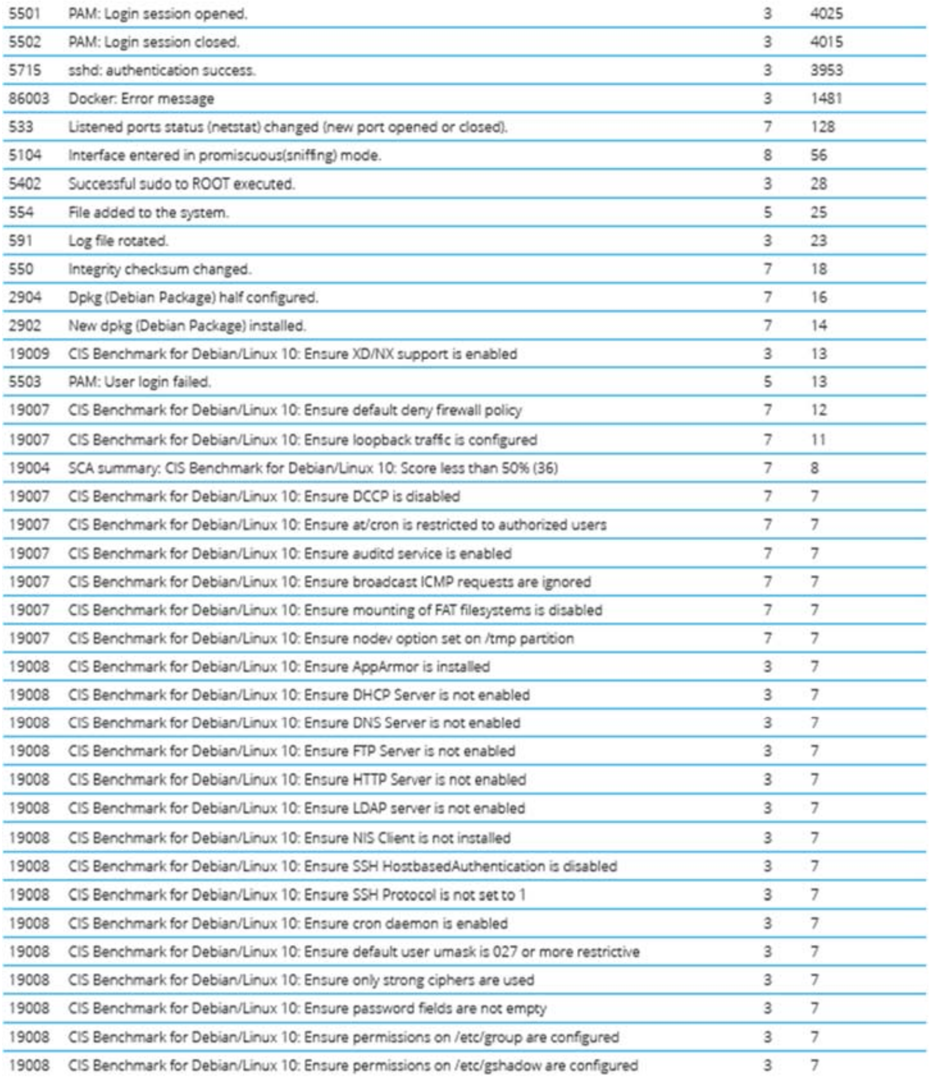
Figure 26. Pilot 3A events list

The following images show the events detected in 60 hours in Pilot 3B:



19008	CIS Benchmark for Debian/Linux 10: Ensure permissions on SSH private host key files are configured	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure rsyslog Service is enabled	3	7
19009	CIS Benchmark for Debian/Linux 10: Ensure a table exists	3	7
19009	CIS Benchmark for Debian/Linux 10: Ensure base chains exist	3	7
19009	CIS Benchmark for Debian/Linux 10: Ensure chrony is configured	3	7
19009	CIS Benchmark for Debian/Linux 10: Ensure default deny firewall policy	3	7
19009	CIS Benchmark for Debian/Linux 10: Ensure ntp is configured	3	7
2901	New dpkg (Debian Package) requested to install.	3	7
501	New ossec agent connected.	3	7
504	Ossec agent disconnected.	3	7
5403	First time user executed sudo.	4	7
5710	sshd: Attempt to login using a non-existent user	5	7
19007	CIS Benchmark for Debian/Linux 10: Ensure AIDE is installed	7	6
19007	CIS Benchmark for Debian/Linux 10: Ensure IPv6 default deny firewall policy	7	6
19007	CIS Benchmark for Debian/Linux 10: Ensure IPv6 router advertisements are not accepted	7	6
19007	CIS Benchmark for Debian/Linux 10: Ensure SCTP is disabled	7	6
19007	CIS Benchmark for Debian/Linux 10: Ensure SSH AllowTcpForwarding is disabled	7	6
19007	CIS Benchmark for Debian/Linux 10: Ensure SSH LoginGraceTime is set to one minute or less	7	6
19007	CIS Benchmark for Debian/Linux 10: Ensure SSH MaxAuthTries is set to 4 or less	7	6
19007	CIS Benchmark for Debian/Linux 10: Ensure SSH access is limited	7	6
19007	CIS Benchmark for Debian/Linux 10: Ensure SSH warning banner is configured	7	6
19007	CIS Benchmark for Debian/Linux 10: Ensure TCP SYN Cookies is enabled	7	6
19007	CIS Benchmark for Debian/Linux 10: Ensure authentication required for single user mode	7	6
19007	CIS Benchmark for Debian/Linux 10: Ensure changes to system administration scope (sudoers) is collected	7	6
19008	CIS Benchmark for Debian/Linux 10: Disable Automounting	3	6
19008	CIS Benchmark for Debian/Linux 10: Ensure AppArmor is enabled in the bootloader configuration	3	6
19008	CIS Benchmark for Debian/Linux 10: Ensure HTTP Proxy Server is not enabled	3	6
19009	CIS Benchmark for Debian/Linux 10: Ensure GDM login banner is configured	3	6
19009	CIS Benchmark for Debian/Linux 10: Ensure wireless interfaces are disabled	3	6
503	Ossec agent started.	3	5
5716	sshd: authentication failed.	5	5
19004	SCA summary: CIS Benchmark for Debian/Linux 10: Score less than 50% (37)	7	4
553	File deleted.	7	4
19004	SCA summary: CIS Benchmark for Debian/Linux 10: Score less than 50% (34)	7	2
2502	syslog: User missed the password more than one time	10	1
40704	Systemd: Service exited due to a failure.	5	1
521	Possible kernel level rootkit	11	1
5404	Three failed attempts to run sudo	10	1

Figure 27. Pilot 3B events list (1)



5501	PAM: Login session opened.	3	4025
5502	PAM: Login session closed.	3	4015
5715	sshd: authentication success.	3	3953
86003	Docker: Error message	3	1481
533	Listened ports status (netstat) changed (new port opened or closed).	7	128
5104	Interface entered in promiscuous(sniffing) mode.	8	56
5402	Successful sudo to ROOT executed.	3	28
554	File added to the system.	5	25
591	Log file rotated.	3	23
550	Integrity checksum changed.	7	18
2904	Dpkg (Debian Package) half configured.	7	16
2902	New dpkg (Debian Package) installed.	7	14
19009	CIS Benchmark for Debian/Linux 10: Ensure XD/NX support is enabled	3	13
5503	PAM: User login failed.	5	13
19007	CIS Benchmark for Debian/Linux 10: Ensure default deny firewall policy	7	12
19007	CIS Benchmark for Debian/Linux 10: Ensure loopback traffic is configured	7	11
19004	SCA summary: CIS Benchmark for Debian/Linux 10: Score less than 50% (36)	7	8
19007	CIS Benchmark for Debian/Linux 10: Ensure DCCP is disabled	7	7
19007	CIS Benchmark for Debian/Linux 10: Ensure at/cron is restricted to authorized users	7	7
19007	CIS Benchmark for Debian/Linux 10: Ensure auditd service is enabled	7	7
19007	CIS Benchmark for Debian/Linux 10: Ensure broadcast ICMP requests are ignored	7	7
19007	CIS Benchmark for Debian/Linux 10: Ensure mounting of FAT filesystems is disabled	7	7
19007	CIS Benchmark for Debian/Linux 10: Ensure nodev option set on /tmp partition	7	7
19008	CIS Benchmark for Debian/Linux 10: Ensure AppArmor is installed	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure DHCP Server is not enabled	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure DNS Server is not enabled	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure FTP Server is not enabled	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure HTTP Server is not enabled	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure LDAP server is not enabled	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure NIS Client is not installed	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure SSH HostbasedAuthentication is disabled	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure SSH Protocol is not set to 1	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure cron daemon is enabled	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure default user umask is 027 or more restrictive	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure only strong ciphers are used	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure password fields are not empty	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure permissions on /etc/group are configured	3	7
19008	CIS Benchmark for Debian/Linux 10: Ensure permissions on /etc/gshadow are configured	3	7

Figure 28. Pilot 3B events list (2)

For the result of the KPI is taken all the alerts of level 7 or higher, for each Pilot and the total average **is 4 alerts/hour.** The result shows that during the trials many events were detected but only few of them are considered as alerts, that should be managed by an operator to investigate what has happened. In this way only 4 alerts per hour has happened as an average in the trials, but this does not mean that these 4 alerts are real attacks that needs to be mitigated with an action, because the operator within the investigation will determine which is the most suitable action that must be taken.

3.2.2.26. KPI 4.8.1 – Automated accountability of interactions/communications performed (defining responsible) (KVI 3.1)

Table 40. Summary of KPI 4.8.1

Name	**Automated accountability of interactions/communications performed (defining responsible)**
Description	This KPI identifies the accountability of the involved actors when they communicate with ASSIST-IoT. To measure this KPI, we measure the number of critical interactions that are logged in the DLT.
Motivation	KPI 4.8.1 plays a pivotal role in promoting trust, compliance, risk management, performance optimization, and continuous improvement within the ASSIST-IoT ecosystem. By measuring and achieving the target threshold for automated accountability

	of interactions, the system reinforces its commitment to transparency, integrity, and responsible governance.				
Initial target	85%	**Score***	100%	**Achieved**	Yes
Rationale target selection	We consider that we comply with this KPI when the number of critical interactions/communications performed in integrated IoT setting is >85%				
Measurement period	5/11/23 – 20/12/23				
Partner/s responsible	CERTH				

Measurement methodology

Critical events are considered the risk of the safety of a worker in a construction site. To measure this KPI, the DLT enablers should capture at least 85% of the scenarios when a worker is in danger in the pilot testing of the construction site. The events that are created when a notification occurs from a location tag of a worker, when the worker is in danger, should be recorded and verified with the DLT verification enabler (Integrity Verification enabler).

Results and outlook

The DLT verification enabler was tested in multiple locations on the construction site. The tests were performed with a total of 10 participants. The functionality of the worker alarm button was tested, wherein pressing the alarm button on the location tag triggered a notification indicating the worker's need for help (critical event), along with their location. On the notification, a details popup provides additional information when users clicked on the "Details" button. Depending on the type of notification, the popup displayed information such as the DLT verification status. Overall, the testing of the DLT verification enabler demonstrated its effectiveness in accurately verifying and recording the event's authenticity when a notification occurs. Every critical event that was created, it was recorded and verified through DLT verification, so the score that was achieved for this KPI was 100%.

3.2.2.27. KPI 4.8.2 – Data governance services supported by IoT-enabled DLT (KVI 3.2)

Table 41. Summary of KPI 4.8.2

Name	**Data governance services supported by IoT-enabled DLT**				
Description	This KPI identifies how the DLT enablers will increase data governance aspects such as security, integrity, availability of data, and accountability of actors. In particular, this KPI (and KVI) will count how many data governance services delivered in the project can be understood as endorsed by DLT enablers.				
Motivation	Incorporating a KPI related to data governance services supported by IoT-enabled DLT underscores the significance of leveraging DLT technology to enhance security, integrity, availability, and accountability within IoT ecosystems.				
Initial target	10	**Score***	12	**Achieved**	Yes
Rationale target selection	We consider that we comply with this KPI when the number of these data governance services is 10.				
Measurement period	5/11/23 – 20/12/23				
Partner/s responsible	CERTH				

Measurement methodology

To measure this KPI the DLT enablers should provide their service and record data to the ledger of the blockchain, providing integrity, accountability and availability of data. The score will be determined by the number of events verified by the (4) developed enablers on pilot trials.

Results and outlook

The DLT enablers were tested and the results are below:

- Integrity verification enabler: The enabler provided integrity and availability of the data in tests that happened in Pilot 2 construction site and in Pilot 3B. The integrity of **11 events** was verified and, also, recorded in the ledger of the blockchain providing availability for the future. 10 events were from the construction site and the hash of a folder of vehicle images were from Pilot 3B.
- Logging and auditing enabler: The enabler was tested from monitoring and notifying enabler and provided availability of the data that were recorded in the ledger for future reference.
- Distributed Broker enabler: The enabler was tested from monitoring and notifying enabler and provided availability of the data that were recorded in the ledger for future reference.
- FL-DLT enabler: The enabler records the reputation scores of local operations in the FL system. When the score of a participant is below a threshold, the reputation set includes only the participants that their reputation scores are above the threshold. This provides accountability of the participants. In the tests **one participant** was below the threshold and was **excluded** from the reputation set.

3.2.2.28. KPI 4.8.3 – Availability of FL ML local models' collection

Table 42. Summary of KPI 4.8.3

Name	**Identification of unreliable local operators**				
Description	This KPI identifies the reliability of the local operators who participate in the training. To define the reliability of the local operators we calculate reputation scores for each of them. To measure this KPI, we compare these reputation scores with proper statistical metrics corresponding to the reputation scores of all the local operators.				
Motivation	The identification of unreliable local operators in FL systems is essential for preserving fairness, integrity, and privacy, while also ensuring the effectiveness of collaborative learning processes.				
Initial target	1	**Score***	1	**Achieved**	Yes
Rationale target selection	We consider that we comply with this KPI when the number of unreliable local operators that we identify is 1.				
Measurement period	5/11/23 – 20/12/23				
Partner/s responsible	CERTH				

Measurement methodology

The FL-DLT enabler calculates the reputation scores of all the local operators that contribute to the federated learning system. A threshold for the scores is provided, if one or more local operators are below this threshold they are excluded from the reputation set, but the scores are still recorded in the blockchain's ledger. To measure this KPI, the participants, which are excluded from the reputation set, are counted.

Results and outlook

FL-DLT enabler was tested and one participant was below the threshold. The test included two participants (local operators), the weights of the local operators and the aggregated model were received from FL-DLT enabler, as well as an a json file about general information (such as training id, round, etc.). The FL-DLT enabler calculated the reputation scores of the local operators and the scores were recorded in the ledger. The reputation set was also recorded in the ledger. That one participant with score lower than the threshold, was excluded from the reputation set.

3.2.2.29. KPI 4.8.4 – Decrease in training dataset biases

After performing an extensive stat of the art, the responsible partner (CERTH) decided that to build the reputation mechanism in order to prevent attacks such as targeted poisoning, untargeted poisoning and free riders, an approach in which the reputation mechanism does not directly target to detect biases in training datasets. For this reason, this KPI is no longer valid.

3.2.2.30. KPI 4.8.5 – Number of use cases successfully tested with the DLT registry enabler

Table 43. Summary of KPI 4.8.5

Name	**Number of use cases successfully tested with the DLT distributed broker enabler**				
Description	This KPI is about the use cases that will contain interaction with the distributed broker enabler.				
Motivation	Incorporating KPIs related to the number of use cases successfully tested with the distributed broker enabler underscores the importance of validating its functionality, interoperability, and readiness for deployment across diverse IoT scenarios.				
Initial target	1	**Score***	1	**Achieved**	Yes
Rationale target selection	We consider that we comply with this KPI when the number of the use cases in which the distributed broker enabler was successfully tested, is 1.				
Measurement period	5/11/23 – 20/12/23				
Partner/s responsible	CERTH				

Measurement methodology

To measure this KPI, the number of use cases that the DLT registry enabler (also known as Distributed broker enabler) is used should be at least one.

Results and outlook

The DLT Distributed Broker Enabler was employed in conjunction with the Monitoring and Notifying Enabler to track the status of devices and gateways. The Monitoring and Notifying Enabler is tasked with monitoring the status of devices and gateways listed in its registry. Whenever an endpoint becomes unreachable, a request is sent to the distributed broker to log pertinent information, including the device ID and the timestamp of unreachability. End users are then able to query the distributed broker to identify any malfunctions in devices or gateways, enabling them to initiate necessary repairs or replacements.

3.2.2.31. KPI 4.8.6 – Number of use cases successfully tested with the DLT integrity verification enabler

Table 44. Summary of KPI 4.8.6

Name	**Number of use cases successfully tested with the DLT integrity verification enabler**
Description	This KPI is about the use cases that will contain interaction with the integrity verification enabler.

Motivation	Incorporating KPIs related to the number of use cases successfully tested with the integrity verification enabler underscores the importance of validating its functionality, interoperability, and readiness for deployment across diverse IoT scenarios.				
Initial target	1	**Score***	2	**Achieved**	Yes
Rationale target selection	We consider that we comply with this KPI when the number of the use cases in which the integrity verification enabler was successfully tested, is 1.				
Measurement period	5/11/23 – 20/12/23				
Partner/s responsible	CERTH				

Measurement methodology

To measure this KPI, the number of use cases that the integrity verification enabler is used should be at least one.

Results and outlook

The integrity verification enabler was used in Pilot 2 and Pilot 3B:

- Integrity verification enabler underwent testing across various sections of the construction site, involving 10 participants. The assessment focused on the functionality of the worker alarm button, where activating the button on the location tag prompted a notification indicating the worker’s urgent need for assistance, along with their premise location. A detailed popup provided information in the details, revealing aspects such as the DLT verification status. Each notification (critical event) generated during the testing phase was recorded and validated through the DLT verification mechanism.
- Integrity verification was also tested in Pilot 3B were a folder hash was recorded in the ledger. Upon receiving a new scan of a vehicle, the images were hashed and were put in an array. Then this array was also hashed creating the hash of the entire folder. The hash of the folder was then pushed in the integrity verification enabler, where it was recorded in the ledger. Later on, to verify the integrity of the folder the same process underwent again and the two hashes (the hash of the folder that was being verified and the hash that it was in the ledger) were compared and they matched so the folder was intact.

3.2.2.32. KPI 4.9.1 – Enablers deployed through interface

Table 45. Summary of KPI 4.9.1

Name	**Enablers deployed through interface**				
Description	One of the enablers to be delivered by the manageability task is the capacity to order the instantiation of an enabler in the IoT ecosystem managed by the solution. While the actual deployment is managed by the Smart orchestrator (from T4.2), the selection of the enabler, the indication of additional parameters, and other information, including “executing” the deployment order, will be done through the user interface controlled by the manageability enabler. This KPI aims at validating the functioning in real (pilot) conditions of this enabler, that will be installed in the four pilots of the project and that will let managers, app developers and stakeholders to deploy software over the equipment that is included in ASSIST-IoT network.				
Motivation	A user-friendly dashboard is needed to bridge the gap among enablers, orchestrator and infrastructure, being the aiming of this KPI to validate the developed manageability interface.				
Initial target	60	**Score***	61 (84 total)	**Achieved**	Yes

Rationale target selection	Challenging number to ensure that pilots deploy a significant number of the enablers implemented in the technical work packages.
Measurement period	Last month of the project (M41), gathering overall figures.
Partner/s responsible	UPV

Measurement methodology

0. Smart orchestrator installed in the top-level cluster of all pilots, with all the clusters registered on it. Involved enablers correctly tested and packaged.
1. The pilot will be executed normally, deploying and integrating the enablers following their respective schedules.
2. Once the pilot activities are coming to their conclusion, a capture of the interface with the enablers list (see next figure) will be taken. It will be included as part of a report that will be shared with the pilot owners.
    a. This step has been modified by a manually-produced list, extracted from Pilots' feedback. The reason is that some enablers (e.g., IdM, Authz, PUD, Smart orchestrator…) and encapsulation exceptions (e.g., MR enabler, cybersecurity monitoring agent) are deployed either jointly with the Smart orchestrator (the former), or are not deployed with it (the latter), therefore the list would not have been complete.
3. The score of the KPI will be the sum of all the successfully deployed enablers using the manageability interface through the monitored pilots. The total unique enablers considered, even those not deployed with the tactile dashboard, are also presented.

Results and outlook

A total of 84 (unique) enablers have been instantiated in Pilots, among which 61 have been deployed via the manageability enablers and are active part of it. It should be mentioned that some of the enablers not listed (or listed but not part of the use cases of some of the pilots) were also deployed on them via the orchestrator, so the list could be increased with tested (but not adopted) ones.

Table 46. Enablers deployed

Enabler	Pilot	Via interface	Unique enablers (instances deployed via interface)
Scan trigger enabler	3B	Yes	1 (2 – 1 instance per cluster)
Smart orchestrator	1, 2, 3A, 3B	No – can deploy itself	4 (0)
Smart orch. Agent	3A	No	1 (0)
Multi-link	1 (lab)	Yes	1 (1)
VPN enabler	3A	Yes	1 (1)
Semantic repository	2, 3A	Yes	1 (1)
Semantic annotation	2	Yes	1 (1)
Semantic translation	2	Yes	1 (1)
Fault-tolerance enabler	3A, 3B	Yes	2 (3 – 1 instance per cluster)
DITE enabler	3B	Yes	1 (3 – 1 instance per cluster)
EDBE	1, 2, 3A, 3B	Yes	4 (6 – some bridged in P3A)
LTSE	1, 2, 3A, 3B	Yes	4 (4)

Tactile dashboard	1, 2, 3A, 3B	No – It hosts the manageability enablers	4 (0)
BKPI	1, 2, 3A, 3B	Yes	4 (4)
Open API enabler	1, 2, 3A, 3B	Yes	4 (4)
PUD enabler	1, 2, 3A, 3B	Partially – it is installed jointly with the smart, but two pilots deployed it independently also	4 (2)
Video augmentation enabler	1, 3A	Yes	2 (2)
MR enabler	2, 3A	No – Encapsulation exception	2 (0)
Resource provisioning	3A, 3B	Yes	2 (4 – 1 instance per cluster)
Location processing	2	Yes	1 (1)
Location tracking	2	No – Encapsulation exception	1 (0)
FL Local operations	2, 3B	Yes	2 (4 – 1 instance per cluster)
FL Orchestrator	3B	Yes	1 (1)
FL Repository	3B	Yes	1 (1)
FL Training Collector	3B	Yes	1 (1)
IdM	1, 2, 3A, 3B	No – Login system should be present before the interface can be used. Instances could be deployed with it for other UCs	4 (0)
Authorization enabler	1, 2, 3A, 3B		4 (0)
Cybersecurity monitoring	1, 3A, 3B	Yes	3 (3)
Cybersecurity monitoring agent	1, 3A, 3B	No – Encapsulation exception	3 (0) – In 3 clusters (1 instance per node)
DLT integrity verification	2, 3B	Yes	2 (2)
DLT-FL	2	Yes	1 (1)
Enablers manager	1, 2, 3A, 3B	No – Itself, not possible	4 (0)
Cluster and topology manager	1, 2, 3A, 3B	No – Installed with the tactile dashboard	4 (0)
ISE enabler	3A	Yes	1 (1)
Active monitoring	3A	Yes	1 (1)
VSFTP	3A	Yes	1 (1)
Construction site controller	2	Yes	1 (1)
Workplace safety controller	2	Yes	1 (1)
BIM processor	2	Yes	1 (1)
Image processor	2	Yes	1 (1)

UV tracking	2	Yes	1 (1)
Total	-	-	84 (61)

The large list showcases the success of the implemented enablers, as well as the utility of the dashboard to deploy them in a user-friendly way. Of course, some of the "pre-installed" enablers (manageability ones, PUD, IdM, Authz, Tactile Dashboard) could be deployed separately with the Smart orchestrator, for other potential use cases, but here the ones used for managing the platform are also used for serving the use cases.

3.2.2.33. KPI 4.9.2 – Service topologies and enablers

Table 47. Summary of KPI 4.9.2

Name	**Service topologies and enablers**				
Description	This KPI measures the number of topologies instantiated in the project. The enablers manager will allow a user (via the manageability user interfaces) to configure, select, obtain information and, most importantly, connect among and interact with enablers that are deployed at specific parts of a deployment's topology. It will need to interact with the APIs of all enablers, and will need to be aware of the network and K8s clusters topology.				
Motivation	It will showcase the number of business scenarios addressed by leveraging the ASSIST-IoT smart orchestrator along with the tactile dashboard and the specific enablers needed to implement them.				
Initial target	4	**Score***	4	**Achieved**	Yes
Rationale target selection	The number of topologies will be, initially, equal to the number of pilots.				
Measurement period	Last month of the project (M41), gathering overall figures.				
Partner/s responsible	UPV				

Measurement methodology

There is no need of a specific procedure for evaluating this KPI, as it will be fulfilled naturally if the ASSIST-IoT Smart orchestrator and manageability tools are used. Once the pilots are finalized, the topological information will be extracted directly from the tactile dashboard deployed on each pilot.

Results and outlook

The final topologies of the pilots are represented how, having the four target topologies expected for this KPI. As ~15 enablers are expected to be deployed per pilot, it is expected that their information can be easily shown in each topology representation, hence fulfilling the expectations of this KPI.

For different topologies have been considered for the pilots:

- In Pilot 1, an Edge – IoT topology was considered (not cloud), considering as access networks fluidmesh, PROFIBUS, WiFi & UWB communications, as next-gen short-range ultra-low latency communications.
- In Pilot 2, a Cloud-Edge-IoT topology was deployed, considering different access technologies for IoT, (5G, WiFi & UWB),
- In Pilot 3A, private cloud (self-hosted) + public networks for supporting IoT devices - vehicles (considering local Ethernet and CAN bus networks for IoT devices),
- Finally, in Pilot 3B, a private cloud and 3 delocalized edge networks (from different stakeholders) over VPN.

Apart from those, some Open Callers (like POSEIDON or PROUD-5G) have also considered the ASSIST-IoT orchestration system to manage their deployments, although not considered for this KPI as any follow-up has been made. An example for P3B topology, extracted from the dashboard, can be seen in the following figure:

Figure 29. Pilot 3B topology

3.2.2.34. KPI 4.9.3 – Configuration parameters

Table 48. Summary of KPI 4.9.3

Name	**Configuration parameters**				
Description	One of the goals of the manageability task in ASSIST-IoT is to allow enabler owners to configure parameters related to those enablers so that changes can be applied either on-the-fly or during the deployment of those enablers. The manageability interface has some reserved spaces in the menu to include entries for specific enablers where specific parameters can be configured (via web). This KPI measures the quantity of parameters that, at the end of the project, could be fine-tuned and/or configured through the manageability interface with effect on the deployment of associated enablers.				
Motivation	It is critical that adopters of the enablers can configure their respective parameters in a user-friendly manner to ease its further adoption.				
Initial target	50	**Score***	66	**Achieved**	Yes
Rationale target selection	Showcasing the tailoring possibilities of the packaging format utilized for the developed enablers, in realistic conditions.				
Measurement period	Last month of the project (M41), gathering overall figures.				
Partner/s responsible	UPV				

Measurement methodology

0. Smart orchestrator installed in the top-level cluster of all pilots, with all the clusters registered on it.
1. As part of a document with templates that will be shared among pilot owners, the following table will be completed, specifying the enablers deployed and the parameters configured (not the number of them, but its name/reference):

Table 49. Template of pilot's configured parameters

Enabler	Parameters modified (Helm values)
Total	

2. The score of the KPI will be the sum of all the successfully configured parameters through the monitored pilots. Only unique parameters will be counted, even if they are modified in different pilots; or between enablers (e.g., the possibility of changing their port is only listed as one).

Results and outlook

Do to some practice of the pilot administrator of modifying the Helm values.yaml manifest directly in advance to have it already customized for the development, those cases are also counted. The list presents the specific parameters of the above-mentioned enablers, but also a final one common to all enablers. It should be mentioned that, for some specific features (e.g., SSL certificates), many environment variables may apply. In those cases, a sentence expressing that some of them are tackling a specific feature are present, counted as one. Also, an exhaustive work presenting all possibilities would not add much value, as it is better to study them enabler per enabler, when going to be adopted – thus, a preliminary effort is presented.

Table 50. Environment variables identified

Enabler	Parameters modified (Helm values)
Scan trigger enabler	`METADATA_TOPIC, IMAGE_TOPIC, hostPath, Environment variables related to Fault-tolerance enabler`
Smart orchestrator	`N/A`
Smart orch. Agent	`Environment variables related to smart's agent`
Multi-link	`Environment variables related to the interfaces to be managed`
VPN enabler	`Environment variables related to the created subnet`
Semantic repository	`Environment variables related to underlying storage systems (minio, noSQL)`
Semantic annotation	`MONGO_HOST, SEAMAN_MQTT_HOST`
Semantic translation	`IPSM_MQTT_SRC_HOST, IPSM_MQTT_TRG_HOST`
Fault-tolerance enabler	`Environment variables related to Kafka`
DITE enabler	`RsApiPort, rsApiHost, hostPath`
EDBE	`DOCKER_VERNEMQ_ALLOW_ANONYMOUS, Environment variables related to SSL`
LTSE	`DiscoveryType, PgrstDBSchema`
Tactile dashboard	`POSTGRES_USER, POSTGRES_DB, POSTGRES_PASSWORD, KIBANA_URL, PROMETHEUS_URL`
BKPI	`elasticsearchHost`
Open API enabler	`Konga and IdM related environment variables`
PUD enabler	`prometheusesadapter`
Video augmentation enabler	`Environment variables related to the video client to be connected`
MR enabler	`No – Encapsulation exception`

Resource provisioning	`N/A`
Location processing	`No`
Location tracking	`N/A`
FL Local operations	`DATA_FORMAT_FILE, DATA_PIPELINE_FILE, Environment variables related to other FL services`
FL Orchestrator	`Environment variables related to other FL services`
FL Repository	`Environment variables related to other FL services`
FL Training Collector	`Environment variables related to other FL services`
IdM	`Database related environment variables`
Authorization enabler	`mqtt_topic`
Cybersecurity monitoring	`Environment variables related to GUI`
Cybersecurity monitoring agent	`N/A`
DLT integrity verification	`No`
DLT-FL	`No`
Enablers manager	`RepoDir, cacheDir`
Cluster and topology manager	`config`
ISE enabler	`Environment variables related to VSFTP and EDBE, mqttTopic, firmware_local_path, sw_ver`
Active monitoring	`Environment variables related to VSFTP`
VSFTP	`Environment variables related to FTP and SSL`
Construction site controller	`No`
Workplace safety controller	`No`
BIM processor	`No`
Image processor	`No`
UV tracking	`No`
Applicable to all	`tier, globalService, replicaCount, imagePullSecrets, repository, port, targetPort, NodePort, cpu (request), ram (request) MinReplicas, maxReplicas, nodeSelector, tolerations, affinity, persistence`
Total	> **66**

3.3. Evaluation of pilot results

3.3.1. Selected KPIs

3.3.2. Data collection and measurement

3.3.2.1. KPI 2.1.1 – Trucks turnaround time

Table 51. Summary of KPI 2.1.1

Name	**Trucks turnaround time**				
Description	This KPI evaluates the reduction on truck turnaround time in the terminal (i.e., the time elapsed for carrying out the whole cycle of a work instruction).				
Motivation	A container terminal business is to move as much containers as possible. If the truck turnaround time is reduced thanks to ASSIST-IoT digitalization services, the terminal can increase the number of movements per day, and consequently, their incomes.				
Initial target	5% reduction	**Score***	8.38% reduction	**Achieved**	Yes
Rationale target selection	This KPI is included in the project since the Grant Agreement. The 5% reduction was considered as a significant improvement from container terminal manager.				
Measurement period	A baseline was analysed for year 2022. After that, time elapsed for work instruction along the last 4 months of the project was averaged and compared to the baseline.				
Partner/s responsible	TL				

Measurement methodology

- First, the average elapsed time to perform the assigned working instructions to different Terminal Tractors during the 7th and 8th February 2024 was obtained from LTSE. This time is obtained by getting the difference of the working instruction cycle from the MVHS_T_CARRY_DISPATCH stage up to the MVHS_T_CARRY_COMPLETE timestamps.
- Next, the average elapsed time to perform the assigned working instructions for the terminal tractors TUG300 on the 7th of February and TUG341 on the 8th February (who were using the mobile app during the trials) was monitored. The same fields / timestamps like described above were collected from the LTSE.
- If the average cycle time, i.e., truck turnaround time of TUG300/TUG341 was lower than 5% of the rest, the KPI was considered fulfilled.

Results and outlook

Table 52. Truck Turnaround Time of different TUGs during 7th and 8th February

TUG	Average truck turnaround time on 7th February	Average truck turnaround time on 8th February	Average both days
TUG200	21,323	29,642	26,48
TUG243	23,415	22,606	23,01
TUG315	25,631	19,9	22,77
TUG360	24,323	21,102	22,71
		Average total TUGs	**23,74**

As it can be observed in the table below, both TTs performed their work instructions at least an 8% lower in time than the other TTs monitored, thanks to the digital solutions of ASSIST-IoT.

Table 53. Truck Turnaround time of TUG300 on 7th and TUG341 on 8th February 2024.

TUG	Average truck turnaround time on 7th February	Average truck turnaround time on 8th February	Improvement vs baseline (%)
300	21,79	-	**8,21%**
341	-	21,71	**8,55%**

3.3.2.2. KPI 2.1.2 – CHE fleet dispatching

Table 54. Summary of KPI 2.1.2

Name	**CHE fleet dispatching**				
Description	This KPI evaluates, thanks to the use of remote operating systems, the dispatching capability increase of a container terminal.				
Motivation	The evaluation of this KPI can illustrate how well the terminal is now utilizing the operators´ working hours.				
Initial target	30% increase	**Score***	31.2%	**Achieved**	Yes
Rationale target selection	Different references estimate that cranes drivers' operational hours are about 50%. Like in previous KPI, the lower the non-operational time of operators, the higher the number of movements they can perform per day, and consequently, their incomes.				
Measurement period	The initial working time during three days for both regular and remote cranes was collected in the LTSE.				
Partner/s responsible	KONE				

Measurement methodology

The approach for the evaluation was to consider that while the remote operators can start to work immediately after arriving to the port in their shift, regular operators have to be physically transported to their RTG crane located in the yard. Hence, this elapsed time is reducing the dispatching time of the operators. According to the Malta Freeport Terminal rules, every operator shall start dispatching working instructions no longer than 8.15 in the first shift.

To evaluate the described above metric, the timestamp in which the cranes were connected and started to work during the first 15mins of the morning shift (i.e., between 08.00 – 08.15) was obtained from the LTSE (che|@|on|status|ioutput|actual|value = true && che|@|working|status|ioutput|actual|value = true) fields. Then, a comparison between the starting timestamp from remote cranes (RTG01 and RTG02) was compared to the starting working timestamp of the rest regular RTG cranes.

If the remote cranes started in average 30% earlier than regular cranes (with respect to the 15mins acceptance), the KPI was considered fulfilled.

Results and outlook

Table 55. CHE fleet dispatching

Dates	Average RTGs No Remote	Average RTG01/RTG02	Difference RTGs – RTG01
2024-03-22	08:04:55.476	08:05:45.905	+50,429s
2024-03-25	08:02:47.005	08:00:00.468	-2,78m
2024-03-28	08:03:12.812	08:00:28.346	-2,74m

From the table aboce, considering a permitted 15 mins delay, the remote operators started working in average = (+0.50, -2.78, -2.74) = 4.68 mins. Comparing that reduction with respect to the 15 mins, the possibility of working remotely would allow to start dispatching 31.2% earlier than with current physical crane manoeuvres. Hence, this KPI was also achieved with the tests carried out in Malta Freeport.

3.3.2.3. KPI 2.1.3 – Yard equipment workforce

Table 56. Summary of KPI 2.1.3

Name	**Yard equipment workforce**				
Description	This KPI is very related with previous KPI 2.1.2. Whereas the former refers to the dispatching dynamics at the beginning of the crane operators' shift, this refers to the increased dynamicity that can be handled thanks to the use of remote cranes.				
Motivation	The evaluation of this KPI can illustrate how well the terminal is now utilizing the operators´ working hours.				
Initial target	20% increase	**Score***	29.45%	**Achieved**	Yes
Rationale target selection	Different references estimate that cranes drivers' operational hours are about 50%. Like in previous KPI, the lower the non-operational time of operators, the higher the number of movements they can perform per day.				
Measurement period	The number of RTG cranes ON and Working for 4 days (12 shifts) was analysed.				
Partner/s responsible	KONE				

Measurement methodology

The approach to evaluate this KPI was more theoretical. It was assumed that if all cranes were remotely managed, the idle times will be almost zero, thanks to the ability of switching from one RTG to another in seconds. Hence, those idle times of RTG operators will be almost eliminated.

To carry out with the evaluation, the number of cranes that were connected for 4 different days (i.e., 12 different shifts) were accounted by extracting number of che|@|on|status|ioutput|actual|value = true value from LTSE. From those connected cranes, a second filter that provided only those cranes that were connected, but also actually working (i.e., gantry or hoist or trolley movement was active at least 1 second during 1 min period) represented as che|@|working|status|ioutput|actual|value = true was triggered. If the number of simultaneously not-working RTG cranes was 20% lower than the actually connected ones, it was assumed that the workforce of the yard can be increased if all cranes were remotely retrofitted.

Results and outlook

As it can be seen in the table below, it was estimated that approximately the workforce can be increased almost 30%. Hence, it was considered that this KPI might be fulfilled if all the Malta Freeport Terminal RTG cranes were remotely retrofitted.

Table 57. Yard equipment workforce

Days	RTGs ON	Maximum RTGs working simultaneously (in a minute)	Difference ON - Working	Potential workflows increase (%)
20th March 2024 Shift 1 (0-8)	25	18	7	28
20th March 2024 Shift 1 (8-16)	25	16	9	36

20th March 2024 Shift 1 (16-24)	22	15	7	31.8
21st March 2024 Shift 1 (0-8)	25	17	8	32
21st March 2024 Shift 1 (8-16)	30	20	10	33.33
21st March 2024 Shift 1 (16-24)	27	20	7	25.93
22nd March 2024 Shift 1 (0-8)	27	21	6	22.22
22nd March 2024 Shift 1 (8-16)	22	17	5	22.72
22nd March 2024 Shift 1 (16-24)	23	17	6	26.08
23rd March 2024 Shift 1 (0-8)	22	16	6	27.27
23rd March 2024 Shift 1 (8-16)	23	15	8	34.78
23rd March 2024 – Shift 1 (16-24)	18	12	6	33.33
			Average	**29.45**

3.3.2.4. KPI 2.1.4 – Yard accidents

Table 58. Summary of KPI 2.1.4

Name	**Yard accidents**				
Description	This KPI evaluates the decreased number of accidents in Malta Freeport container terminal due to less persons moving around quay and yard thanks to ASSIST-IoT automation services.				
Motivation	This KPI aims at proving the enhanced safety guarantees to terminal staff thanks to ASSIST-IoT automation services.				
Initial target	80% reduction baseline	**Score***	100%	**Achieved**	Yes
Rationale target selection	Why the target number was selected. Try not to exceed 4-5 lines of text, unless needed.				
Measurement period	The number of accidents at the terminal (either mild or serious) are recorded from October '23, given that the deployment of ASSIST-IoT services in Malta Freeport was concluded in September '23 (i.e., measurement period for this KPI lasts for last 5 months of the project).				
Partner/s responsible	TL				

Measurement methodology

On the one hand, the average value of yard accidents in 2021 for the Malta Freeport container terminal was collected from internal reports: 61. This in average led to 5.08 accidents/collisions per month.

Then, for the period February ’24 and March ’24, in which the RTG cranes were fully working, the same information that can be associated with those two cranes was retrieved from internal reports.

If the average number of accidents during the monitored period is reduced to an 80% with respect to the baseline value, the KPI was considered fulfilled.

Results and outlook

Table 59. Yard accidents

Month monitored	Total	Unit	Difference vs 5.08 (%)
February ‘24	0	Accidents	100%
March ‘24	0	Accidents	100%
		Average	100%

Consequently, given there was not any accident nor collision, it was considered that this KPI was fulfilled.

3.3.2.5. KPI 2.1.5 – Remote wireless bandwidth

Table 60. Summary of KPI 2.1.5

Name	**Remote wireless bandwidth**				
Description	This KPI evaluates the transmission bandwidth of Malta Freeport terminal wireless access.				
Motivation	The use of high bandwidth systems will help remote crane operators to properly visualize the video streams captured by the cameras, and, consequently, helping the remote operating conditions.				
Initial target	> 60 Mbps	**Score***	21 Mbps (max)	**Achieved**	No
Rationale target selection	This value was obtained from previous remote operating cranes conditions by Konecranes in other container terminals.				
Measurement period	4 times from the two remote RTG cranes were ready for operation				
Partner/s responsible	TL				

Measurement methodology

To evaluate this KPI, Fluidmesh network proprietary monitoring tool provided by Cisco is used. The bandwidth measurement was acquired for the two Fluidmesh access points installed at RTG01 and RTG02 remote cranes during different days with different weather conditions (sunny, cloudy, rainy, daylight, day night). If the uplink bandwidth in average was higher than 60 Mbps, this KPI will be fulfilled.

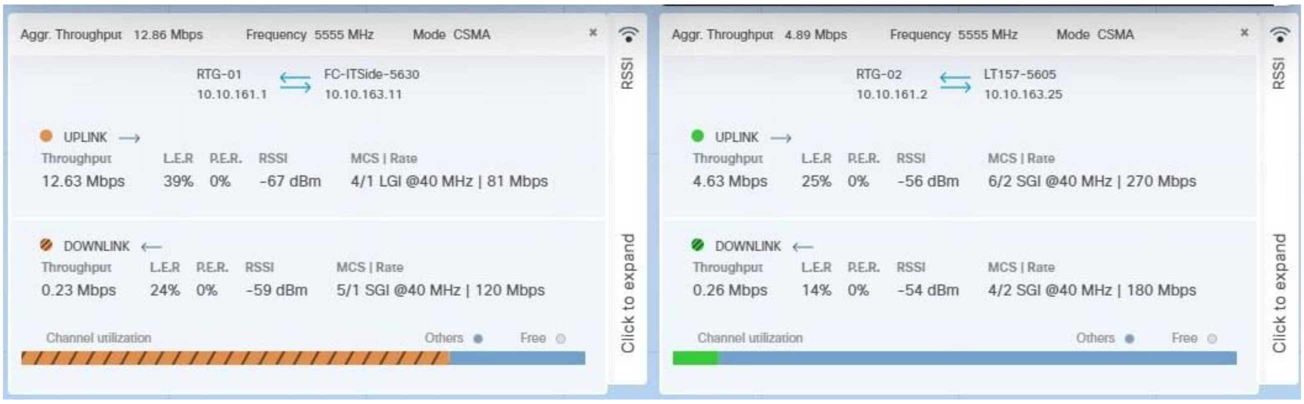
Results and outlook

An example of the throughput metrics provided by the Cisco network monitoring tool is shown in Figure 30. As it can be observed in the it, as well as in the d table below, the 60 Mbps requirement was never achieved. Consequently, this KPI was not fulfilled. However, it should be noted that the remote cranes were completely operative without any network failure. Therefore, the port partners consider that the initial requirement of 60 Mbps established by Konecranes experts was proposed for the worst-case conditions.

Table 61. Wireless performance

Times measured	RTG01 uplink	RTG02 uplink	> 60 Gbps
8th March 2024	12.63 Mbps	4.63 Mbps	No
11th March 2024	11.89 Mbps	3.89 Mbps	No

15th March 2024	21.72 Mbps	2.69 Mbps	No
20th March 2024	15.04 Mbps	5.45 Mbps	No



Aggr. Throughput 12.86 Mbps Frequency 5555 MHz Mode CSMA

RTG-01 10.10.161.1 ⇆ FC-ITSide-5630 10.10.163.11

UPLINK →

Throughput	L.E.R	P.E.R.	RSSI	MCS | Rate
12.63 Mbps	39%	0%	-67 dBm	4/1 LGI @40 MHz | 81 Mbps

DOWNLINK ←

Throughput	L.E.R	P.E.R.	RSSI	MCS | Rate
0.23 Mbps	24%	0%	-59 dBm	5/1 SGI @40 MHz | 120 Mbps

Aggr. Throughput 4.89 Mbps Frequency 5555 MHz Mode CSMA

RTG-02 10.10.161.2 ⇆ LT157-5605 10.10.163.25

UPLINK →

Throughput	L.E.R	P.E.R.	RSSI	MCS | Rate
4.63 Mbps	25%	0%	-56 dBm	6/2 SGI @40 MHz | 270 Mbps

DOWNLINK ←

Throughput	L.E.R	P.E.R.	RSSI	MCS | Rate
0.26 Mbps	14%	0%	-54 dBm	4/2 SGI @40 MHz | 180 Mbps

Figure 30. RTG01 (left) and RTG02 (right) network bandwidth.

3.3.2.6. KPI 2.1.6 – Remote wireless latency

Table 62. Summary of KPI 2.1.6

Name	**Remote wireless latency**				
Description	This KPI evaluates the application latency from the source (camera) to the destination (screen) in the remote operating cranes system.				
Motivation	The remote operation use of the RTG cranes to be deployed requires of ultra-low latencies to support the tactile internet capabilities needed to provide a successful user experience for those crane drivers that are remotely managing the crane.				
Initial target	< 20 ms	**Score***	< 28 ms	**Achieved**	Yes
Rationale target selection	This value was obtained from previous remote operating cranes conditions by Konecranes in other container terminals.				
Measurement period	4 times from the two remote RTG cranes were ready for operation				
Partner/s responsible	TL				

Measurement methodology

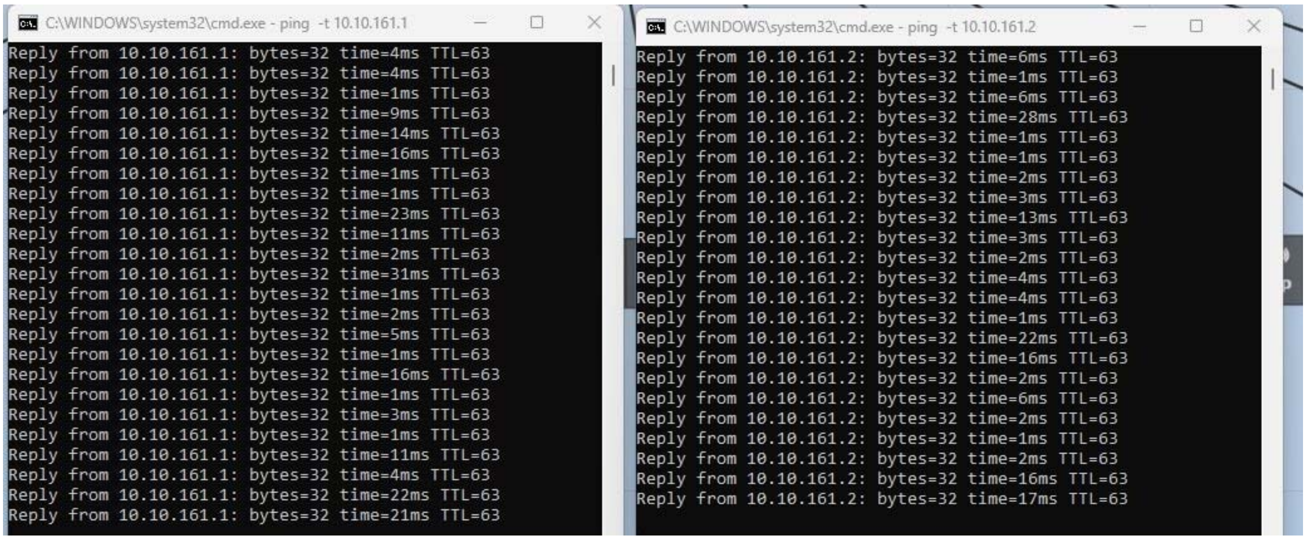
For testing the latency of the remote operating system of RTG crane the basic OS-native **ping** mechanism was used. **ping** is the simplest mechanism that measures the Round-Trip Time between a client and a specified target server. It has been used in the following way:

- A console or terminal window is opened, and just by typing ping domain, it provides the RTT latency of 4 IP packets to the specified IP address destination.

Like the previous KPI, the latency measurement was conducted for 4 different times with different weather conditions (sunny, cloudy, rainy, daylight, daynight).

Results and outlook

An example of the latency metrics provided by the ping command is shown below. As it can be observed in the it, as well as in the different values reported in Table 63, the <30 ms requirement was generally achieved by RTG02, but some high values are recorded for RTG01. Consequently, this KPI was considered fulfilled, given that the remote cranes were completely operative without any network failure.



```
Reply from 10.10.161.1: bytes=32 time=4ms TTL=63
Reply from 10.10.161.1: bytes=32 time=4ms TTL=63
Reply from 10.10.161.1: bytes=32 time=1ms TTL=63
Reply from 10.10.161.1: bytes=32 time=9ms TTL=63
Reply from 10.10.161.1: bytes=32 time=14ms TTL=63
Reply from 10.10.161.1: bytes=32 time=16ms TTL=63
Reply from 10.10.161.1: bytes=32 time=1ms TTL=63
Reply from 10.10.161.1: bytes=32 time=1ms TTL=63
Reply from 10.10.161.1: bytes=32 time=23ms TTL=63
Reply from 10.10.161.1: bytes=32 time=11ms TTL=63
Reply from 10.10.161.1: bytes=32 time=2ms TTL=63
Reply from 10.10.161.1: bytes=32 time=31ms TTL=63
Reply from 10.10.161.1: bytes=32 time=1ms TTL=63
Reply from 10.10.161.1: bytes=32 time=2ms TTL=63
Reply from 10.10.161.1: bytes=32 time=5ms TTL=63
Reply from 10.10.161.1: bytes=32 time=1ms TTL=63
Reply from 10.10.161.1: bytes=32 time=16ms TTL=63
Reply from 10.10.161.1: bytes=32 time=1ms TTL=63
Reply from 10.10.161.1: bytes=32 time=3ms TTL=63
Reply from 10.10.161.1: bytes=32 time=1ms TTL=63
Reply from 10.10.161.1: bytes=32 time=11ms TTL=63
Reply from 10.10.161.1: bytes=32 time=4ms TTL=63
Reply from 10.10.161.1: bytes=32 time=22ms TTL=63
Reply from 10.10.161.1: bytes=32 time=21ms TTL=63
```

```
Reply from 10.10.161.2: bytes=32 time=6ms TTL=63
Reply from 10.10.161.2: bytes=32 time=1ms TTL=63
Reply from 10.10.161.2: bytes=32 time=6ms TTL=63
Reply from 10.10.161.2: bytes=32 time=28ms TTL=63
Reply from 10.10.161.2: bytes=32 time=1ms TTL=63
Reply from 10.10.161.2: bytes=32 time=1ms TTL=63
Reply from 10.10.161.2: bytes=32 time=2ms TTL=63
Reply from 10.10.161.2: bytes=32 time=3ms TTL=63
Reply from 10.10.161.2: bytes=32 time=13ms TTL=63
Reply from 10.10.161.2: bytes=32 time=3ms TTL=63
Reply from 10.10.161.2: bytes=32 time=2ms TTL=63
Reply from 10.10.161.2: bytes=32 time=4ms TTL=63
Reply from 10.10.161.2: bytes=32 time=4ms TTL=63
Reply from 10.10.161.2: bytes=32 time=1ms TTL=63
Reply from 10.10.161.2: bytes=32 time=22ms TTL=63
Reply from 10.10.161.2: bytes=32 time=16ms TTL=63
Reply from 10.10.161.2: bytes=32 time=2ms TTL=63
Reply from 10.10.161.2: bytes=32 time=6ms TTL=63
Reply from 10.10.161.2: bytes=32 time=2ms TTL=63
Reply from 10.10.161.2: bytes=32 time=1ms TTL=63
Reply from 10.10.161.2: bytes=32 time=2ms TTL=63
Reply from 10.10.161.2: bytes=32 time=16ms TTL=63
Reply from 10.10.161.2: bytes=32 time=17ms TTL=63
```

Figure 31. RTG01 (left) and RTG02 (right) network latency.

Table 63. Remote wireless latency

Times measured	RTG01 Max. latency	RTG02 Max. latency	< 20 ms
8th March 2024	45 ms	28 ms	RTG01 no; RTG02 yes
11th March 2024	31 ms	28 ms	RTG01 yes; RTG02 yes
15th March 2024	256 ms	16 ms	RTG01 no; RTG02 yes
20th March 2024	101 ms	16 ms	RTG01 no; RTG02 yes

3.3.2.7. KPI 2.1.7 – Proximity range

Table 64. Summary of KPI 2.1.7

<table>
<tr><td>Name</td><td colspan="5">Proximity range</td></tr>
<tr><td>Description</td><td colspan="5">This KPI analyses up to how extent the short-range wireless UWB systems tags installed on the cranes and trucks can be properly communicated, given they are mutually authenticated.</td></tr>
<tr><td>Motivation</td><td colspan="5">The CHEs that performs the trials for the Trial #2 of Pilot 1 have to precisely perform the alignment process, but they should communicate within a limited area.</td></tr>
<tr><td>Initial target</td><td>10m</td><td>Score*</td><td>17.8</td><td>Achieved</td><td>Yes</td></tr>
<tr><td>Rationale target selection</td><td colspan="5">Why the target number was selected. Try not to exceed 4-5 lines of text, unless needed.</td></tr>
<tr><td>Measurement period</td><td colspan="5">Initial tests were performed in Prodevelop lab premises. Final tests were carried out during the execution of Trial #2 - Pilot 1 in Malta Freeport terminal.</td></tr>
<tr><td>Partner/s responsible</td><td colspan="5">PRO</td></tr>
</table>

Measurement methodology

In the lab period, the coverage range has been measured by performing a ToF test. To do so, the Arduino DW1000 library is run with the longest operation mode that the library supports (110 kbps, 16 MHz, 2048 preamble length), which according to the UWB-manufacturer specifications, allows for a receiver sensitivity around -100 dBm, which theoretically permits at the highest transmission power, a communication range of about 20-25 meters. Once the receiver sensitivity is below this value, it is considered that the communication is not feasible.

Results and outlook

As it can be observed in the below table, the different tests conducted during the project confirmed that the UWB communication is more than enough for the proximity range requirement of the trials of the project. Hence, this KPI was successfully achieved.

Table 65. Result of Proximity range

Location test	Achievable distance	> 10 m
Prodevelop Lab test 1 (indoors)	15.3 m	Yes
Prodevelop Lab test 2 (outdoors)	17.8 m	Yes
Malta Freeport outdoors test	16.5 m	Yes

3.3.2.1. KPI 2.1.8 – Redundant access networks

Table 66. Summary of KPI 2.1.8

Name	**Redundant access networks**				
Description	This KPI identifies the number of supported wireless access networks for the proper operation of remote cranes.				
Motivation	The remote operation use on RTG cranes requires very high reliability. Despite the theoretical reliability statistics of a single access network, due to the harsh conditions affecting to wireless networks in container terminals (e.g., containers walls blockages and the faraday cage effect of the RTG cranes), project partners considered that having a second/backup redundant wireless access will guarantee zero-error operation.				
Initial target	≥2	**Score***	2	**Achieved**	Yes
Rationale target selection	The main reasoning comes from having at least a second access network in case of network failures with the primary one, so that the remote operating crane continues working smoothly without interruptions.				
Measurement period	Initial tests were performed in UPV lab premises with the Multilink enabler. Final tests were carried out during the execution of Trial #3 - Pilot 1 in Malta Freeport terminal.				
Partner/s responsible	PRO				

Measurement methodology

To evaluate this KPI, the ASSIST-IoT multilink software to be used in the pilot should be capable of supporting at least two different redundant networks. For testing the reliability of the redundant access network over the remote operating cranes a more in-depth configuration of the GStreamer tool was used. It provides multiple metrics of video streaming parameters, such as Packets sent, packets lost, average jitter, or maximum jitter.

Six different tests of multilink enabler were carried out in UPV labs across. These tests are differentiated among them in the measurement QoE period of the enabler (i.e., how often the enabler monitors the QoE of the network access in order to evaluate if a network switch is needed).

From different literature references, it was considered that the deterioration of a video being streamed through RTSP protocol cannot be perceived by human beings unless the packets lost is higher than 0.5%, and/or the jitter is higher than 200 ms. Hence, some of the different scenarios evaluated provide packets lost lower than 0.5%, and jitter lower than 200 ms in average, the KPI is considered succeeded.

Results and outlook

As it can be observed in the below table, the different scenarios evaluated during the tests confirmed that the multilink enabler can guarantee the non-network failure as long as a second access network is available. However, it should be noticed that the monitoring interval should be always shorter than 500 ms for not experiencing video deterioration issues. Consequently, it was concluded that this KPI was successfully achieved.

Table 67. Result of Multilink testing

Multilink ARP interval	UDP Packet sent	UDP Packet lost	Max Jitter
50 ms	6752	0	16,9
100 ms	6317	0	46,77
200 ms	5655	0	42,96
500 ms	6785	0	95,44
1000 ms	5810	0	**201,54**
2000 ms	7607	**219 (2,8%)**	**413,65**

3.3.2.2. KPI 2.1.9 – New human-to-machine interfaces

Table 68. Summary of KPI 2.1.9

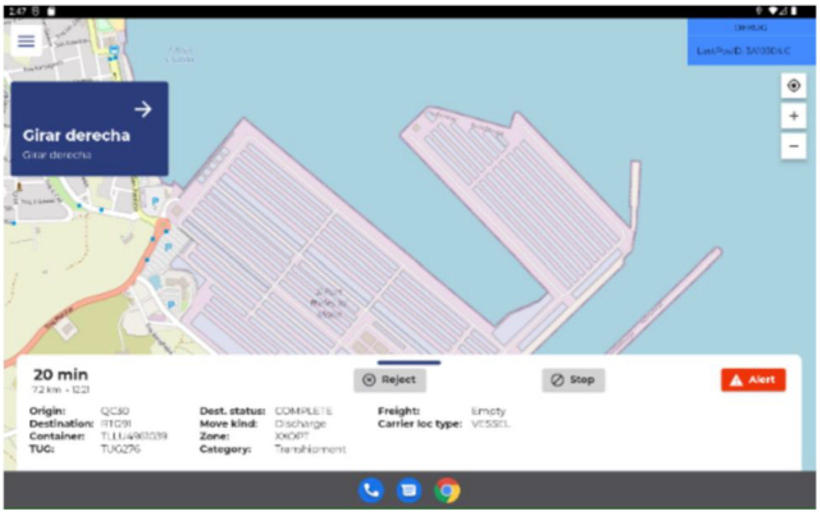
Name	**New human-to-machine interfaces**				
Description	This KPI aims at identifying at least 3 graphical interfaces for internal/external truck drivers about e.g., location of the crane over which trucks should cooperate, alignment graphical notifications, and/or container loading/unloading process complete.				
Motivation	The lack of additional contextual information for internal/external truck drivers leads to lower operational efficiencies.				
Initial target	≥3	**Score***	3	**Achieved**	Yes
Rationale target selection	The workflow stages of truck driver are mainly 3. Providing a graphical interface per stage was considered sufficient by pilot partners.				
Measurement period	After the execution of Pilot 1 – Trial#1 and Pilot 1 – Trial#2				
Partner/s responsible	PRO				

Measurement methodology

KPI partner responsible identifies the list of human-to-machine interfaces deployed and tested in Pilot 1 – Trial#1 and Pilot 1 – Trial#2.

Results and outlook

The following human-to-machine interfaces have been developed, deployed, and successfully tested in Pilot 1:



20 min
7.2 km · 12:21

Origin: QC30
Destination: RTG91
Container: TLLU4961039
TUG: TUG276
Dest. status: COMPLETE
Move kind: Discharge
Zone: XXOPT
Category: Transhipment
Freight: Empty
Carrier loc type: VESSEL

Figure 32. Map guiding interface

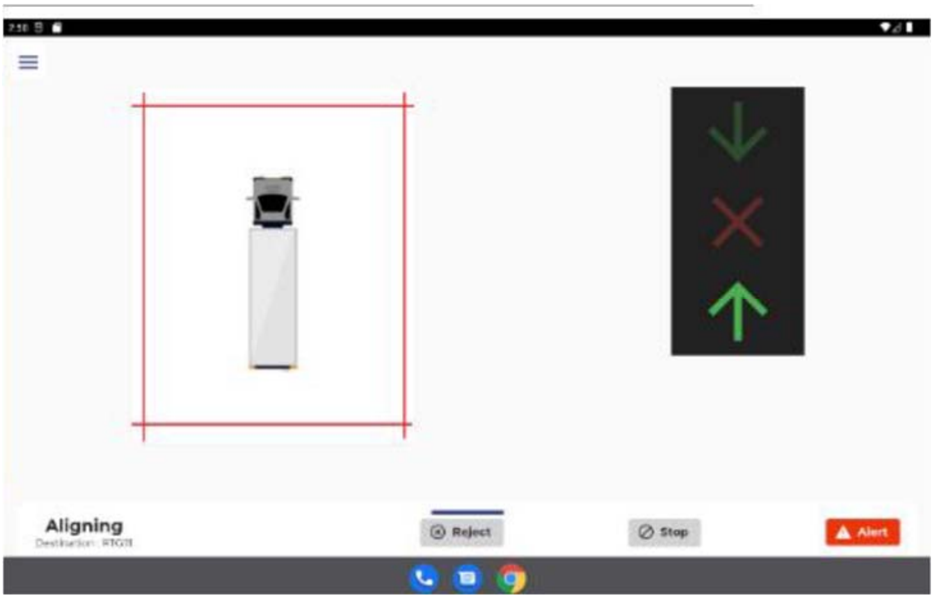


Figure 33. CHE Alignment interface

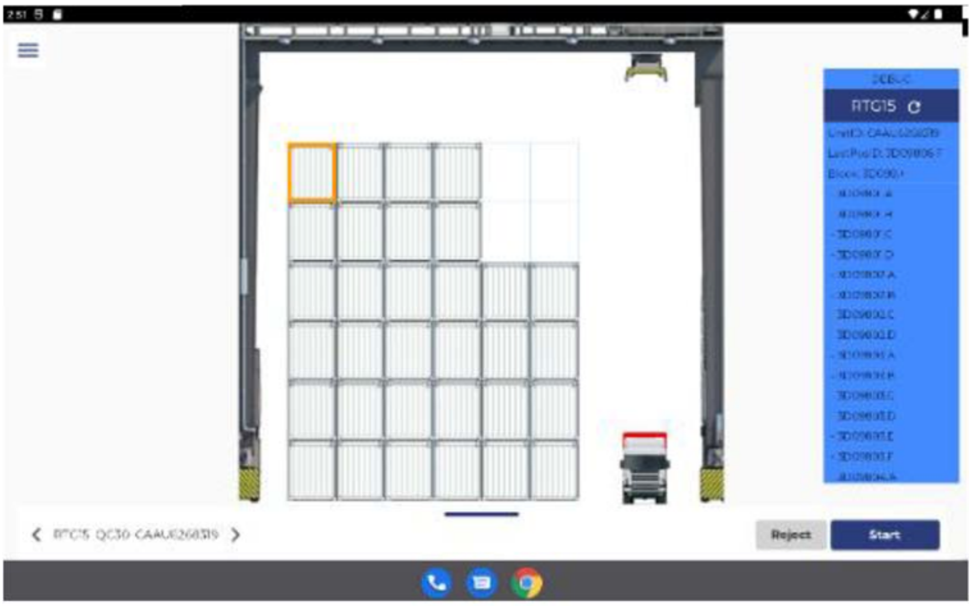


Figure 34. Container stack and crane’s spreader snapshot

3.3.2.3. KPI 2.2.1 – Safety notification false positive rate

Table 69. Summary of KPI 2.2.1

Name	**Safety notification false positive rate**				
Description	ASSIST-IoT provides two levels of notifications (alerts) to increase workers’ safety on the construction site. The first (lower) level will be provided directly to the worker. The second (higher) level will be provided to the OSH.				
Motivation	Informing both the worker and the OSH manager is important to be able to quickly respond to potentially dangerous situations that they might not be aware of without receiving appropriate notifications. Receiving notification in a short time can shorten the time needed to respond to a given event and thus take appropriate action earlier.				
Initial target	5%	**Score***	3.98%	**Achieved**	Yes

Rationale target selection	Due to the very high variety of potentially dangerous situations detected within ASSIST-IoT, achieving a false positive rate of less than 5% would already constitute an effective system
Measurement period	Main trials on the construction site – July 2023
Partner/s responsible	CIOP

Measurement methodology

The testing methodology of this KPI is closely related to the types of hazards detected (KPI 2.2.2). During validation phase simulations were performed for appropriate hazards as described in KPI 2.2.2. For each of the detected hazards, several repetitions were performed to verify the repeatability of the system. With each repetition, the system's response to the situation was recorded, including false positive notifications.

The detailed methodology can be found in deliverable D7.4 in the indicated validation activities.

Results and outlook

The percentage of false positive alerts was calculated as the ratio of false positive alerts to all repetitions performed during validation. This is not a "false positive rate" *per se*, which is usually calculated by dividing the number of false positives by the sum of false positives and true negatives. However, in this case, "true negatives" correspond to all situations in which a notification should not be generated (the entire time span of the system being turned on) and really was not generated. This number of situations is essentially infinite (or, at least, very large) and therefore the resulting false positive rate would be meaningless. Instead, here we choose a slightly different metric, one that gives an intuition about how frequently false positives occur in practice.

Table 70. Safety notification false positive rate

Times measured	**False positive**	**% False positive**
704	28	3.98%

3.3.2.4. KPI 2.2.2 – OSH hazards detected

Table 71. Summary of KPI 2.2.2

Name	**OSH hazards detected**				
Description	This KPI is about detection of potentially dangerous situations that may occur on the construction site. The following hazards are assumed to be detected: (1) heart disruptions, (2) overheating, (3) immobility, (4) fall from heights , (5) slips and falls on the ground, , (6) collision with machines, (7) entrance to a dangerous zone, (8) UV radiation, (9) lack of PPE, (10) unauthorised entrance, (11) too high air velocity in relation to crane work.				
Motivation	As a construction site is a multi-hazard work environment, it is important to detect potentially dangerous situation. Detecting these hazards will help improve workers' health and safety by preventing potential accidents and health issues.				
Initial target	10	**Score***	11	**Achieved**	Yes
Rationale target selection	10 types of hazards were selected that most often occur on construction sites and those that may pose a potential threat to the health and safety of workers.				
Measurement period	• Main trials on the construction site – July 2023 • Laboratory tests – January/February 2024				
Partner/s responsible	CIOP				

Measurement methodology

The following methodology was performed for each hazard:

1. heart disruptions – described in Trial #1 Pilot2_ValAct ID12 and Pilot2_ValActID13 in deliverable D7.4.
2. overheating – described in Trial #1 Pilot2_ValActID14 in deliverable D7.4.
3. immobility – described in Trial #1 Pilot2_ValAct ID12 and Pilot2_ValActID13 in deliverable D7.4.
4. fall from heights – described in Trial #2 Pilot2_ValAct ID1 and Pilot2_ValAct ID2 in deliverable D7.4.
5. slips and falls on the ground – described in Trial #2 Pilot2_ValAct ID2 in deliverable D7.4.
6. collision with machines – described in Trial #1 Pilot2_ValAct ID9 in deliverable D7.4.
7. entrance to a dangerous zone – described in Trial #1 Pilot2_ValAct ID10 in deliverable D7.4.
8. UV radiation – described in Trial #1 Pilot2_ValAct ID15 and Pilot2_ValAct ID8 in deliverable D7.4.
9. lack of PPE – described in Trial #1 Pilot2_ValAct ID11 in deliverable D7.4.
10. unauthorised entrance – described in Trial #1 Pilot2_ValAct ID11 in deliverable D7.4.
11. too high air velocity in relation to crane work – described in Trial #1 Pilot2_ValAct ID15 in deliverable D7.4.

Results and outlook

Table 72. Types of OSH hazards detected

Type of hazard	**Times measured**	**Scenarios**
1. heart disruptions	72	• low heart rate mobile • high heart rate mobile • high heart rate immobile • low heart rate immobile Low heart rate – multiplier 0.5 applied to the measured heart rate value High heart rate – multiplier 3.5 applied to the measured heart rate value
2. overheating	7	• adjusting cooling power to heat stress (weather station simulations) • adjusting cooling power to heart rate (high hear rate multiplier) • adjusting cooling power to skin temperature (skin temperature offset) • saving user preferences
3. immobility	36	Same as heart rate (where immobility is determined)
4. fall from heights and 5. slips and falls on the ground	140	• 42 fall simulations in 13 different points on the construction site • 7 different daily activities performed on a construction site by 10 participants • 4 types of dummy falls performed in laboratory, 7 repetitions for each
6. collision with machines	24	• worker stands at the designated point, the machine moves towards him, parallel • worker and machine move in their directions, parallel to each other • worker stands at the designated point, the machine passes by him, perpendicular to each other • worker and machine move, perpendicular to each other

7. entrance to a dangerous zone	231	Crane: • 2 workers walking around the zone, 1 worker with all permissions entering danger zone "Crane" • 1 worker entering danger zone "Crane" without permissions • 1 worker with all permissions entering danger zone "Crane" Danger zone – outdoor: • worker entering danger zone "Excavation" • 2 workers entering danger zone "Excavation" at the same time • 2 workers entering danger zone "excavation" at the same time, after 15 s another 2 workers entering danger zone "Excavation" at the same time • 5 workers walking around the zone, 1 worker entering danger zone "Excavation" Danger zone – indoor: • 1 worker entering danger zone "Electric hazard" • 1 worker entering danger zone "Fall" • 2 workers entering danger zone "Electric hazard" at the same time • 1 worker entering danger zone "Electric hazard", after 15 s another 1 worker entering danger zone "Electric hazard" • 1 worker entering danger zone "Electric hazard" and 1 worker entering danger zone "Fall" at the same time
8. UV radiation	?	Multiplier applied to the measured UV index and exposing one tag to direct sun for the duration of the test
9. lack of PPE	59	• 6 workers with PPE entering/exiting construction site • 4 workers with PPE, 2 workers without helmets entering construction site • 1 worker with PPE, 2 workers without helmets entering construction site, after 1 min another 2 workers without helmets entering construction site • 3 workers with PPE, 1 worker without a tag entering construction site • 1 worker with PPE, 2 workers without a tag, 1 worker without PPE and a tag entering construction site • 1 worker with PPE, 1 worker without training, 1 worker without medical tests, 1 worker without permissions entering construction site • 3 workers with PPE, 1 worker without helmet and training • 2 workers with PPE exiting, 2 workers without helmet entering construction site • 3 workers with PPE, 1 worker without helmet
10. unauthorised entrance	26	• 3 workers with PPE, 1 worker without a tag entering construction site • 1 worker with PPE, 2 workers without a tag, 1 worker without PPE and a tag entering construction site • 1 worker with PPE, 1 worker without training, 1 worker without medical tests, 1 worker without permissions entering construction site

		- 3 workers with PPE, 1 worker without helmet and training
11. too high air velocity in relation to crane work	12	Simulation of high wind speed

3.3.2.5. KPI 2.2.3 – Hazard detection time

Table 73. Summary of KPI 2.2.3

Name	**Hazard detection time**				
Description	This KPI is about reduction of detection time of hazard/risk situation. To confirm the improvement of safety and health at work by means of ASSIST-IoT solutions, a starting point of hazard detection time will be established according to current methods used at the construction site.				
Motivation	The time it takes to inform the OSH manager about accident is important in order to react to the situation in a timely manner. Informing about the situation in a traditional way may take up valuable time, which is important when it comes to workers' health and safety. Therefore, it is important to shorten this time so that the reaction can be taken almost immediately after the situation occurs.				
Initial target	50%	**Score***	94.39%	**Achieved**	Yes
Rationale target selection	The choice was made to reduce hazard detection time by at least 50% to set a goal that was challenging but realistic and would represent a significant improvement in the process.				
Measurement period	Main trials on the construction site – July 2023				
Partner/s responsible	CIOP				

Measurement methodology

As there are no measures of hazard detection on the construction site, baseline was measured. It was assumed that the baseline would be the time a worker would inform to the OSH manager about an accident or threat. On construction sites, workers are obliged to work in pairs at work, which is why this type of baseline was adopted. Baseline was measured from three points on the construction site to the OSH manager office. Points were selected corresponding to the locations of validation tests. If it was not possible to determine a point in the exact validation location due to construction works, a point with a similar distance to the construction exit was selected. The walk from the designated point to the OSH manager's office was by the shortest possible route allowed by the ongoing construction work. Three points were selected:

- point on level 0 – a point corresponding to tests carried out outside the building. Entry on the roofing felt was no longer possible so it was necessary to change the location to a point with a similar distance to the exit.
- point on level +2,
- point on level +6

Results and outlook

Measured baseline time:

- from point on level 0: 1 min 47 s (107 s)
- from point on level +2: 3 min 23 s (203 s)
- from point on level +6: 3 min 30 s (210 s)

Measured times from points on level +2 and +6 are similar due to ongoing construction work, which significantly extended the walking time from the point at level +2. The shortest recorded baseline time was selected for comparison to compare the system's indications to the best case. When determining the time reduction, the longest reaction time of the system to the event was considered, which represents the most extreme conditions of its operation. The system's response time was tested in selected scenarios – danger zones and fall simulations. Testing two hazard types is sufficient, as the time from the event being detected and the OSH manager being notified does not depend on the hazard type. In fact, the notification pipeline is exactly the same for each hazard.

In the case of danger zone (outdoor), the time was measured with a stopwatch from the moment of entering the zone until the OSH manager was notified. In the case of danger zone (indoor) and fall, the time of entering the zone and starting the simulation as well as the time of receiving the notification to the OSH manager were recorded, respectively.

Table 74. Hazard detection time measurements

Times measured	208
Mean	9.12 s
Standard deviation	7.87 s
Median	6.00 s
Minimum notification time	approx. 0 s (at the limit of measurement accuracy)
Maximum notification time	49.00 s
Time reduction	$\frac{107\ s - 6\ s}{107\ s} \cdot 100\% = \mathbf{94.39}\%$
Time reduction (worst case)	$\frac{107\ s - 49\ s}{107\ s} \cdot 100\% = 54.21\%$

3.3.2.6. KPI 2.2.4 – User acceptance

Table 75. Summary of KPI 2.2.4

Name	**User acceptance**				
Description	The acceptance of technology by workers will be evaluated in the survey research based on the five-point Likert scale. To achieve this KPI, the ASSIST-IoT should obtain more than 75% of at least grade '4' on to technology acceptance from the construction workers.				
Motivation	User acceptance is an important aspect that allows assessing the usability and ergonomics of the tested technologies.				
Initial target	75%	**Score***	84%	**Achieved**	Yes
Rationale target selection	On the basis of gathered results from all test participants, mean values for each statement will be calculated and on this basis verification whether 75% of statements reached mean value over 4 (meaning 'Agree').				
Measurement period	Main trials on the construction site – July 2023				
Partner/s responsible	MOW				

Measurement methodology

After the validation tests, participants received a questionnaire with several variables (e.g. perceived use, perceived ease of use) and statements related to technology acceptance by the user. For each statement, test participant was asked to choose the score from 1 to 5, where 1 according to the Likert scale means ‘Strongly disagree’ and 5 means ‘Strongly agree’. 4 surveys were prepared:

- General survey – general assessment of the technology, assessment of the comfort of using the tag and smartwatch, assessment of the usefulness of the technology, 12 statements (statements presented in Table 76).
- Smartwatch Survey – assessment of the intuitiveness of the smartwatch interface, assessment of received alerts, 13 statements (statements presented in Table 76).
- Mobile Application Survey – assessment of the intuitiveness of the mobile application interface, assessment of received alerts, 10 statements (statements presented in Table 76).
- MR device Survey – assessment of the intuitiveness of the MR interface, assessment of received alerts, assessment of reporting functionality, 17 statements dived into individual group applicable for specific use case scenario (statements presented in Table 76):
  - General issues,
  - Issues applicable only for “Health and safety inspection support – Reporting” use case scenario,
  - Issues applicable only for “Health and safety inspection support – Alerting” use case scenario,
  - Issues applicable only for “Health and safety inspection support – Workers’ data visualization” use case scenario,
  - Issues applicable only for “Safe navigation instructions tests” use case scenario.

On the basis of gathered results from all test participants, mean values for each statement were calculated and on this basis verification whether 75% of statements reached mean value over 4 (meaning ‘Agree’).

Results and outlook

Table 76. Survey results of user acceptance

Survey type	Topic	Mean value*
General survey	The ASSIST-IoT solution is easy to use.	4.23
	The ASSIST-IoT solution interface is intuitive and easy to use.	4.54
	The ASSIST-IoT solution is convenient to use.	4.08
	The ASSIST-IoT solution does not affect routine activities and does not restrict movement.	4.46
	The ASSIST-IoT solutions can contribute to the increase of my safety and health.	4.77
	The ASSIST-IoT solution can have a positive impact on work efficiency.	4.31
	The tested functionality is needed at the construction site.	4.69
	Extensive training in the use of the ASSIST-IoT solution and its proposed functionalities is needed.	3.08
	The use of the ASSIST-IoT solution is good idea in terms of increasing safety on the construction site.	4.85
	I accept the ASSIST-IoT solution as intended to improve health and safety.	4.69
	The ASSIST-IoT solution could find a practical application on a construction site in the future.	4.69
	The ASSIST-IoT solution may infringes on my privacy.	1.69

	Any other comments on the tested ASSIST-IoT solution (Open question, optional).	-
Smartwatch Survey	The received alerts are useful.	4.73
	There is no problem with the operation of the smartwatch.	4.64
	The interface of the smartwach is clear.	4.73
	The advantage of receiving notifications is being aware of working environment.	4.82
	Newly appearing alerts are easy to notice.	4.64
	The alerts are easy to read.	4.82
	The text of the alerts is relevant and appropriate.	4.82
	The content of the alerts is understandable.	4.91
	The vibration notification helps to notice new alerts.	4.82
	The vibration notification is strong enough.	4.45
	The duration of the vibration signal is long enough.	4.55
	The flashing screen signal is visible.	4.64
	The duration of the flashing screen signal is long enough.	4.73
	Any other comments on the tested ASSIST-IoT solution (Open question, optional).	-
Mobile Application Survey	The received alerts are useful.	4.64
	There is no problem with the use of the mobile application.	4.45
	The interface of the mobile application is clear.	4.73
	The advantage of receiving notifications is being aware of working environment and potential hazard to workers.	4.82
	Newly appearing alerts are easy to notice.	4.64
	Previous alerts are shown clearly.	4.45
	The alerts are displayed legibly.	4.55
	The title of the alerts is relevant and appropriate.	4.73
	The content of the alerts is understandable.	4.73
	The information provided in the content of the alert is sufficient to assess the given event.	4.73
	Any other comments on the tested ASSIST-IoT solution (Open question, optional).	-
MR device Survey – General issues	The interface of the mobile application is clear.	3.89
	Navigating through the application elements on the MR device is simple.	3.44
	After the provided training I was able to operate the MR device on my own.	4.22
	The interaction with the BIM model in the MR device is useful.	4.22
	Any other comments on the tested ASSIST-IoT solution (Open question, optional).	-

MR device Survey – Health and safety inspection support – Reporting	Filling the data in the MR device app is easy.	3.67
	It is convenient to prepare a report in the MR device application.	3.78
	The form of the report in the MR device application is appropriate.	4.33
	Using an MR device to create a report can speed up construction site inspections.	3.56
	ASSIST-IoT solutions work accordingly to the currently used OSH-related methods.	4.78
MR device Survey – Health and safety inspection support – Alerting	Newly appearing alerts are easy to notice.	4.33
	Previous alerts are shown clearly.	4.00
	The alerts are displayed legibly.	3.89
	The title of the alerts is relevant and appropriate.	4.22
	The content of the alerts is understandable.	4.56
	The information provided in the content of the alert is sufficient to assess the given event.	4.33
MR device Survey – Health and safety inspection support – Workers' data visualization	Worker information is displayed clearly.	4.00
MR device Survey – Safe navigation instructions tests	Using the MR device to familiarize with evacuation routes on a construction site may result in a better outcome than the traditional teaching method	4.17

*** Options go from 1 (lower result) to 5 (higher result), except "Extensive training in the use of the ASSIST-IoT solution and its proposed functionalities is needed" and "The ASSIST-IoT solution infringes on my privacy"**

Table 77. Aggregated metrics of user acceptance

Survey type	**Number of questions**	**Number of questions with an average above 4**	**Number of questions with an average below 4**
General Survey	12	10	0
Smartwatch Survey	13	13	0
Mobile Application Survey	10	10	0
MR device Survey – General issues	4	2	2
MR device Survey – Health and safety inspection support – Reporting	5	2	3
MR device Survey – Health and safety inspection support – Alerting	6	4	2
MR device Survey – Health and safety inspection support – Workers' data visualization	1	0	1
MR device Survey – Safe navigation instructions tests	1	1	0

Sum	50	42	8
% of statements reached mean value over 4 (meaning 'Agree')	$\frac{42}{50} \cdot 100\% = \mathbf{84}\%$		

3.3.2.7. KPI 2.2.5 – Notification and alerting

Table 78. Summary of KPI 2.2.5

Name	**Notification and alerting**				
Description	To confirm that the HSO (Health and Safety Officer) is aware about the majority of the danger event within the worksite through the MR device, a series of tests will be performed to measure the reliability of the mixed reality device. The tests should ensure that the notifications of the events mentioned in the below motivation reach the MR enabler and thereafter the HSO inspector.				
Motivation	Due to the need of HSO's information about hazardous events within the construction area, alerts and notifications are used to notify the HSO inspector for incidents such as falling and other accidents, exceedance of permitted physiological and environmental parameters, unauthorized access, or when a worker is approaching of dangerous zones.				
Initial target	90 %	**Score***	100%	**Achieved**	Yes
Rationale target selection	During the pilot test phase, the alerts that will be generated from the other systems and components and will be transmitted to the MR device via the edge data broker, should achieve more than 90% success rate to deliver the message. This number means that from the 10 messages sent, the 9 are succeeded.				
Measurement period	July				
Partner/s responsible	ICCS				

Measurement methodology

To effectively test this specific KPI, a series of actions will be performed in Pilot 2. The exclusive selection of this pilot for testing is because only in Pilot 2 we are going to use the HoloLens. The HSO user is required to follow these steps:

- Firstly, the Health and Safety Officer (HSO) needs to initiate an alert, which will be published to the EDB enabler. This involves triggering the alert and sending it to the specific topic designated for alerts.
- Subsequently, the HSO should verify that the alert has been successfully received and saved in the alert list, located within the MR alert system.
- Lastly, the HSO must verify that the information displayed within the MR enabler regarding the alert is accurate and corresponds correctly to the specific alert triggered.

For this process to work seamlessly, the necessary enablers involved are the MR enabler, the EDB enabler, and an additional enabler responsible for publishing alerts to the EDB enabler.

Results and outlook

This KPI contributes to the optimization of safety and health system at the pilot case ensuring a safe working environment.

In each of the tested scenarios, a minimum of 10 notifications were dispatched to the EDB enabler from the corresponding enablers, to promptly apprise the HSO of any incidents occurring within the construction site. In each case, all 10 alerts were not only successfully transmitted but also effectively conveyed to the HSO via the MR device, which displayed comprehensive information regarding each alert raised during these scenarios, ensuring the HSO was well-informed of the respective incidents.

01 Worker Monika Kobus (CIOP, 4) requests help

Alert ID a569487f-6808-4ce1-a6d6-9ef0acd7f901

WSC ID f5e74f54-9e4d-4e89-80a0-0b5759b095b3

Worker ID 5

Timestamp 11/07/2023 11:05:00 GMT+2

The heart rate of worker Małgorzata Okrasa (CIOP, 5) is too high: 357 bpm.

Figure 35. MR enabler receiving alerts on runtime, during the trials of Pilot 2

3.3.2.8. KPI 2.2.6 – Reporting

Table 79. Summary of KPI 2.2.6

Name	**Reporting**				
Description	This KPI aims at validating the reporting functionality. To that end, the inspector will generate different reports that include photos and relevant information, and the system will save it to the LTSE.				
Motivation	During inspection, one of the primary responsibilities of the OSH inspector is to report unusual or dangerous situations to the stakeholders (for example, when a construction worker is not equipped with their appropriate personal protective equipment, or when a construction element requires attention, should be reported as an incident). This should be properly reported and stored.				
Initial target	90 %	**Score***	100%	**Achieved**	Yes
Rationale target selection	To achieve this KPI, more than 90% of the reports should be saved to the ASSIST-IoT databases successfully. This number means that from 10 reports, the 9 are successfully saved.				
Measurement period	July				
Partner/s responsible	ICCS				

Measurement methodology

To effectively test this specific KPI, a series of actions must be performed in Pilot 2, where the HoloLens are going to be used. The user, specifically the HSO, is required to follow these steps:

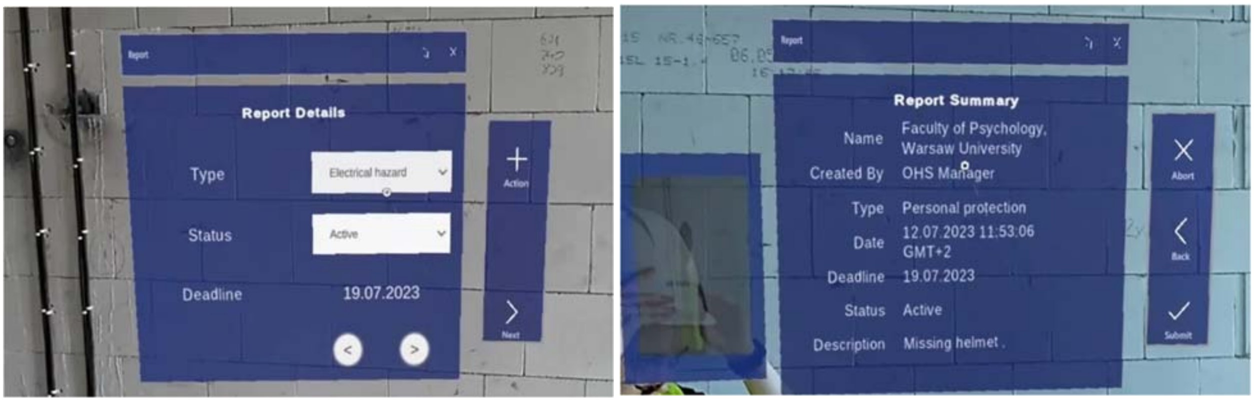
- Firstly, the HSO should open the Report panel within the MR application.
- Fill in all the necessary fields with the appropriate values, providing all required information for the report.
- Once the report is complete, click the Submit button to send the report.
- Next, verify at the LTSE enabler that the report data, including both text and media elements, is stored correctly and accurately.

For this testing process to proceed smoothly, the essential enablers involved are the MR enabler (responsible for creating the reports) and the LTSE enabler (designed to store the reports).

Results and outlook

This KPI contributes to the control of the workers' equipment and ensures the compliance with safety measures.

Throughout Pilot 2, a minimum of 10 diverse reports were transmitted to the ASSIST-IoT ecosystem from the MR enabler, covering a wide array of topics (workers not wearing their personal protection equipment, electrical hazards etc.). Each of these 10 reports was effectively archived within the LTSE enabler of the ecosystem, ensuring their availability for subsequent review by the HSO. These reports were securely stored within the non-SQL database of the LTSE enabler, with each report meticulously timestamped for clear distinction and traceability among the stored records.



Report Details

Type: Electrical hazard
Status: Active
Deadline: 19.07.2023

Report Summary

Name: Faculty of Psychology, Warsaw University
Created By: OHS Manager
Type: Personal protection
Date: 12.07.2023 11:53:06 GMT+2
Deadline: 19.07.2023
Status: Active
Description: Missing helmet .

Figure 36. MR enabler supporting the preparation and store of a new report to the LTSE

3.3.2.9. KPI 2.2.7 – BIM manipulation

Table 80. Summary of KPI 2.2.7

<table>
<tr><td>Name</td><td colspan="5">BIM manipulation</td></tr>
<tr><td>Description</td><td colspan="5">The MR enabler is designed in a way that allows the user to manipulate the 3D model rendered in order to provide better understating of the information linked to it.</td></tr>
<tr><td>Motivation</td><td colspan="5">The HSO manager needs access to the BIM model to assess all needed information for the access points, such as the location of dangerous zones, and authorized areas. Object visualization and manipulation capabilities of the MR enabler ensure that the operator of the device has a full overview of the IFC model components.</td></tr>
<tr><td>Initial target</td><td>9 degrees of freedom</td><td>Score*</td><td>9 degrees of freedom</td><td>Achieved</td><td>Yes</td></tr>
<tr><td>Rationale target selection</td><td colspan="5">This KPI will be fulfilled by manipulating the 3D object in nine degrees of freedom (9DOF) which include 3DOF for object positioning (x, y, and z-axes), 3DOF for object rotation (x, y, and z-axes) and 3DOF for object scaling (x, y, and z-axes).</td></tr>
<tr><td>Measurement period</td><td colspan="5">July</td></tr>
<tr><td>Partner/s responsible</td><td colspan="5">ICCS</td></tr>
</table>

Measurement methodology

To effectively test this specific KPI, a series of actions must be performed. The user, particularly the HSO, is required to follow these steps:

- Firstly, the HSO should click on a designated button to present the Building Information Modelling (BIM) object.
- Next, the HSO can interact with the virtual objects by grabbing their handlers[5]. Using these handlers, the OSH can manipulate the position, rotation, and scale of the 3D object within the real-world environment.

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[5] The model includes some handlers in the corners of the BIM model, that allows the user to scale the mode. In addition, the handlers that are located in the middle of the BIM edges allows the user to rotate the model in each direction. Finally, user can transfer the 3D model in each location of their field of view by selecting the handler which is located in the centre of each edge of the BIM model.

For this testing process to proceed smoothly, the essential enablers involved are the MR enabler, responsible for presenting the BIM model, and the Semantic enabler, designed to store the 3D object.

Results and outlook

This KPI facilitates the visualization of safety and health system at the pilot case using MR devices.

The HSO possessed the flexibility to access the BIM model and visualize it, on-demand. Additionally, the HSO could access real-time instructions for adjusting the model's position, rotation, and scale as needed. This feature enabled the HSO to manipulate the BIM model in 6DOF and to fine-tune its scale, to ensure it could be inspected properly, without obstructing their field of vision.

Figure 37. MR enabler showing the BIM model and instructions on how to manipulate it on 6DOF, plus modifying its scale. The respective handlers on the BIM model can be used to modify its rigid body

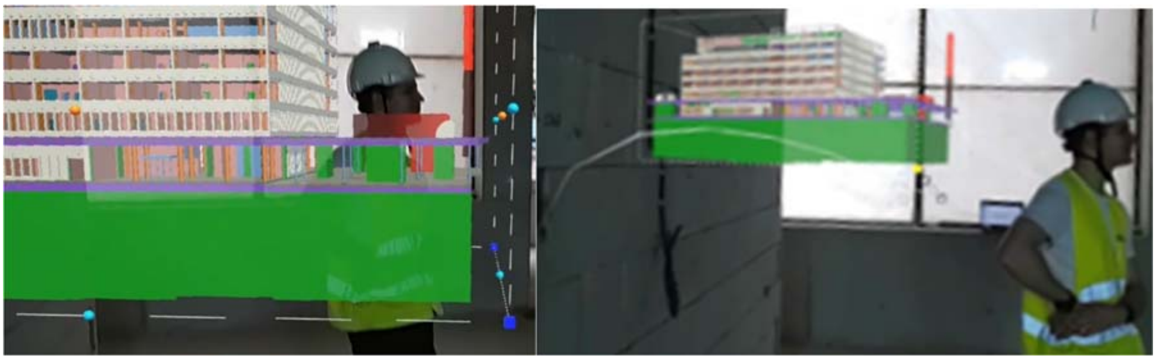


Figure 38. The BIM model is scaled down to optimize the HSO's visibility and maintain a clear view of the surrounding environment

3.3.2.10. KPI 2.2.8 – Near-miss fall from a height

Table 81. Summary of KPI 2.2.8

<table>
<tr><td>Name</td><td colspan="5">Near-miss fall from a height</td></tr>
<tr><td>Description</td><td colspan="5">The fall detection system should achieve a target percentage of correctly recognized falls from a height.</td></tr>
<tr><td>Motivation</td><td colspan="5">The system must be able to reliably and effectively detect falls on a construction site to ensure the safety of workers.</td></tr>
<tr><td>Initial target</td><td>85%</td><td>Score*</td><td>98%</td><td>Achieved</td><td>Yes</td></tr>
<tr><td>Rationale target selection</td><td colspan="5">Due to the very high variety of activities and types of falls on construction sites, achieving a true positive rate of more than 85% would already constitute an effective system.</td></tr>
<tr><td>Measurement period</td><td colspan="5">After the main trials on the construction site.</td></tr>
<tr><td>Partner/s responsible</td><td colspan="5">SRIPAS</td></tr>
</table>

Measurement methodology

To measure the success rate of the fall-from a height detection method, a series of tests will be performed involving simulated drops of an OSH mannequin. The drop scenarios will be varied to reflect a variety of hazardous situations that may occur on the worksite. The KPI will be achieved, if the system correctly recognizes the near-miss situation in at least 85% of test cases. The tests will be performed in a specialized laboratory, to ensure the consistency of results. Conducting the tests on the construction site was deemed infeasible, due to the danger these tests would create for the workers on-site.

Results and outlook

The tests for fall from height detection were performed in the laboratory and consisted of a variety of fall types depending on the starting position of the OSH mannequin and the position of the OSH harness. Overall, following the data collection procedure for training of detection model, 4 distinct fall types were tested. Example of mannequin before and after the fall is given in Figure 39.

For each fall type, 7 trials were performed to introduce a variety to the fall arrest system responses. Moreover, to increase the number of detection attempts without increasing the actual number of demanding mannequin falls, mannequin was equipped with two acceleration reporting tags instead of one. Therefore, each time a fall was performed two devices independently were used for fall detection. Table 82 shows the types of fall tested and the True Positive Rate (TPR) for each trial set.

Figure 39. Example of mannequin position before and after the fall from height with fall arrest and fall detection equipment for fall type 4

Table 82. Fall detection model results

Fall Type	Fall Type Description	Detection Attempts	True Positive Rate
1	Fall forward from height. Vertical starting position, front attachment point of a harness.	14	100%
2	Fall forward from height. Vertical starting position, back attachment point of a harness.	14	93%
3	Fall forward from height. Starting position — mannequin forward tilt, back attachment point of a harness.	14	100%
4	Fall backward from height. Starting position — mannequin tilt backwards, front attachment point of a harness.	14	100%

For fall type 1-2, mannequin was positioned on height around 1.3 - 1.5 meters and for fall types 3-4, the height of the structure the mannequin standing on was 2 meters.

As can be seen from the Table, out of 56 fall detection attempts performed, only 1 false negative was recorded for fall type 2, meaning, that out of two devices attempting to detect a fall, only one succeeded. Overall, making the TPR for the tests equal 98%, therefore, fulfilling the defined KPI.

3.3.2.11. KPI 2.2.9 – Worker alert latency

Table 83. Summary of KPI 2.2.9

Name	**Worker alert latency**				
Description	The delay between the worker entering a danger zone and them being alerted should be lower than the specified target.				
Motivation	A large delay in the notification would prevent the system from effectively warning workers of dangers on the construction site.				
Initial target	1.5 s	**Score***	0.747 s	**Achieved**	Yes
Rationale target selection	A delay of 1.5 seconds gives the worker enough time to react when entering a danger zone that is typically a few meters wide.				
Measurement period	After the main trials on the construction site – January 2024.				
Partner/s responsible	SRIPAS				

Measurement methodology

The scenario was simulated by instructing a worker to enter a temporarily set dangerous zone and then measuring the time between the incursion and the triggering of the worker's alarm system. There was no actual risk to the worker during the test, to ensure their safety. The test was supported by additional painted lines, to delimit the dangerous zone set in the BIM model. The delay was measured by examining a recorded video of the experiment with the wristband clearly visible, to accurately assess the time at which the notification arrived on the device. The participants of the test were also asked to raise their hand in the moment they felt vibrations indicating a notification. The recording included an accurate timestamp, allowing for calculating the latency.

The measurement methodology is summarized in Table 84:

Table 84. Methodology for measuring the worker alert latency

Scenario No.	**Scenario**	**Repetitions**
1	1 worker entering danger zone – entrance from the front, left side	12
2	1 worker entering danger zone – entrance from the front, right side	12
3	2 workers entering danger zone at the same time	12
4	2 workers entering danger zone in 5 s intervals	12
5	3 workers entering danger zone one after another (1-2 step interval)	12

Results and outlook

Table 85. Results of worker alert latency

Scenario No.	**Times measured**	**Mean notification latency**	**Standard deviation**	**Median**

1	12	0.678 sec	0.461 sec	0.747 sec
2	12	0.871 sec	0.244 sec	0.855 sec
3	12	0.795 sec	0.267 sec	0.801 sec
4	12	0.769 sec	0.374 sec	0.779 sec
5	12	0.623 sec	0.259 sec	0.598 sec
Mean latency (from all scenarios)		0.727 sec		
SD (from all scenarios)		0.321 sec		
Median (from all scenarios)		**0.747 sec**		

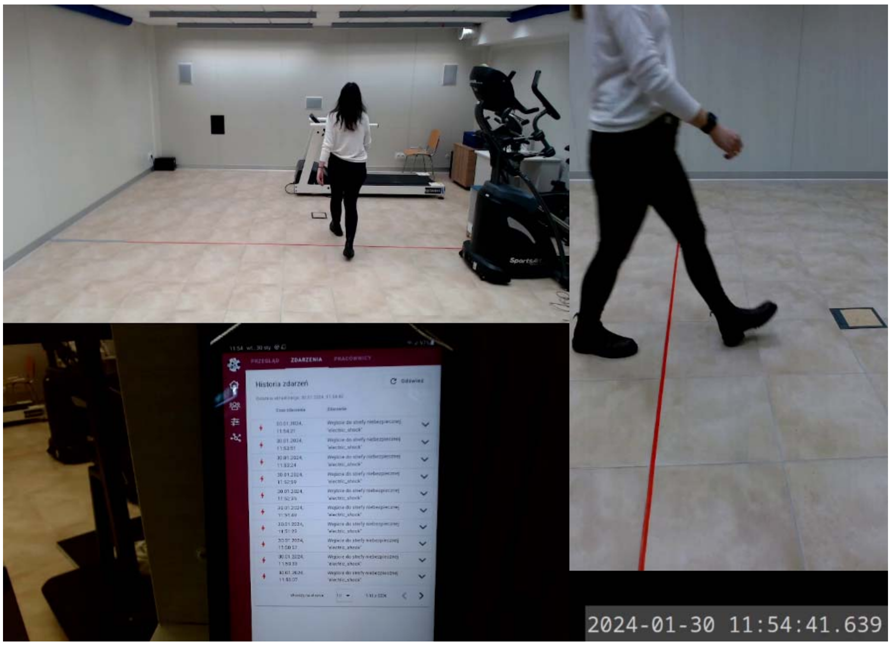


Figure 40. Entrance proof from one selected repetition

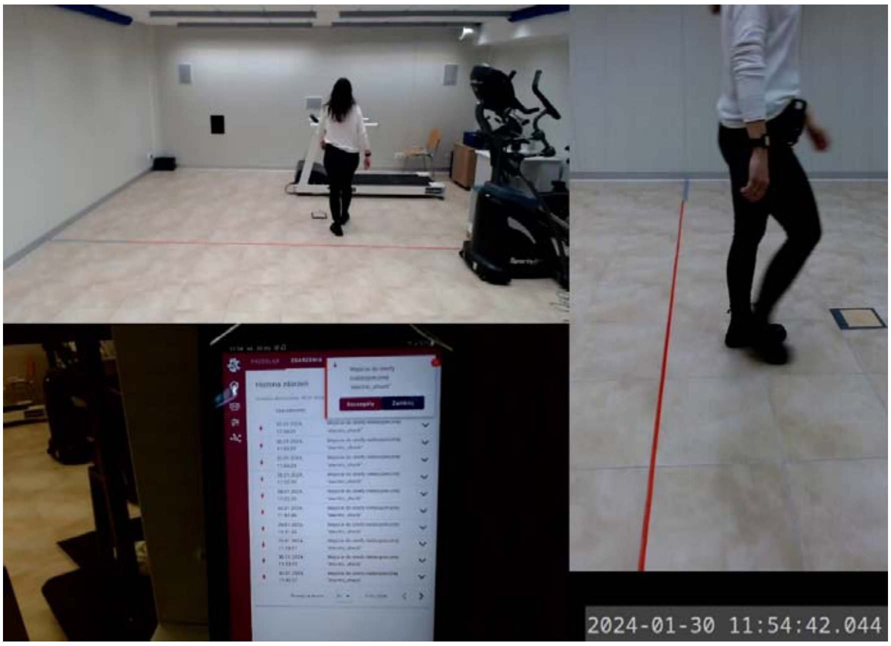


Figure 41. Notification proof from one selected repetition

3.3.2.12. KPI 2.2.10 – OSH manager notification

Table 86. Summary of KPI 2.2.10

Name	**OSH manager notification latency**				
Description	The latency between the worker's incursion into a danger zone and the manager's notification should be minimized.				
Motivation	The latency should be minimized so that the OSH manager can react in time to the dangerous situation.				
Initial target	5 s	**Score***	0.657 s	**Achieved**	Yes
Rationale target selection	A delay of 5 seconds was deemed both acceptable from the OSH standpoint (in comparison to the current practice it is nearly instantaneous) and achievable for the system, bearing in mind the various delays introduced by the network and all involved software components.				
Measurement period	After the main trials on the construction site.				
Partner/s responsible	SRIPAS				

Measurement methodology

The measurement setup was the same as in KPI 2.2.9. The screen of the OSH manager's device was recorded using an additional camera, synchronized with the one observing the worker. The delay was measured by examining the recorded footage.

Results and outlook

Table 87. Results of OSH manager notification

Scenario No.	Times measured	Mean notification latency	Standard deviation	Median
1	12	0.922 sec	1.217 sec	0.644 sec
2	12	0.751 sec	0.187 sec	0.805 sec
3	12	0.655 sec	0.237 sec	0.617 sec
4	12	0.662 sec	0.422 sec	0.644 sec
5	12	0.589 sec	0.256 sec	0.585 sec
Mean latency (from all scenarios)		0.675 sec		
SD (from all scenarios)		0.488 sec		
Median (from all scenarios)		**0.657 sec**		

3.3.2.13. KPI 2.3.1 – Reduce emission related series recalls by fleet monitoring and fleet maintenance

Table 88. Summary of KPI 2.3.1

Name	**Reduce emission related series recalls by fleet monitoring and fleet maintenance**
Description	With the help of ASSIST-IoT vehicle emissions will be monitored and a fleet emission distribution will be calculated. By identifying and addressing emission outlier vehicles, the amount of emission related recalls will be reduced substantially.

Motivation	Series recalls can have a substantial financial and reputational impact on car manufacturers. At the same time, also the car owner is affected leading to dissatisfaction and potentially reduced trust in the purchased product. Therefore, a prevention or reduction of recall actions with the help of the tools implemented within Pilot 3A is a KPI beneficial for both the car manufacturer and the customer alike.				
Initial target	(Reduction by) 50%	**Score***	50% (estimated)	**Achieved**	Yes
Rationale target selection	Chosen to set a challenging, yet realistic target. No further rationale.				
Measurement period	July 2023 – February 2024				
Partner/s responsible	FORD				

Measurement methodology

The following methodology is to be followed:

1. Simulate various fleets of vehicles by multiplying the available Pilot 3A vehicle data with different Gaussian distributions.
2. Define threshold levels for outlier vehicles which would trigger a recall action.
3. Apply ASSIST-IoT tools to fleets which would usually trigger a recall action.
4. Verify if with the help of the ASSIST-IoT tools a recall action could have been prevented.

Results and outlook

According to the measurement methodology described above, a simulated fleet of 5000 vehicles was generated, based on the detailed emission data, gathered by the ASSIST-IoT edge device in the Pilot 3A test vehicle during real-world driving in the Valencia area. For this evaluation, the output data of the series emission sensor was altered, to model an expected sensor drift seen in an aging vehicle fleet versus the exact values provided by the HiFi sensors throughout vehicle life.

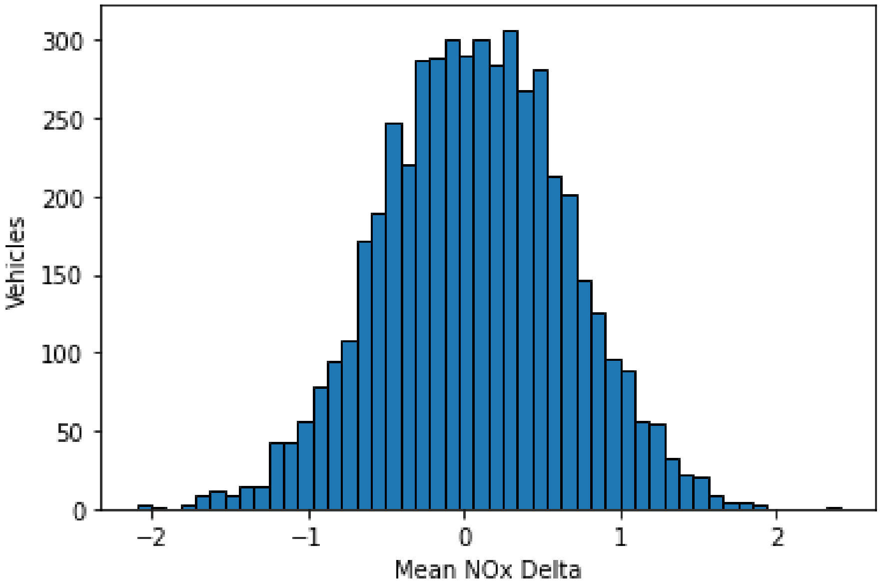


Figure 42. Exemplary performance of standard vs. HiFi NOx sensors in a simulated vehicle fleet of 5000 vehicles

This vehicle fleet was designed to show an expected emission performance within a Gaussian distribution, including an unwanted number of outlier vehicles. In the past, if the number of outliers exceeded a critical threshold, a fleet recall would have been the final consequence, generating major logistical, financial and reputational implications for the vehicle manufacturer.

With the help of the tools offered by ASSIST-IoT, individual vehicles can be identified, based on freely definable emission thresholds. In a next step, vehicle drivers can be informed via dashboard messages, to see a dealership technician. This appointment would then restore the expected original emission performance within legal thresholds on individual level, while still having the wanted impact on fleet performance. As a result, this approach ensures, that the fleet in total is never outside it's legal thresholds, consequently reducing the risk of a recall.

It was thereby demonstrated that this approach can easily reduce the potential of a series recall by at least 50%.

3.3.2.14. KPI 2.3.2 – Reduce development time for diagnostic software updates

Table 89. Summary of KPI 2.3.2

Name	**Reduce development time for diagnostic software updates**				
Description	With the help of the tools implemented within ASSIST-IoT Pilot 3A, the time to run in depth diagnostics is significantly reduced. As this task has proved to be the main challenge within the efforts to find, understand, fix and update software faults in a vehicle fleet, a flexible approach made possible within Pilot 3A will help to reduce the development time for diagnostic software updates significantly.				
Motivation	Unknown or unidentified faults are a major concern for car manufacturers and customers alike. For customers with limited insight to the E/E architecture of a vehicle, any deviation from the expected behaviour can cause a significant frustration. Therefore, it is a top priority for the car manufacturer to identify and understand previously unknown issues as fast as possible.				
Initial target	(Reduction by) >50%	**Score***	>50% (estimated)	**Achieved**	Yes
Rationale target selection	Chosen to set a challenging, yet realistic target. No further rationale.				
Measurement period	July 2023 – February 2024				
Partner/s responsible	FORD				

Measurement methodology

1. Create database of in-market software faults and the time needed for their identification, understanding, fixing and updating. As there is no database available, this information is gathered verbally by interviewing technical matter experts from different vehicle modules.
2. Compare the information in the database with an ideal scenario offered by the tools implemented within Pilot 3A.

Results and outlook

During the above describe series of short interviews with technical matter experts, it clearly became evident, that while facing a previously unknown field issue, the efforts and time invested to gather relevant data create the most challenges.

Two examples included in the field issue survey below:

1. A driver from a northern European country complained about issues noticed while driving the car in every-day situations. Due to the safety critical nature of the involved module and the (subjectively) critical description of the incident, a field engineer was sent on location to investigate the incident. During a two-day investigation neither the reported issue could be reproduced, even with the original driver on the exact same roads, nor any critical faults could be retrieved from the failure storage of the module. Similar incidents were reported from other drivers in the following months, but due to the low frequency of reports and the very subjective descriptions, an in-depth

investigation was impossible. The issue was finally solved, after all reports vaguely pointed towards an uncritical and intentional driver assist functionality, and a new – slightly smoother - tuning for the module in question was introduced into series production.

2. During vehicle production, more specifically during End-of-line failure checks, one module repeatedly reported generic failure codes. Due to the nature of the vehicle-built process, as electronic modules are installed sequentially, initial failures are unavoidable and are cleared automatically on several occasions. With some modules requiring further calibration (potentially even by driving the vehicle), along with the strict timing constraints of series production, this environment makes detailed and reliable measurements very difficult, if not impossible. It took the module experts several months of bench testing instead, to reproduce the issue and come up with a solution for series production.

Both example issues would have benefited from the tools described and developed in Pilot 3A dramatically. Firstly, an automatic supervision of the affected modules could have been initiated, most likely generating helpful in-depth measurement data in a fraction of the time reported here. Also, much more vehicles could have been supervised in parallel, reducing the time for a reproduction of the individual failures even further. Secondly, by automatically triggering in depth measurements of the driving situation when a fault appears, especially for faults like in the first example, the communication with the driver would have been much easier, as the non-critical nature of the incident would have been obvious very early, meaning less effort for the vehicle manufacturer and increased customer satisfaction in parallel.

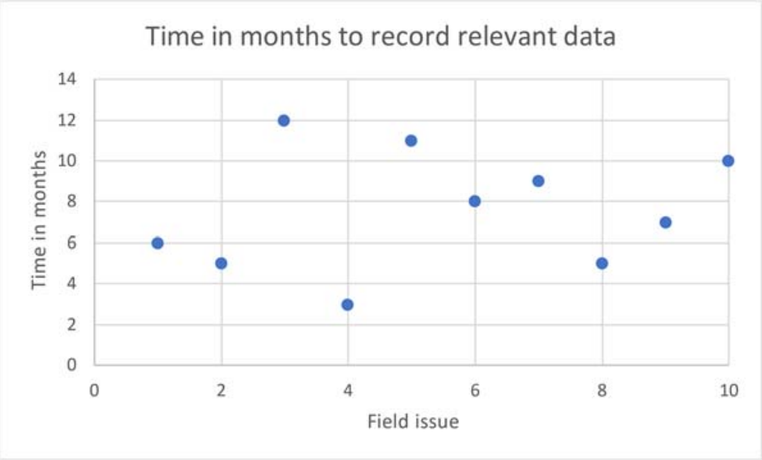


Figure 43. Different field issues with estimated times in months until relevant data was gathered

The average value calculated from the expert's feedback was 7.6 months, until enough data was gathered to understand the root cause of the issue and to start the actual software fix of the underlying problem.

During these interviews, the tools offered by ASSIST-IoT within Pilot 3A were presented and highly appreciated by the technical matter experts. Due to the fact, that ASSIST-IoT allows to implement safe and secure data gathering via containerized algorithms in a highly flexible way on multiple vehicles in parallel, all experts independently came to the same conclusion, that gathering crucial data to solve previously unknown field issues can be reduced significantly to less than a month, instead of the previously mentioned 7,6 months in average.

With this, the KPI to reduce the development time for diagnostic software updates by 50% or more is easily met.

3.3.2.15. KPI 2.3.3 – Number of data channels measured in parallel

Table 90. Summary of KPI 2.3.3

Name	**Number of data channels measured in parallel**
Description	In order to measure all relevant data transmitted by the vehicle, a minimum number of data channels is expected to be received with a minimum update frequency.

Motivation	Emission performance evaluation is relying on detailed vehicle data, mainly from the PCM. Emission related models additionally need data describing the current driving condition provided by other vehicle modules. At the same time, an in-depth monitoring is only possible with a reasonable update frequency, usually with a signal period of 10ms or less. Therefore, this KPI was implemented to ensure, that ASSIST-IoT is meeting the requirements demanded in the automotive sector.				
Initial target	≥ 200	**Score***	382	**Achieved**	Yes
Rationale target selection	Projected number of signals based on current and future usage				
Measurement period	Offline database generated from October 2021 to the end of the project. Online During the third phase of the trials				
Partner/s responsible	UPV				

Measurement methodology

The capability of the ASSIST-IoT architecture for dealing with a sufficient number of measurement channels has been verified both using a database of historic recordings and online in the prototype operation.

- For providing data for the laboratory testing, a systematic recording of the operation of the vehicle on real life driving was done. Tests started by October 2021 and were conducted till the end of the project (Mars 2024). Overall more than 24000 short distance trips (*drivelets*) were recorded. Along the project, the number of measured channels in the file has increased from to 237 data channels in the first tests (all of them from the PCM), to 424 data channels by the end of the project (including PCM values -381 data channels-, data retrieved from CAN bus, and from Modbus TCP). Hence, all the recorded files are relevant for the KPI evaluation. Drivelets, as described in D7.4, cover a wide range of operation conditions and a variety of driving cases. The laboratory testing used such recorded data files for feeding the ASSIST-IoT edge node, emulating the operation on the vehicle.
- For the final verification, the system was tested in real driving operation. Here the data feed was generated in real time as the vehicle was operated, and the edge software, encapsulated as an enabler instantiated from either the cloud dashboard on the vehicle tactile dashboard was used for analysing the mf4 data files.

In both cases the instantiated enabler must open the mf4 file corresponding to the drivelet to be processed, extract the data, verify its integrity, and provide metrics on all the measurement channels. The resulting value is added in the local NSQL data base. The values are later sent to the cloud LTSE using the EDBE.

Results and outlook

The formal fulfilment of the KPI was checked verifying the capability of the system to deal with the data both in online and laboratory testing (emulating the online operation of the system). The developed enabler was able to process the complete data base of drivelets, and also to process the drivelets at they were generated in real driving operation.

The enabler checked the integrity of the data file (discarding those files with an insufficient number of data samples or errors in the file), extracted information all PCM measured channels, and injected the drivelet metrics for those data channels into the database. In the stress tests, the enabler was set for extracting values from a maximum of 382 data channels, over 24069 drivelets. Values were successfully processed and sent to the LTSE. Those values were later used for filtering and selecting the drivelets in the remote dashboard. For the online tests, drivelets were processed in runtime, and processed data was made available to the cloud in real time.

In addition to the formal fulfilment of the KPI, the following characteristics were also implemented:

- Ability to integrate data coming from different sources: PCM measured channels, PCM calculated channels, CAN bus data (as data from emission sensors), high frequency data (acquired and processed by an additional real time system -see D7.4), MQTT data, and Modbus TCP data.

- Ability to add data channels on demand: if the enabler needs a PCM data channel which is not present in the current recording configuration, the enabler tries to add the requested channel to the recorded channel list. If no error is issued by the PCM interface SW, the channel is added to the recording tasks and it will be included in the future drivelets.

Overall, the KPI may be marked as successfully achieved as it has been demonstrated the capability of processing a number of measurement channels higher than the target value (up to 418, against a target value of 200 data channels). The limit on the number of data channels has not been researched, but will be probably related with the recording capabilities of the PCM interface software or the edge node processing power or memory.

3.3.2.16. KPI 2.3.4 – Available connectivity channels provided by ASSIST-IoT

Table 91. Summary of KPI 2.3.4

Name	**Available connectivity channels provided by ASSIST-IoT**				
Description	This KPI was implemented to confirm the availability of various connectivity channels (2G, 3G, 4G, 5G, WiFi, Bluetooth, CAN) provided by ASSIST-IoT, in order offer adjustable solutions towards the various automotive use cases.				
Motivation	Based on the automotive use case, there is either a demand for real-time mobile connectivity solutions to handle small but urgent data packages, or WiFi based solutions to download large raw data packages. Between the aforementioned examples, there are more use cases either focusing on data size or the real time aspect, showcasing the need to offer a wide range of connectivity options.				
Initial target	7 (2G, 3G, 4G, 5G, WiFi, Bluetooth, CAN)	**Score***	7 (2G, 3G, 4G, 5G, WiFi, ~~Bluetooth~~, CAN, ethernet) + 6 different transmission protocols	**Achieved**	Yes
Rationale target selection	Current and projected connectivity solutions used in the automotive sector.				
Measurement period	During the third phase of the trials				
Partner/s responsible	UPV				

Measurement methodology

This KPI covers two important aspects of the automotive application: mobile network availability, and the ability of the system for integrating data vomming from different vehicular networks.

For the first, it must be considered that connectivity strongly depends on the vehicle position; in the limit the connection may be unavailable (e.g. in underground parking or remote rural areas). As an example, Figure 44 shows the network availability in a real-life trip between two population nuclei in a remote rural area (Olocau to Marines Viejo, Valencia, Spain). ASSIST-IoT must be able to ensure the operation of the system with different network qualities and to recover from out of network situation. In order to perform the test in a repetitive way, the operation of the system was tested limiting the network options from the vehicle router. Main features of the ASSSIT-IoT pilot were tested: capability to remotely instantiate an enabler (active monitoring) from the cloud dashboard; operation of the active monitoring enabler and the upload of data files to the system; and upload of processed data to the LTSE from the edge.

On the other hand, current vehicular networks are multi-agent and use a variety of vehicular networks. In the context of the project, the integration of signals from a variety of sources was verified (CAN, Ethernet, WiFi, Modbus TCP, TCP IP and UDP data sockets, MQTT).

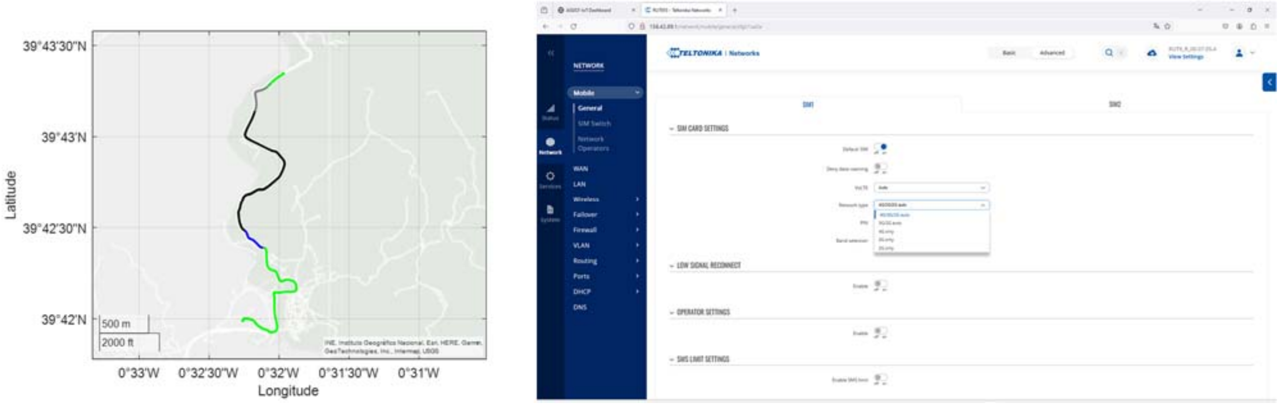


Figure 44. Left: network connection in a real-life trip in a remote rural area (black: no connection available; grey: connected but no data network available; blue: HSPA/3G; green: LTE/4G). Right: limitation of the network connection time in the vehicle router (TELTONIKA TUR955)

Results and outlook

Connectivity tests results are summarized in the following table. Tests were carried out by restricting the network connection at the vehicle router side. For the 5G tests, a different router was used (C365-5G-H900).

Table 92. Results of the connectivity tests

Connection Type	Data sent to cloud and successfully integrated into LTSE	Active monitoring instantiated from cloud	Extended data files successfully sent to cloud
2G (EDGE)	yes	yes	yes*
3G (HSPA+)	yes	yes	yes
4G (LTE B20)	yes	yes	yes
5G**	yes	yes	yes
Ethernet	yes	yes	yes
WiFi	yes	yes	yes

*: in 2G operation upload time doubled recording time. **: 5G tests were done using a C365-5G-H900 router.
Ethernet and WiFi tests were done in laboratory testing.

The capability of the architecture for adequately dealing with network reconnections and recover from out of network situations, was verified with a long-distance trip between Valencia and Portugal border, as shown in Figure 45. Along the trip, the system was subject to a wide variety of network situations, as also shown the figure. Upon completion of the trip, it was verified that the drivelets generated along the trip were successfully uploaded to the cloud.

Figure 45. Left: connection type along the validation trip (green: 4G; blue: 3G; black: no connection). Center: zoom of a zone in central Spain with limited connectivity. Right: Elasticsearch on the cloud LTSE, verifying that the drivelets generated along the no-connection zone were uploaded to the LTSE when connectivity was recovered.

Finally, Table 93 summarizes the details of the integration of different communication protocols in the project. The list shows those protocols that have been used at different stages of the project for integrating different systems in the vehicular network (e.g. emission sensors, vehicle calculated signals, enablers running on third party hardware, etc.).

*Table 93. Results of the connectivity tests. *: times for uploading 5 drivelets are reported*

Connection Type	Integrated into Pilot 3A	Implementation details
CAN	yes	Used for integrating vehicle CAN signals, HiFi sensors and to communicate high frequency data acquisition system with the PCM control PC
Modbus TCP	yes	Used for providing connectivity state from router
MQTT	yes	Used for communicating the tactile dashboard with some enablers at the edge node, and for integrating third parties HW (open calls)
TCP-IP data sockets	yes	Used at early states of the project for communicating enablers with the PCM control PC. Discontinued in the final setup
UDP data sockets	yes	Used at early states of the project for communicating enablers with the PCM control PC. Discontinued in the final setup
http GET/POST	yes	Used for the deny/accept answer to the geolocation and active monitoring requests
Bluetooth Low Energy (BLE)	no	While edge node has been satisfactorily paired to third party HW using BLE, the connection has not been used in the project. No technical limitations have been detected

With exception of BLE (not technical barrier was found for adding BLE, but it has not been used), all protocols specified in the KPI have been implemented. In addition, the project has used Modbus TCP and different kinds of M2M communication systems as MQTT, or TDP-IP and UDP sockets. If we list the number of communication channels implemented we get an aggregated score of 12 over the 7 requested.

3.3.2.17. KPI 2.3.5 – Time to update a PCM calibration on the edge, after a vehicle was offline

Table 94. Summary of KPI 2.3.5

Name	**Time to update a PCM calibration on the edge, after a vehicle was offline**				
Description	One goal of Pilot 3A is to ensure, that the emission performance of a single vehicle and the vehicle fleet in total is close to optimal. Therefore, it has to be guaranteed, that each vehicle is running with the latest PCM calibration ensuring the best possible emission performance.				
Motivation	Pilot 3A focuses on the emission distribution of a vehicle fleet by addressing outlier vehicles. If, for example, a sensor drift is noticed on an outlier vehicle, this can be addressed by an updated PCM calibration, bringing the vehicle back to expected emission levels, without triggering a costly fleet recall action. Therefore, it is important to ensure, that all vehicles are running with the latest PCM calibration.				
Initial target	<1h (after vehicle goes online and is in a safe state)	**Score***	<5 min (after vehicle goes online and is in a safe state)	**Achieved**	Yes

Rationale target selection	For this KPI, safety and security are more important than time. Therefore, a reasonable time was chosen to update the vehicle, after it went online and is in a safe driving state.
Measurement period	During the third phase of the trials
Partner/s responsible	UPV

Measurement methodology

In this KPI the ability of the system for restoring the system to the current version after it has been offline for a while has been evaluated. The scenario to be addressed is that of vehicles that are without network available for a prolonged period of time. This can create the firmware version and the instantiated enablers to be out of synchronism with the requested configuration.

In order to test the KPI, the following procedure was done:

1. Take vehicle offline (either by removing the SIM card from the router, or by driving to the second level of an underground parking lot).
2. Alternatively, to update the PCM calibration in the server and to request a calibration update, or to trigger an ASSIST-IoT enabler update from the cloud while the vehicle is offline.
3. Make vehicle go online again (resetting the connection or driving out of the no connection zone).
4. Measure the time until a task to update the PCM calibration is triggered, or the new version of the enabler is installed.

Results and outlook

Tests were done for both the instantiation of enablers (Active Monitoring enabler and Pilot 3A main Enabler), and for the downloading and update of the PCM calibrations. Under 4G connectivity, the detection of the new PCM calibration version was done within seconds following the restoring of the connectivity. PCM was subsequently updated once the engine was disconnected, since calibration update is set to be done when the vehicle is not in operation (because of driver safety). For the case of enablers, the detection of the enabler version was done also in the first minutes following the connection is available. If the image of the enabler was already present at the edge node, its instantiation was done automatically, while downloading was necessary for the case where the version was not available at edge.

3.3.2.18. KPI 2.3.6 – Number of Drivelets, which can be stored on a GWEN for later download

Table 95. Summary of KPI 2.3.6

Name	**Number of Drivelets, which can be stored on a GWEN for later download**				
Description	Drivelet data of interesting driving scenarios or issues can't be uploaded to the ASSIST-IoT cloud via mobile solutions due to the tight cost restrictions in the automotive industry. Therefore, these identified Drivelets have to be stored locally instead to allow a later download via cost efficient connectivity channels.				
Motivation	In order to identify and understand issues, relevant data has to be stored on the GWEN for later download. Therefore, the storage capacity for a certain number of drivelets has to be provided.				
Initial target	≥100 drivelets	**Score***	≥24000 drivelets (for 70 GB of memory)	**Achieved**	Yes
Rationale target selection	Reasonable number of drivelets to ensure an in-depth analysis of unknown issues noticed in the field.				

Measurement period	Before the third phase of the trials.
Partner/s responsible	UPV

Measurement methodology

The edge node has a limited available storage, so memory overflow must be avoided as the number of recorded drivelets increases along time. The system must compress data and verify that the occupied number memory is below a certain threshold (e.g. at least 20% of the disk is free); if the free storage is below the threshold, older data files must be removed.

The KPI is to be verified in laboratory tests (where pre-recorded drivelets are sent to the edge node emulating vehicle operation) and in real-life driving in the vehicle.

Results and outlook

Figure 46 summarises the metrics of the real-life drivelets recording along the project (24069 unique files). Size varies between them because: (1) driving conditions are different, resulting on different size length due to variations on the vehicle speed; (2) a different number of recorded data channels may be selected; and (3) compression results depends on the raw data. According to the maximum size of the compressed file, a total amount of 70 GB is needed for allowing storing 24069 drivelets. In the current implementation, available storage is 120 GB, which allows 20480 files (for maximum file size around 6MB) or 27306 files (average file size of 4.5MB). Minimum dedicated storage for the target 100 drivelets would be 600 MB (for maximum file size).

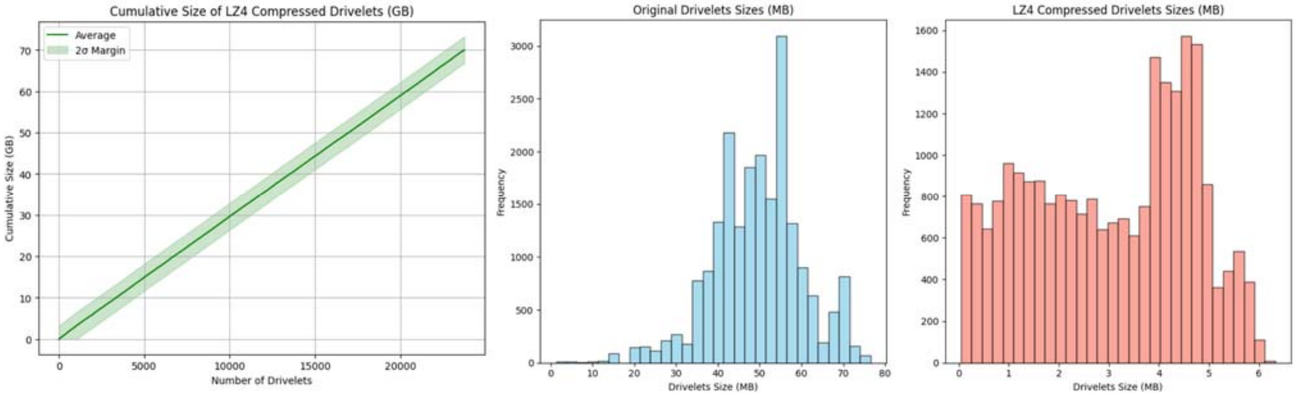


Figure 46. Number of files against GB of memory (left), and histograms of the file size before compression (center), and following lz4 compression (right).

Finally, it was tested the ability of the system of keeping the minimum free storage memory along the system operation. For that, files were added gradually, and free storage space was verified in each iteration, as shown in Figure 47.

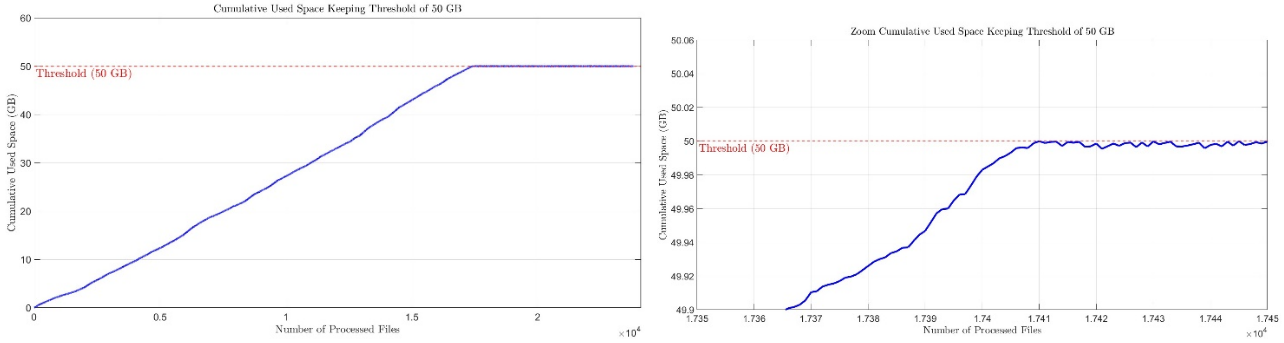


Figure 47. Evolution of free storage memory as new files are added to the system.

3.3.2.19. KPI 2.3.7 – Sever capacity to manage and monitor vehicle fleet

Table 96. Summary of KPI 2.3.7

Name	**Sever capacity to manage and monitor vehicle fleet**				
Description	The number of vehicles in a vehicle fleet is likely the most challenging number of GWENs within all ASSIST-IoT Pilot projects. Therefore, a KPI needs to be implemented which reflects the server capacity to handle a large number of edge nodes.				
Motivation	Even single model vehicle fleets can consist of a large amount of vehicles, as certain models are produced in numbers of several 100.000 units per year. Therefore, it is essential, that the ASSIST-IoT infrastructure is able to handle this vast amount of edge nodes. This can be supported by intelligent solutions like load balancing and queuing mechanisms.				
Initial target	≥200	**Score***	38.736	**Achieved**	Yes
Rationale target selection	The first target of ≥200 edge node was selected because of the limited testing capacities, however we acknowledge that a much higher value should be targeted. Thus, we increase this value to 10.000.				
Measurement period	M32-M36				
Partner/s responsible	UPV				

Measurement methodology

The ability to accommodate a greater number of connected vehicles depends primarily on the performance of the entry gate, that is, the edge provided by MQTT. Other factors (e.g., processing capacity of the APIs involved, e.g., LTSE and Fault-tolerance enabler, CPU/RAM/storage allocated, etc.) are considered by architecture design decisions, like the use of K8s for increasing the number of pods, if needed; the use of a load balancer for distributing the incoming traffic among them; and the implementation of the resource provisioning enabler to provision these resources in advance, when peaks of traffic are expected, to prevent any stress on the system. A

For the actual testing, the capacity of the tests depends on different factors such as VM configuration, network card capacity, and testing software capability to handle all these connections. Due to these limitations, the tests do not capture the real potential that could be achieved with greater testing resources. Thus, results should be bounded to the setup used.

The KPI measurement methodology leverages the tests has been emqtt-bench for conducting laboratory tests as testing with a real fleet of vehicles was not feasible.

Results and outlook

Results shown (Figure 48) that it has been possible to reach 38.736 online clients, considering a system of 8GB of RAM and 4 vCPU. In the case of the tests, there were two main limitations: the capacity of the server hosting the ASSIST-IoT deployment, meaning the resources available for the edge, and the Docker responsible for generating the connections.

Thus, with basic infrastructure upgrades, the connectivity is solved, and with the self-allocation capabilities of the system, the processing needs are controlled. Final aspect would be about the capacity of the storage and analysis engine to manage the data received. ASSIST-IoT considers Elasticsearch as part of the LTSE. Although some basic tests were performed filling the LTSE with one day of simulated data from 100.000 vehicles and queries could be performed correctly, dedicated effort is still required to further characterize its performance for large-scale fleets, including: optimization of data mapping considered (indexing load), data retention period, and multi-zone availability. In any case, elastic is a mature technological stack that could fit the use case, however, the pilot has not delved into full stress tests to properly validate the configurations that would be needed to accommodate the (expected) incoming data, in the proper transfer rate.

All good! No cluster issues found!

Cluster Overview

Cluster Size	Clients online	Clients offline	Connect Rate	Publish In Rate	Publish Out Rate	Msg Drop Rate	Msg Queue
1	38736	28235	0 sec	0 sec	0 sec	0 sec	0

Node Status

Node	Clients	Connect Rate	Publish In Rate	Publish Out Rate	Msg Drop Rate	Msg Queued	Su
VerneMQ@10.210.2.22 1.13.0	38736						

Figure 48. EDB webserver with cluster-related data

3.3.2.20. KPI 2.4.1 – Detected defects

Table 97. Summary of KPI 2.4.1

<table>
<tr><td>Name</td><td colspan="5">Detected defects</td></tr>
<tr><td>Description</td><td colspan="5">Detection and documentation of the vehicle’s exterior detection via manual user- or automated, KI-based inspection</td></tr>
<tr><td>Motivation</td><td colspan="5">It is the main business objective of the pilot. The system should enable the user to manually review the vehicle condition in time with the proper security and ergonomy. Additionally, it should assist him by automatically detect existing exterior defect with the help of AI-methodologies and interact with him towards a coherent status documentation. This should be available to multiple stakeholders of the application / business case</td></tr>
<tr><td>Initial target</td><td>40-60% recognition rate</td><td>Score*</td><td>40%-67%</td><td>Achieved</td><td>Yes</td></tr>
<tr><td>Rationale target selection</td><td colspan="5">The targets are set according to the expected KI-performance possibilities, end-user relevance and existing project goals.</td></tr>
<tr><td>Measurement period</td><td colspan="5">During the execution of the Pilot 3B trials</td></tr>
<tr><td>Partner/s responsible</td><td colspan="5">TWOT</td></tr>
</table>

Measurement methodology

For the documentation and digital reviewing of the images of the scanned vehicles we have created a dedicated version of the new frontend-environment of TwoTronic and integrated it with the new, upcoming ASSIST-IoT technologies. The resulted user-frontend supports the inspection of all acquired images and allows various users according to their role to review the vehicle conditions at the time of their scan. Local vehicle inspectors are enabled to review only the results of their corresponding scanners. Global reviewers can access all configured scanners and judge the vehicle conditions of several scanners. It is a functional proof, and no special measurement is necessary for that. To support a human-centred reviewing of the vehicle conditions the Pilot 3B system supports the acquisition, the processing and the transport of highest quality colour images via its edges, cloud and the end user. Even if the very high and fast data volume stresses the underlying infrastructure for processing power, storage demands and fast communication, the ASSIST-IoT architecture smooths this stress and allows the final reviewers to interactively review and detect all the existing defects of the vehicles on their monitors, offering an almost 100% manual recognition rate. The measurement methodology is empirical and statistically checked by comparing visualisation results against real vehicles inspections. Vehicles with known, typical damages have been guided through the scanner and the resulting scanner pictures were good enough to show almost all the damages in details. Thus, a physical human presence at the vehicle itself becomes redundant and the wished process digitalisation can be used.

For the automated, AI-based inspection the case is different, as extensive measurements are necessary to judge the system suitability and performance for the user's needs. Detection accuracy and speed of results generation for the interactive user are essential. Developing the AI-based vehicle surface-inspection framework we had to proceed in parallel: we were investigating the basic AI-algorithms to provide sufficient performance for the Pilot 3B application (recall & precision values of the surface inspection) and we were adapting the FL-framework of ASSIST-IoT to encapsulate these algorithms into the pilot environment. From the final business cases' point of view all surface damage categories are relevant with different priorities. However, as ASSIST-IoT is not a dedicated quality-assurance project and Pilot 3B a pilot-specific testbed for the major IoT-technologies we have focussed only on two major categories. They have been here studied as they have the most user added value: rim damages and scratches.

It was not possible in the project framework to integrate all the studied AI-algorithms into the FL-framework of the pilot. However, many AI-models have been separately studied (outside the FL-framework of the project) to evaluate their surface inspection performance. To evaluate the other benefits of the FL-approach for a IoT-hybrid architecture like the Pilot 3B independently of the underlying, application-optimised algorithms, only some basic algorithms have been utilized to give the necessary feedback of the FL-advantages.

During the development and the investigations of the basic surface-inspection algorithms the AI-training has been performed by a training data set. This has been created with certified reviews by experts (annotators) via the frontend-software. Several damage types have been annotated over months by many annotators creating both the needed ground-truth training-dataset as well as an *evaluation dataset*. The following figure gives an overview of the annotated damages by the human operators. We observe that the damage categories, most relevant to the end users, have got the highest priority during this work. This dataset was acting as the testbed of the developed solution for the pilot.

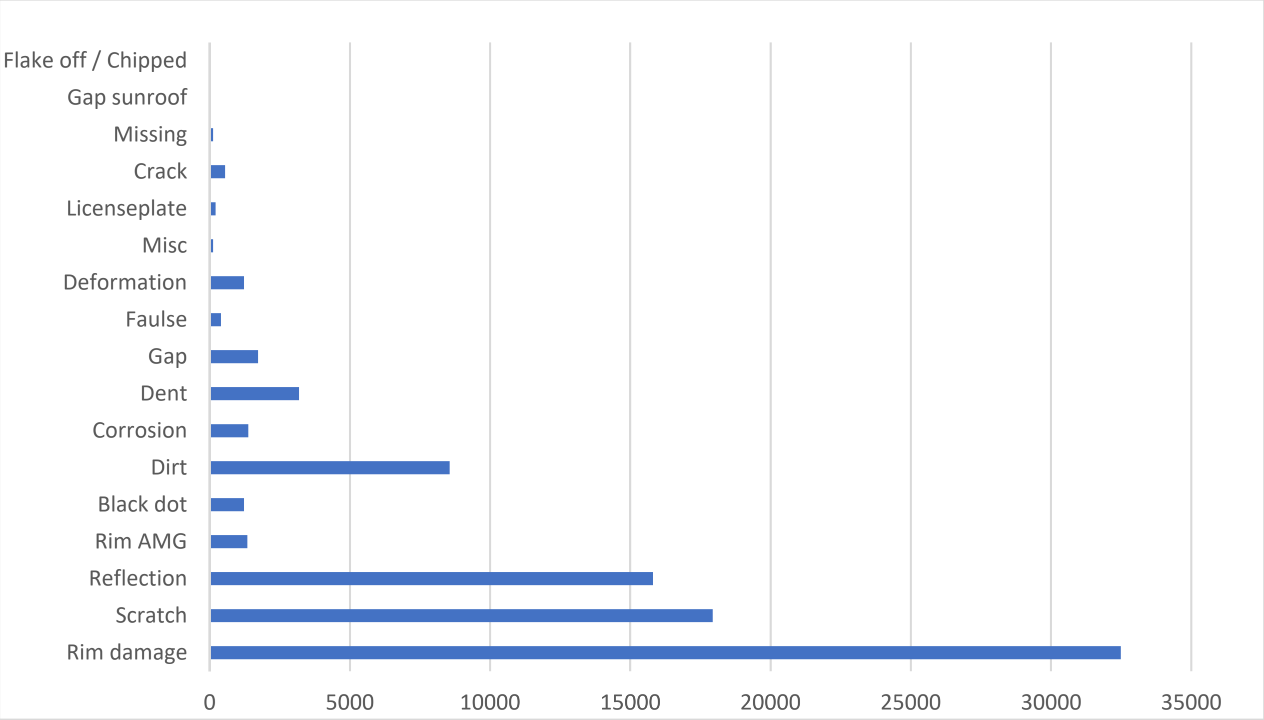


Figure 49. Amount of various annotated damage types as ground-truth data for AI-training

Our examination for the basic AI-algorithms for the vehicle surface inspection has seen good results with the Mask RCNN and ResNet 50 backbone algorithms. The following table shows an overview of the corresponding results.

Table 98. Performance overview of investigated AI-algorithms (Mask RCNN)

Damage	Ground truth	True positives	False positives	Recall (%)	Precision (%)
Rim	615	412	208	67	66.5
Scratch	279	168	148	60.2	53.2

Experiments with individually configured variances of the SegFormer algorithm are shown in the following table. Their performance fulfils the quantitative KPIs and are given in the following table. Only the precision-aspect would need further improvement.

Table 99. Performance overview of investigated AI-algorithms (SegFormer)

Damage	Ground truth	True positives	False positives	Recall (%)	Precision (%)
Rim	615	436	132	70.9	76.7
Scratch	279	173	291	62.0	37.3

Several methodologies have been applied to determine the recognition rate as performance measure of the used approaches. We are differentiating between manual, automated and hybrid reviewing & detection:

- In the manual reviewing process, the defects must be manually detected by the human operator by observing the images displayed by the pilot system on its own display (PC-monitor, or tablet or smartphone) within a given delay (after the vehicle scan) and / or after his own request for a given vehicle (via introduction of its licence plate number).
- For the automated inspection we have first applied the developed algorithms against a dedicated evaluation data set with human-reviewed and annotated damages on a statistically relevant number of images. The system results have been automatically checked against the known and annotated damages of the images - the evaluation dataset with its ground-truth data. Having a minimal level of reviewing quality of the system, the automated FL-AI system has been then activated to check all the incoming scanned images from fresh scans (100-200 images per scan). The results are validated by an active human-reviewing using the tactile dashboard. In the case of system mistakes a correction is offered to the final user, thus offering a hybrid usage. The resulting overall system performance will be checked and documented.
- Finally, having the pilot system in the loop of the daily operations of the pilot users, their overall, qualitative (not quantitative) experience will be also used to evaluate, whether the system offers a good enough detection rate and accuracy for their job.

The automated measurement with the evaluation dataset has been selected as the basic evaluation method, as the manual reviewing of scanned vehicles by an inspector team is a very time- and resources-consuming process. Major emphasis was placed on obtaining a dataset which would be extensive and realistic enough, allowing for the precise evaluation of the model's performance in laboratory conditions. Thus, the resulted structure comprises of 739 images, with 385 images with damages and 354 images without damages. The overall numbers of rim damage instances are 615, of scratch instances 279, of dent instances 124 and of deformation instances 14. Even if we have concentrated on rim- & scratch instances, we have also annotated existing anomalies in the reviewed images, because we wanted to have a complete damage description of the images within our evaluation dataset. The two considered damage types (rim & scratch) are enough to evaluate the core ASSIST-IoT capabilities.

In this context two major damages categories have been selected for the pilot operation due to their end-user importance (the remaining categories are not threatened during this pilot as this project has not the focus on quality assurance): **rim damages and scratches.** They are enough to evaluate the core ASSIST-IoT capabilities. The expected results will be evaluated and documented with respect to the corresponding targets of this KPI. They also be discussed with the pilot users for practical feedback as base to determine the next possible steps towards exploitation.

Results and outlook

With the evaluation dataset available, the two damage categories were evaluated based on the F1 score measure, as it considers both the precision of the detections and whether all target damages were covered. As mentioned in the previous paragraph the evaluation dataset consisted of 739 images, including 275 unique scratches and 578 unique rim damages. In 85% of the images, manually labelled scratches were limited to up to 2 separate instances of damage. Conversely, for rim damage, 85% of the images contained up to 6 unique instances. In both cases, the remaining images had a higher count of labelled target damages.

Since the evaluation dataset also contained images with no labelled damages, the true negative rate was measured alongside the F1 score to provide additional context in regard to the models' sensitivity and ability to properly process images of unimpaired vehicles.

Table 100. Results of the model for detecting defects

Damage category	F1 (%)	True negative rate (%)
Rim	45	82
Scratch	40	86

It is important to notice that, despite KPI being met, the overall result can further be improved by incorporating user's feedback, acquiring more relevant data and targeting specific systematic errors. These actions can contribute to the improvement of the detection accuracy of the model without compromising its performance on true negative images with no actual damages. Another possible improvement could be the redesign of the image acquisition conditions during the scanning process. In this case more versatile, general AI-methods may be required as the already manually won patterns for the training may not be well-suitable for the new illumination conditions. Further research would be necessary to bring the inspection quality to the next performance level.

The developed models were integrated into the FL Local Operations, which was then connected with the tactile dashboard, providing inference results for users to visualise, evaluate and store.

3.3.2.21.KPI 2.4.2 – Vehicle inspection elapsed time

Table 101. Summary of KPI 2.4.2

Name	**Vehicle inspection elapsed time**				
Description	It is the time needed to inspect and determine the entire exterior of a vehicle.				
Motivation	The targeted digitalisation process in these automotive applications shall offer a significant added value to the everyday operations. Shorter execution time of very often repetitive, daily work massively supports the operations productivity and supports the badly needed cost reductions.				
Initial target	10 min saving / vehicle	**Score***	10-15 min / vehicle	**Achieved**	Yes
Rationale target selection	Today the inspection process takes about 10-15 min (initial discussions with the customer (vehicle-owner), walk to the outside parking place of the vehicle, visual inspection around the vehicle, notification of the status, walk back to the office). Having the vehicle pictures on the desktop (or tablet) screen, before the customer arrives, improves quality of consultancy and it saves about 10 min. of the time of the customer consultant. Thus, he can support more customers per day.				
Measurement period	During the execution of the Pilot 3B trials				
Partner/s responsible	TWOT				

Measurement methodology

The KPI is the comparison between two numerical values indicating the elapsed time between the scenarios. The amount of time necessary for a manual inspection will serve as the basis for the comparison that will be made. While we are going to measure the amount of time that has passed for the ASSIST-IoT platform. An indirect success indication hereby is also the fact, whether the final users are changing their everyday operations utilizing the shorter inspection elapsed time. An example is to foresee less time dedicated to a customer service appointment, today being about 30 min to a shorter planning one.

Results and outlook

As the whole parking area of a service providing organisation as well as the individual parking place for any arriving customer varies, we have to do with statistical values and assumptions. Assuming a medium to large organization as the first place to digitalize their processes in the automotive sector via a scanner, a walking event (there and back) for the customer consultant to his customer´s vehicle is assumed with about 7-10 min. Adding a physical inspection of the exterior of the vehicle of about 3-5 min we come to a sum of 10-15 min needed time. At least some 5 min are also needed for manual documentation of the found vehicle status. With the digital scanner the walking event and the documentation time are eliminated. Thus, assuming a similar inspection time for the physical onsite or digital review, the whole process is cut by 10-15 min. We have been reported, that based on this fact, a large automotive manufacturer started experimenting with less necessary time per customer-appointment towards an efficiency improvement in his organisation. Final evaluation will be done after several weeks of trial. On this base, we are defining this KPI as achieved.

3.3.2.22. KPI 2.4.3 – Revenues for repairing services

Table 102. Summary of KPI 2.4.3

Name	**Revenues for repairing services**				
Description	Impact of the applied technologies of the revenue stream of the stakeholders adopting the solution				
Motivation	Business improving means particularly the introduction of new, innovative business models and turnover improvement. Getting more information about the status of the exterior of the vehicles allows the systematic introduction of additional services, like repair-on-the-spot of rim damages, so called upselling revenues. For instance, garages and their service advisers (customer consultants) can streamline their processes to promote solutions that are better suited to the needs of their clients. For instance, if the service consultant of a garage discovers a damaged rim on a scanned vehicle, he might ask the customer if he would be interested in purchasing a smart repair service for his rim, thereby generating unanticipated revenue for the company.				
Initial target	10% (more revenue)	**Score***	5.000 € / month est.	**Achieved**	Yes
Rationale target selection	Expected upselling revenue by the business modelling of automotive branches with yearly repeatable maintenance services. Additional argumentation for the amortisation of the investment of digital scanners				
Measurement period	During the execution of the Pilot 3B trials				
Partner/s responsible	TWOT				

Measurement methodology

Estimation / empirical methodology based on the real facts of the end users during the execution of the Pilot 3B on confidentiality base incl. anonymisation of operating units. The contact with a representative manager (technology innovator within his organisation actively using the pilot system) will be used to get in an anonymised way preliminary estimation about so call up-selling revenues. This revenue stream is being seen as opportunity-business. If the customer consultants of the automotive dealership are being informed by the pilot system about potential vehicle damages, they can optimize their consultancy interaction with their customers by proposing additional, cost-effective repairs having a win-win situation. A strong example is the case of rim damages. At high-class cars the rims have a cost range of 200-2.000 € each. Having seen in-time rim damages a recommendation to the customer for a smart-rim-repair with 200-300 € costs is highly appreciated and often accepted with pleasure.

Results and outlook

damages Within the testing period statistically 1-2 rim repair-proposals have been observed and 50% had been accepted. The average revenue- / repair costs were about 200 € per case. Thus, 200€ - 400€ additional revenue has been created. Within a monthly period of 25 working days 25 * 200€ = 5.000€ additional revenues could be realised, i.e. 60.000 € in a year. They are in the order of magnitude of one simple digital scanner (a bit less), meaning that the amortisation time could be just one year!

The additional revenues are seen as a good, additional motivation argument for an automotive organisation to improve their digital processes via a vehicle scanner. Although it is hard to mathematically prove them and even that it is true for organisations with rather expensive cars, the existing experience of the service managers of these organisations is supported by the actual KPI and is used to apply with additional arguments for the badly needed digitalisation of the European automotive business.

3.3.2.23. KPI 2.4.4 – Decrease in the transfer of data to preserve network bandwidth and adhere data privacy

Table 103. Summary of KPI 2.4.4

Name	**Data volume transferred**				
Description	The average data volume needed to be transferred between the edge and the cloud computing systems (per scan / per day / per week).				
Motivation	This KPI is about data traffic in the network connecting the edge-scanners with the cloud services of the organizations. Keeping the AI-execution in the cloud, all images from the scanned vehicles must be uploaded. This is a very large data volume creating a lot of communication costs as well as interaction delays between the system and the users. Missing ultra-fast networks don't support yet in many places of SMEs vast data transfers (starting from internal networks within the organisations and including public networking infrastructure). Additionally, the associated high-communication costs put a lot of challenges to support the digitalisation processes into the automotive world. Federated learning should be applied to minimise the data transfer (as only images with damages potentially need to be uploaded to the cloud for further processing), while the network's enablers can enhance the bandwidth according to various prioritised application criteria.				
Initial target	50% less data volume	**Score***	93% - 97% saving *(for all usual cases)*	**Achieved**	Yes, for most cases
Rationale target selection	The target is a result of the expected number of images after KI-reduction, target-pricing for network according to the business model and the reaction time for the user-centred system interaction.				
Measurement period	During the execution of the Pilot 3B trials				
Partner/s responsible	TWOT				

Measurement methodology

The amount of transferred data during a scan process cycle will be measured and compared by the system against the total amount of data won during this scan and will be compared against each other. A typical scan has a current data volume of its associated 150 images of about 150-250 MB. Finally, what matters for the end-user (vehicle inspector) are not all the images but only those with found damages. The additional data transfer needed for the FL-approach is here considered to be negligible, as only a few parameter values of the AI-models need to be transmitted in both directions.

Results and outlook

We have counted how many pictures the AI-based, automated inspection is producing per scan. If the accuracy of the used AI-approach would be 100% then we could reliably count with high efficiency and accuracy. Unfortunately, the accuracy of the used AI-algorithms was not high enough to allow the counting without human intervention. This is why, we could perform only limited, manually driven experiments by the counting by those images, which have been validated by a human validator (vehicle inspector).

The results were that the number of pictures with proposals diverge according to the scanner location. Classical OEM-dependencies with usual annual yearly services were featuring only about 3-5 images with damage proposals, whilst dependencies (garages) with paint-shop focus were naturally producing more images, about 5-10 per scan. As the final customer expects to get only his vehicle pictures with existing proposals (the others represent a "don´t care"-case) we are saving about 98%-97% respectively 97%-93% pictures to be uploaded into the computing server of the organisation (to be further processed in their integrated, business-oriented workflows). However, if the AI-performance is not good enough, then only two subsequent alternatives can be applied: either to locally store all the picture on an attached permanent storage for the needed time (depending on the use case typically 1-3 days or 1-2 weeks) or to send all the picture for permanent storage (for those use cases for longer period requirements - 6 to 12 months - leasing case) to the customer cloud. In all cases we would have a saving of up to 97% of data volume transfer except the last one, where no saving would be possible. For the long-term perspectives we are here considering, that the KPI has been achieved for the typical use case of the normal automotive garages.

3.3.2.24. KPI 2.4.5 – Deliver vehicle images to the user in time, after vehicle scanning

Table 104. Summary of KPI 2.4.5

Name	**Delivery time of vehicle images to the user**				
Description	It is the maximal time between the moment when the vehicle passes via the scanner and the presence of the results on the end-user screen. This is true for both use cases: with and without AI-support for the exterior inspection. In later case the execution time of the AI-engines is of course added to the overall elapsed time.				
Motivation	To be synchronised with the process operations using the digital scanner in an optimal way. The customer consultant wants to be visually informed about the vehicle's exterior and have time to think about his consultancy before his customer arrives at his desk.				
Initial target	3-5 min	**Score***	32,11 s	**Achieved**	Yes
Rationale target selection	An elapsed time of 3-5 min is typically less than the elapsed time between the scan time and the time, when the vehicle images are needed by the customer consultants, i.e., it is the time, which is normally needed by the vehicle driver to access his consultant after he has driven the car via the scanner, parked it in the parking area of the organisation and walked to the offices and the reception of the garage / automotive branch.				
Measurement period	During the execution of the Pilot 3B trials				
Partner/s responsible	TWOT				

Measurement methodology

We will measure the time between the registered time of one vehicle scan (included in the acquired scan meta data) and the time, when the images in the long-term storage are accessible to the via the Tactile Dashboard. Several measurements for different times during the time will be done and the max-min values will be determined.

Results and outlook

To determine the measurement of the end-to-end process, two measurements are done:

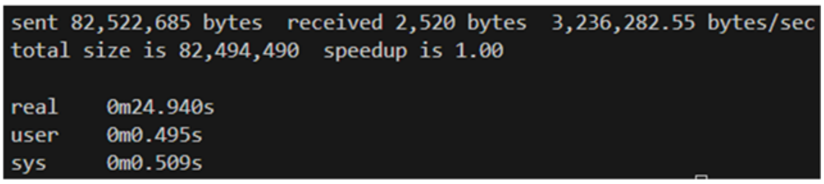
1. The time to send the data of the scan from the edge to cloud.
2. The time to process the scan images with FL (inference) in the edge.

To obtain the time needed to send a scan from the edge to the cloud, the time for processing 5 different scans has been computed:

Table 105. Elapsed time for sending a scan from edge to cloud with the DITE enabler

Scan name	Scan Size (MB)	Time (s)
Ablage/2024-03-06/GS001_MB_Prag-1_1709706890/	82,52	24,94
Ablage/2024-03-06/GS001_MB_Prag-1_1709706903/	86,88	24,9
Ablage/2024-03-06/GS001_MB_Prag-1_1709707037/	83,32	24,94
Ablage/2024-03-07/GS001_MB_Prag-1_1709794105	67,63	17,77
Ablage/2024-03-27/GS001_MB_Prag-1_1711525251/	73,46	25,25
Mean		**23,44**

One example of log can be found in the following figure, for the first scan:



```
sent 82,522,685 bytes  received 2,520 bytes  3,236,282.55 bytes/sec
total size is 82,494,490  speedup is 1.00

real    0m24.940s
user    0m0.495s
sys     0m0.509s
```

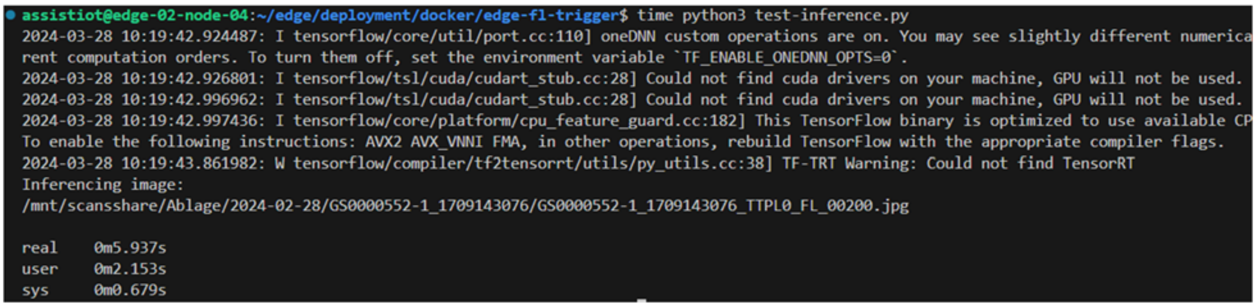
Figure 50. Log of one scan sent from edge to cloud

Besides, to obtain the average time for processing the received images with the FL local operations, a test has been made with 5 different images:

Table 106. Elapsed time for processing 5 images with the FL Local operations, in Pilot 3B edge premises

Image name	Time (s)
Ablage/2024-02-28/GS0000552-1_1709143076/GS0000552-1_1709143076_TTPL0_FL_00200.jpg	5,94
Ablage/2024-02-28/GS0000552-1_1709143076/GS0000552-1_1709143076_TTPL0_FL_00201.jpg	6,93
Ablage/2024-02-28/GS0000552-1_1709143076/GS0000552-1_1709143076_TTPL0_FL_00351.jpg	8,38
Ablage/2024-02-28/GS0000552-1_1709143076/GS0000552-1_1709143076_TTPL0_FL_00350.jpg	4,39
Ablage/2024-02-28/GS0000552-1_1709143076/GS0000552-1_1709143076_TTPL0_RL_00040.jpg	4,37
Mean	**6,00**

One example of log can be found in the following figure, for the first image:



```
● assistiot@edge-02-node-04:~/edge/deployment/docker/edge-fl-trigger$ time python3 test-inference.py
  2024-03-28 10:19:42.924487: I tensorflow/core/util/port.cc:110] oneDNN custom operations are on. You may see slightly different numerica
  rent computation orders. To turn them off, set the environment variable `TF_ENABLE_ONEDNN_OPTS=0`.
  2024-03-28 10:19:42.926801: I tensorflow/tsl/cuda/cudart_stub.cc:28] Could not find cuda drivers on your machine, GPU will not be used.
  2024-03-28 10:19:42.996962: I tensorflow/tsl/cuda/cudart_stub.cc:28] Could not find cuda drivers on your machine, GPU will not be used.
  2024-03-28 10:19:42.997436: I tensorflow/core/platform/cpu_feature_guard.cc:182] This TensorFlow binary is optimized to use available CP
  To enable the following instructions: AVX2 AVX_VNNI FMA, in other operations, rebuild TensorFlow with the appropriate compiler flags.
  2024-03-28 10:19:43.861982: W tensorflow/compiler/tf2tensorrt/utils/py_utils.cc:38] TF-TRT Warning: Could not find TensorRT
  Inferencing image:
  /mnt/scansshare/Ablage/2024-02-28/GS0000552-1_1709143076/GS0000552-1_1709143076_TTPL0_FL_00200.jpg

  real    0m5.937s
  user    0m2.153s
  sys     0m0.679s
```

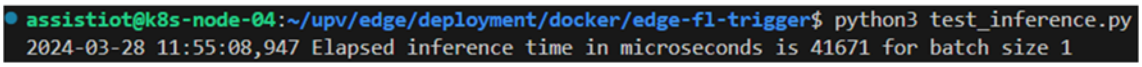
Figure 51. Log of the inference time for a single image, at TWOT's edge

In Pilot 3B, this time was too large. It was due an unexpected underperformance of the GPU at the edge, as in a desktop computer with GPU capabilities, this time was much lower, as one can see in the following table:

Table 107. Elapsed time for processing 5 images with the FL Local operations, in local desktop with GPU

Image name	**Time (ms)**
Ablage/2024-02-28/GS0000552-1_1709143076/GS0000552-1_1709143076_TTPL0_FL_00200.jpg	41,67
Ablage/2024-02-28/GS0000552-1_1709143076/GS0000552-1_1709143076_TTPL0_FL_00201.jpg	45,12
Ablage/2024-02-28/GS0000552-1_1709143076/GS0000552-1_1709143076_TTPL0_FL_00351.jpg	42,54
Ablage/2024-02-28/GS0000552-1_1709143076/GS0000552-1_1709143076_TTPL0_FL_00350.jpg	38,76
Ablage/2024-02-28/GS0000552-1_1709143076/GS0000552-1_1709143076_TTPL0_RL_00040.jpg	48,65
Mean	**43,35**

Considering that a scan contains approximately 200 images, the mean time to inference all the images in a scan should be around **8,67 seconds** for the GPU considered (Desktop-grade one).



```
● assistiot@k8s-node-04:~/upv/edge/deployment/docker/edge-fl-trigger$ python3 test_inference.py
  2024-03-28 11:55:08,947 Elapsed inference time in microseconds is 41671 for batch size 1
```

Figure 52. Log of the inference time for a single image, at local computer

Thus, the total time for having all the images ready at the cloud and passed through the inference system is 32,11 seconds, adding both times. In the real premises, this time was greater due to two factors: the underperformance of the GPU (which could take around 20 minutes per scan), and the fact of adding a second computer at the edge site instead of using the scanners' one (mainly for avoiding any potential disruption in their normal operation, more details can be found in D7.4). The latter aspect delayed having the scans at the edge some minutes, as a SAMBA environment had to be set up to share the scans from the scanner itself to the edge provisioned for the project. It also showed much slower results for sharing scans in comparison to the DITE enabler. Since in the future that time would not exist, it has not been considered.

3.3.2.25. KPI 2.5.1 – Architecture integrated in lab conditions (KVI 1.2)

Table 108. Summary of KPI 2.5.1

Name	**Architecture integrated in lab conditions**
Description	This KPI is about readiness of laboratory for implementation of most advanced elements of pilot's realizations (TRL6). This KPI is of Boolean type. Fulfilment of this KPI is considered when there is a readiness for testing and evaluation in a high-fidelity laboratory environment or in a simulated operational environment. To identify the compliance of this

	KPI, WP6 will monitor that all work is in line with the plan of Testing and integration (D6.2-6.3).				
Motivation	The integration of the various software and hardware components needs to be tested ahead of pilot trials on the construction site, to ensure smooth operation in real-life conditions.				
Initial target	True	**Score***	True	**Achieved**	Yes
Rationale target selection	–				
Measurement period	Before the main trials on the construction site.				
Partner/s responsible	SRIPAS				

Measurement methodology

All components needed for the pilot's operation (see deliverables D7.2 and D7.3) were deployed in laboratory conditions. The software was configured in the same way as for the trials on the construction site, and the all use cases were tested in a simplified manner. In case a particular device could not be used in the laboratory (e.g., the weather station), software emulators with identical interfaces were used.

Results and outlook

Over several days of virtual-only and physical tests, the deployed environment has demonstrated that it was able to support all use cases, on a basic level. The gathered performance metrics, user experience feedback, and identified software bugs were used to improve the solution ahead of the trials on the construction site. The tests were led by SRIPAS, with on-site participation of CIOP and MOW, and remote presence by ICCS and CERTH.

Figure 53. Laboratory tests of the integration of the MR device with the rest of the enablers.

3.3.2.26. KPI 2.5.2 – AI-driven pilots (KVI 4.1)

Table 109. Summary of KPI 2.5.2

Name	**AI-driven pilots**
Description	This KPI will account the number of all AI-driven use cases that have been successfully tested in the final pilot operations, either coming from the ASSIST-IoT pilot partners, or from external open calls.
Motivation	The project of ASSIST-IoT is formed by 3 pilots, each with different use cases. Although not all the use cases to be trialled will be AI-driven, several have considered any kind of intelligence within its purposes.

Initial target	> 20% trials (> 5)	**Score***	11 (6+5 Open Calls)	**Achieved**	Yes
Rationale target selection	As a KVI, it was selected in the proposal and approved by the European Commission evaluators. The reasoning was to provide a high percentage real use of AI-based demonstration.				
Measurement period	After the last execution of pilot trials				
Partner/s responsible	PRO				

Measurement methodology

KPI partner responsible requests the list of human-centric use cases deployed and tested to every pilot trial owner.

To consider that this KPI is fulfilled, at least 20% of the demos (i.e., at least **5 demos** from the total ***11 pilot trials + 15 open calls***) should contain some AI/ML ASSIST-IoT functionality listed below:

- Computer vision solution with the video augmentation enabler
- Intent-based network orchestration by making use of the network orchestrator enabler.
- Self-healing / self-geolocation functionalities provided to ASSIST-IoT smart devices.
- Any AI-based tool from open projects.

Results and outlook

Just considering the pilot trials, this KPI is met. Even if the recent AI bloom fully exploded in 2023, this was not unexpected for the project partners, who were already well-aware of the many possibilities it offers. For that reason, the number of trials in which AI is involved is quite significant (plus underlying systems that are also supporting by AI, like the smart orchestrator and the resource-provisioning enabler, transparent for the pilots). Some Open Call-specific trials also made use of AI, as listed in the table.

Table 110. AI-driven trials

Trial	**AI-based justification**
Pilot 1 – Trial #3	We needed to recognize containers from the video streams captured by the cameras installed in the remote crane. This additional functionality would help crane operators to work more efficiently as they will be able to easily identify the container assigned in the work instruction. We used the Video Augmentation enabler training and inference components.
Pilot 2 – Trial #1	Location Tracking and Location Processing enablers are used to localize workers and assets in real time on the construction site.
Pilot 2 – Trial #1	Frugal AI for heart rate measurement correction was implemented for the smartwatch worn by construction workers. See: Sowiński, P., et al., "Frugal Heart Rate Correction Method for Scalable Health and Safety Monitoring in Construction Sites. Sensors, 23(14), 6464"
Pilot 2 – Trial #2	Real-time fall detection using acceleration values from the workers' localization tags, with a custom LSTM model. The model was deployed using the FL Local Operations Inference component. See: Danilenka, A., Sowiński, P., Rachwał, K., Bogacka, K., Dąbrowska, A., Kobus, M., ... & Paprzycki, M. (2023). Real-time AI-driven fall detection method for occupational health and safety. Electronics, 12(20), 4257.
Pilot 3A – Trial #1	As in Pilot 1, the video augmentation enabler was considered with AR glasses to guide a garage operator to tackle possible issues of a car's engine. This could help reducing repairing time, bridging the gap between technical aspects (e.g., values from a sensor) and real life operations.
Pilot 3B – Trial #2	AI is in the core of this business. Detecting damages in cars is a slow, exhaustive task that offer big possibilities for AI. This pilot has demonstrating the possibility of AI for detecting

	several types of damages, aiming also at improving current models by the incorporation of FL in the end-to-end pipeline.
OC1 - ADDICTIVE	ADDICTIVE develops an innovative approach to reduce the effort needed for annotating large sets of time-series images. The annotation tool combines a preference elicitation approach with explainable AI and addresses data experts and domain experts. Overall, it hugely reduce the need of manual labelling, thus effort needed by annotators that could then devote time to other more productive tasks.
OC1 - RAZOR	RAZOR developed a scalable **IoT application to automatically detect road hazards in real time**. It automatically monitors road network conditions, contributing to a significant reduction of accidents and vehicle damages. The system is based on a **custom in-vehicle IoT board and a containerized backend software infrastructure**, towards timely alerting the involved stakeholders, connected to ASSIST-IoT. It uses Deep Learning Networks to estimate road hazards; vehicle abnormality requiring inspection; detect incident; correlate road conditions with fuel consumption (if available), etc.
OC2 - HazardMiner	The data collected from a vest worn by the users was used to train Machine Learning models to detect possible fall from highs as well as other trips, falls and slips that may occur at dangerous sites. The data gathered in different sites could be combined (via FL) to protect users' data while still ensuring a good model performance. The obtain model had very good accuracy, and could be used for further notification to OSH managers making use of the ASSIST-IoT platform.
OC2 – POSEIDON	They considered the use of Artificial Neural Networks to correct the lectures of GPS in maritime logistic environments. This is the great utility as these environments are surrounded of several metallic elements that can affect the performance of localisation systems. Thanks to it, the positioning accuracy of the assets could be increased, thus enhancing other use cases like e.g., path finder systems.
OC2 - MOTION	This Open Call supports exterior vehicle inspection by building a solution that provides, a fast image stitching algorithm, a robust Structure from Motion method combining depth data and images and a framework for illumination invariant image matching. It uses computer vision, deep learning, image to point cloud matching, considering the Fast Image Stitching Algorithm (FISA), and the marker-base Structure from Motion (SfM) method.

3.3.2.27. KPI 2.5.3 – Successful pilots' implementation (KVI 6.1)

Table 111. Summary of KPI 2.5.3

Name	**Successful pilots' implementation**				
Description	This KPI will identify the total number of pilot scenarios identified at the proposal phase (9), which have been successfully tested in the final pilot trials.				
Motivation	The main motivation ASSIST-IoT RIA-based is not only to develop technical solutions tested in lab but going beyond and also deploy and test those development for things and users that matter in real industrial scenarios.				
Initial target	>95%	**Score***	100%	**Achieved**	Yes
Rationale target selection	As a KVI, it was selected in the proposal and approved by the European Commission evaluators. The reasoning was to test most of technical solutions developed in the project under real environment conditions.				
Measurement period	After the last execution of pilot trials				
Partner/s responsible	PRO				

Measurement methodology

If 95% of the pilot scenarios identified in the proposal phase are successfully tested, the KPI is considered succeeded. Aiming at reducing repeated information across project deliverables, the rationale for this KPI will point to D7.4.

Results and outlook

All the final activities related to pilots' implementation are reported in D7.4, considering all the trials a success. A small summary taken from the conclusions of that deliverable are here provided:

- Pilot 1 successfully completed the three trials. From the integration perspective with ASSIST-IoT enablers, 14 of them were tested during the course of the trials and well-integrated with the pre-production environment of Malta Freeport. It has been agreed to move on after project ends, and put under operation tests the mobile app. Finally, there is also a clear intention to shift to a more microservices-oriented infrastructure the whole infrastructure being managed at the port.
- In Pilot 2, all the trials were successfully conducted during two stages, one at the construction site during summer 2023, and a final stage at CIOP labs early 2024. The pilot, divided into three trials (being the first one the one with higher number of use cases), has implemented a large number of features. All in all, the ASSIST-IoT solution tested during the pilot exceeded Mostostal expectations and showed potential in creating high value for the OSH processes at a construction site.
- Pilot 3A has focused on emissions and advanced diagnostics at the vehicle fleet level. Ford-Werke GmbH (FORD) has provided a state-of-the-art Ford Kuga equipped with an open-access Powertrain Control Module (PCM), serving as a prototype unit of the future connected, intelligent fleet. The project has successfully fulfilled its expectation in several aspects, including the gathering and pre-processing of local data, the management of services and data at large, distributed fleets, and the deployment of new calibrations and advanced diagnostic methods, among others.
- Finally, in Pilot 3B several standard ASSIST-IoT enablers have integrated, as well as modified versions of some of them have been developed, also including the integration of their dedicated application into the whole functional system. One key aspect of this pilot is that it was tested using two real scanners operating under real market conditions, with a supporting cloud environment. All in all, the project results support an enhanced scanner system of a new generation product line with multiple highlines, with promising validation features supported by DLT and exploiting FL-based AI-approach for automated surface inspection.

These insights are endorsed by the KPIs presented before, and with the context and explanations provided in D7.4.

Table 112. Successful pilot implementations

Pilot	Pilot Scenario	Brief trial execution justification
Port Automation	Automated alignment of CHE	Pilot 1 – Trial #2
	Yard fleet assets location	Pilot 1 – Trial #1
	Augmented Reality and Tactile Internet HMIs for fleet yard drivers	Pilot 1 – Trial #3
	Remote control of CHE	Pilot 1 – Trial #3
Smart Safety of workers	Optimization of safety and health plan with AR support	Pilot 2 –Trial #3
	Smart actuation of intelligent IoT devices with an adjustment to individual needs	Pilot 2 –Trial #1
	Identification of suspicious and undesirable behaviours within the construction site	Pilot 2 –Trial #2
	Advanced powertrain monitoring and diagnostics	Pilot 3A –Trial #1

Cohesive vehicle monitoring and diagnostics	Vehicle condition monitoring	Pilot 3B –Trial #1
		Total: 9/9 (100%)

3.4. Process evaluation

3.4.1. Selected KPIs

3.4.2. Data collection and measurement

3.4.2.1. KPI 1.1.1 – Stakeholders expressing interest (KVI 7.2)

Table 113. Summary of KPI 1.1.1

Name	**Stakeholders expressing interest**				
Description	This KPI aims at measuring the number of stakeholders that would be willing to adopt ASSIST-IoT to manage their infrastructure, to deliver NGIoT services or to anyhow improve their businesses. This KPI will be generated drawing from formal expressions of interest (letters/emails/publications/web notes/open calls' submissions) and will be tightly related with the work exerted in T8.4 and in T9.4.				
Motivation	This KPI aims at measuring the pervasiveness of ASSIST-IoT in terms of interest by stakeholders (external to the project).				
Initial target	>10	**Score***	74	**Achieved**	Yes
Rationale target selection	This number was defined during the proposal phase and confirmed in the GA signature.				
Measurement period	Last month of the project (M41)				
Partner/s responsible	UPV				

Measurement methodology

The measurement means will be to gather formal expressions of interest (letter/emails/publication/web notes/presence in open calls' submissions) by entities that are external to the project. Aiming at ensuring that sensitive information from those stakeholders is not publicly available, aggregated data are presented (per entity type, per country), with a short description of the motivation of such interest.

Results and outlook

Table 114. Stakeholders expressing interest

Topic	**Results**
Open call #1 proposals, with the objective of validating the ASSIST-IoT architecture and enablers while bringing added value to the project pilots	37 proposals received (1 from France, Slovenia, Denmark, Romania, UK, Austria, 2 from the Netherlands and Portugal, 3 from Belgium and Germany, 4 from Italy, 8 from Greece and 9 from Spain; 28 SMEs, 2 research centres, 7 universities)
Open call #2 proposals, with the objective of validating the ASSIST-IoT architecture and enablers while bringing added value to the project pilots	34 proposals received (1 from Switzerland, UK, Estonia, Belgium, 2 from The Netherlands and France, 4 from Poland, 5 from Italy, 7 from Spain and 10 from Greece; 26 SMEs, 1 research centre and 7 universities)
Email contacts	3 contacts received (1 from SMEs)

3.4.2.2. KPI 1.1.2 – External adopters

Table 115. Summary of KPI 1.1.2

Name	**External adopters**				
Description	Intimately linked with the Open Call success, as well as with the transferability analysis, this KPI will register how many "adoptions" of ASSIST-IoT have been successfully performed. Here, "adoption" applies either to the solution as a whole or to specific enablers adopted in external eco-systems, interoperating with other technologies.				
Motivation	This KPI measures the adoption scale of ASSIST-IoT results, and similarly to the former, depicts the relevance of the proposed solutions.				
Initial target	25	**Score***	25	**Achieved**	Yes
Rationale target selection	This target was selected as a balance between the complexity of integration of the different tools, operational structure and time.				
Measurement period	Last month of the project (M41)				
Partner/s responsible	UPV				

Measurement methodology

For each adoption, there is still the plan to document how these have been done. The ways of measurement of this KPI will be by providing the following information out of each of those adoptions:

- Scope (brief description)
- Adopting entity
- Integrated components (enablers, architecture…)
- Timeframe

Results and outlook

A minimum of 25 successful adoptions of ASSIST-IoT outcomes have been achieved. This number is expected to increase as long as partners keep evolving their solutions in the scope of further research actions, innovation lines within their entities or as part of their exploitation activities.

Table 116. External adopters

Scope	Entity	Components	Timeframe
R&D within the scope of execution of OC1 - BREATH	UPCT	ASSIST-IoT architecture (compliant enablers developed)	June 2022 – February 2023
R&D within the scope of execution of OC1 - ATHEMS	ComSensus	EDBE, LTSE	June 2022 – February 2023
R&D within the scope of execution of OC1 - RAZOR	INSIGHIO P.C.	EDBE, LTSE	June 2022 – February 2023
R&D within the scope of execution of OC1 - SPINE	Ubiwhere	ASSIST-IoT architecture, Video augmentation enabler	June 2022 – February 2023
R&D within the scope of execution of OC1 - SMART SONIA	DOTSOFT	ASSIST-IoT architecture, LTSE	June 2022 – February 2023

R&D within the scope of execution of OC1 - HAIR	Allbesmart LDA	EDBE, LTSE, ASSIST-IoT architecture (compliant enablers developed)	June 2022 – February 2023
R&D within the scope of execution of OC1 - ADDICTIVE	Bytefabrik.AI GmbH	EDBE, LTSE, ASSIST-IoT architecture (compliant enablers developed)	June 2022 – February 2023
R&D within the scope of execution of OC2 - POSEIDON	MYWAI	ASSIST-IoT architecture (compliant enablers developed), EDBE, LTSE, Smart orchestrator	June 2023 – January 2024
R&D within the scope of execution of OC2 - IOTLORAMESH	UPC	EDBE, Federated Learning enablers	June 2023 – January 2024
R&D within the scope of execution of OC2 - PROUD5G	ISRD Sp. z o.o.	ASSIST-IoT architecture (compliant enablers developed), Multi-link enabler, Smart orchestrator	June 2023 – January 2024
R&D within the scope of execution of OC2 - CHEEaaS	Kentyou	ASSIST-IoT architecture (compliant enablers developed), EDBE, LTSE	June 2023 – January 2024
R&D within the scope of execution of OC2 - MANTRA	FAVIT	Semantic Repository Enabler	June 2023 – January 2024
R&D within the scope of execution of OC2 - HAZARDMINER	Pumacy Technologies AG	Federated Learning suite, OpenAPI enabler	June 2023 – January 2024
R&D within the scope of execution of OC2 - HOOPS	Hopcast	ASSIST-IoT architecture (compliant enablers developed). Integration of D2D solution in the device and edge plane	June 2023 – January 2024
R&D within the scope of execution of OC2 - MOTION	UNIWA	OpenAPI enabler	June 2023 – January 2024
R&D within the scope of execution of the project HFREMEDI	UPV	Smart orchestrator, LTSE, Fault-tolerance enabler, EDBE	From January 2023
R&D within the scope of execution of the project aerOS	SRIPAS	Semantic suite	From September 2022
R&D within the scope of execution of the project aerOS	SRIPAS	Federated Learning suite	From September 2022
R&D within the scope of execution of the project aerOS	UPV	Smart orchestrators’ network management system	From September 2022
R&D within the scope of execution of the project RE4DY	S21SEC	Cybersecurity suite components – Incident detection and response applied to different environments	From September 2022
R&D within the scope of execution of the project ODIN	S21SEC		From January 2022
R&D within the scope of execution of the project IDUNN	S21SEC	Cybersecurity suite components – Incident response	From January 2022

Innovation applied within PRO's initiatives in port logistics	Autoridad Portuaria Bahía de Algeciras	Tactile Dashboard	From June 2021
Innovation applied within PRO's initiatives in port logistics	Autoridad Portuaria de Las Palmas	Tactile Dashboard	From February 2022
Innovation applied within PRO's initiatives in port logistics	Maritime transport agency of Georgia	Tactile Dashboard	From March 2024

3.4.2.3. KPI 1.1.3 – Satisfaction of tactile applications (KVI 5.1)

Table 117. Summary of KPI 1.1.3

Name	**Satisfaction of tactile applications**				
Description	This KPI aims at measuring the satisfaction of end users in ASSIST-IoT that will be making use of tactile applications (dashboard, MR enabler, glasses, AR functionalities, defects inspection, etc.). The surveyed users will come from both the project pilots (stakeholders of WP7) and from the Open Call participants (whenever appropriate).				
Motivation	It does not matter how good an application or system might be if it does not satisfy the expectations of potential end users. This KPI aims at having a measure of that satisfaction.				
Initial target	85%	**Score***	86,2 %	**Achieved**	Yes
Rationale target selection	A relatively high value is targeted to not neglect their design and development.				
Measurement period	Last month of the project (M41)				
Partner/s responsible	UPV				

Measurement methodology

To measure this KPI, the "*Revised Technology Acceptance Model*" will be used. Again, this classic methodology has now new, modern ways of application that will be explored in ASSIST-IoT. It will consist of a survey to be distributed to several persons that will be making use of ASSIST-IoT's tactile applications (dashboard, MR enabler, glasses, AR functionalities, defects inspection, etc.). The detailed procedure will be as follows:

1. A survey will be prepared, including questions directly inspired from the Revised Technology Acceptance Model, adapted to the features of the ASSIST-IoT specific tactile application. Questions are presented in the table of results.
2. This survey will be circulated to the funded Open Call projects of the second round, around M40 of ASSIST-IoT. Results will be gathered following all ethics and data protection instructions.
3. This survey will be fulfilled by the stakeholders of ASSIST-IoT pilots before the finalisation of the project (M40-M41). Partners requested will be KONECRANES, MFT, CMA CGM, MOSTOSTAL, CIOP-PIB, UPV and TWOTRONICS. A minimum of 5 members per pilot are requested to answer these questions, in a rank **from 0-10**.

Results and outlook

The number of surveyees depended on the topic under consideration, as some tactile applications were common to all pilots and others were specific. The target score was quite high (85%), but still it has been slightly surpassed (86,2%). In any case, analysis should be made per topic. Some interesting takebacks are the following: according to the users, although quite useful, the ease of use of the tactile dashboard of Pilot 1 & Pilot 2 has room for improvement. In Pilot 3A, although the score was higher, it was still the lower of the scores among the 4 options.

The computer vision and AR systems were the ones that got lower scores in all pilots (computer vision in Pilot 1, MR enabler in Pilot 2, and AR system for Pilot 3A), showing larger rooms for improvement. The only case in which reality surpassed the initial expectations was in the Pilot 3A system.

Finally, comparing expectation with reality, higher “deceptions” were found in the computer vison system (based on video augmentation enabler) of Pilot 1, FL management and AR enabler. In any case, most of the interfaces met the expectations of the users, being a very good result given that usability is a not the primary target of the action.

Table 118. Survey results of Satisfaction of tactile applications

Topic	**Mean value***
Manageability enablers (all pilots)	**8,85**
Intention (actual aim of using the application, before having used it)	9,11
Usefulness	9,17
Ease of use	8,44
Post-intention (related to uptaking/recommending it after using it)	8,67
Tactile dashboard web – Pilot 1 application	**8,4**
Intention (actual aim of using the application, before having used it)	9,0
Usefulness	8,4
Ease of use	7,6
Post-intention (related to uptaking/recommending it after using it)	8,6
Tactile dashboard mobile – Pilot 1 application	**8,9**
Intention (actual aim of using the application, before having used it)	9,0
Usefulness	9,2
Ease of use	8,8
Post-intention (related to uptaking/recommending it after using it)	8,6
Computer vision custom interface – Pilot 1 application	**5,8**
Intention (actual aim of using the application, before having used it)	6,8
Usefulness	6,0
Ease of use	5,6
Post-intention (related to uptaking/recommending it after using it)	4,8
Tactile dashboard web/mobile – Pilot 2 application	**9,2**
Intention (actual aim of using the application, before having used it)	9,6
Usefulness	9
Ease of use	8,6
Post-intention (related to uptaking/recommending it after using it)	9,6
Smartwatch custom interface – Pilot 2 application	**9,8**
Intention (actual aim of using the application, before having used it)	10

Usefulness	9,8
Ease of use	9,6
Post-intention (related to uptaking/recommending it after using it)	9,8
MR enabler – Pilot 2 application	**7,65**
Intention (actual aim of using the application, before having used it)	8,6
Usefulness	8
Ease of use	7,4
Post-intention (related to uptaking/recommending it after using it)	6,6
Tactile dashboard web – Pilot 3A application	**9,7**
Intention (actual aim of using the application, before having used it)	9,8
Usefulness	10
Ease of use	9,0
Post-intention (related to uptaking/recommending it after using it)	10
Edge car interface – Pilot 3A application	**9,35**
Intention (actual aim of using the application, before having used it)	9,0
Usefulness	9,8
Ease of use	8,8
Post-intention (related to uptaking/recommending it after using it)	9,8
AR custom interface – Pilot 3A application	**8,35**
Intention (actual aim of using the application, before having used it)	7,4
Usefulness	7,6
Ease of use	9,8
Post-intention (related to uptaking/recommending it after using it)	8,6
Tactile dashboard – Pilot 3B application	**9,55**
Intention (actual aim of using the application, before having used it)	10
Usefulness	9,4
Ease of use	9,6
Post-intention (related to uptaking/recommending it after using it)	9,2
FL management (pilots 2 & 3B)	**7,95**
Intention (actual aim of using the application, before having used it)	8,6
Usefulness	8
Ease of use	7,6
Post-intention (related to uptaking/recommending it after using it)	7,6
Total:	**8,62 (86,2%)**

3.4.2.4. KPI 1.1.4 – IoT pillar institutions involved

Table 119. Summary of KPI 1.1.4

Name	**IoT pillar institutions involved**				
Description	This KPI measures the collaboration capacity with relevant institutions in Europe related to the different technical fields of the project. In particular, entities related to IoT (AIOTI, NGIoT, EU-IoT…), 5G (6GIA, 3GPP…), IA (DSBA, DAIRO, Gaia-X…) will be contacted and requested for collaboration to ensure that the prominent visions of the state of the art and beyond are incorporated into the project. This KPI will gather the different interactions and involvement of those entities with ASSIST-IoT.				
Motivation	This KPI aims at showcasing the relevance of the project among the relevant entities related to the technological fields of the project.				
Initial target	12	**Score***	14	**Achieved**	Yes
Rationale target selection	This target was selected as a balance between the human effort needed to effectively contribute in these entities and time.				
Measurement period	Last month of the project (M41)				
Partner/s responsible	UPV				

Measurement methodology

The measurement means of this KPI will consist of listing the contact/interaction/liaison activities performed with the relevant IoT pillar institutions. Since a continuous monitoring of this activity is performed under the scope of WP3, the KPI will depict the outcomes of such task, considering innovation, pre-standardization and standardization associations.

Results and outlook

The project has collaborated with the following initiatives: EU-IoT (white papers, webinars, Hackathon), AIOTI (white papers, webinars, workshops), EUCEI (publications, seminars), HipeaC (workshop, conference), NG-IoT (workshops), BDVA (participation in data weeks, forums), ETSI (physical meeting), EU-OSHA (seminar), ITU (active participation in working groups SG13 & SG16, also contributed in SG20), IEEE SA (active participation in CEC & CCSC), TIC4.0 (partners with key role in the board, specific for the port ecosystem), AGVES (partners with key role in the subgroup, specific for automotive ecosystem), IoTForum (workshops and papers presented in organized workshops of its main conferences), CEN (key participation in WG31, for the safety of work ecosystem).

Other interactions have taken place as one can see in concurrent WP9 deliverables, being the former the most relevant ones in terms of successful collaborations.

3.4.2.5. KPI 1.1.5 – System usability scale

Table 120. Summary of KPI 1.1.5

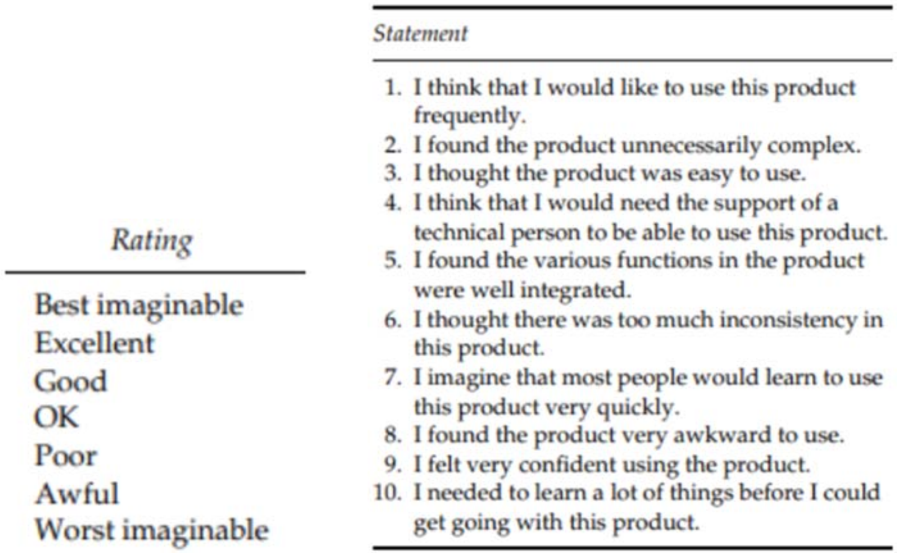
Name	**System usability scale**
Description	This KPI aims at measuring the usability of ASSIST-IoT system as a whole. ASSIST-IoT is an NG-IoT platform that covers all the layers of an IoT deployment and will be able to provide real time services over real time data, devices, network and applications. This KPI will determine how good, in terms of usability, will this platform be.
Motivation	It represents the usability of the system for both experts (system administrators, enablers developers, IT staff…) and non-experts (stakeholders, data scientists…) in NG-IoT

	deployments. Needed to assess whether the provided outcomes will be easier to be embraced after the project ending.				
Initial target	70%	**Score***	73,9%	**Achieved**	Yes
Rationale target selection	According to references consulted (see methodology below), those products (in this case, ASSIST-IoT evaluated results) that are acceptable are those of score 70 and beyond.				
Measurement period	From 1/6/23 (M32) to end of the project (M41).				
Partner/s responsible	UPV				

Measurement methodology

the indications settled in the work "*An Empirical Evaluation of the System Usability Scale. Aaron Bangor, Philip T. Kortum & James T. Miller*" will be followed. This work comes from an article originally published in 2008, but it has been reviewed, applied and commented repeatedly over the years. A summary of the procedure for measuring this KPI is:

- Categorisation of the respondents depending on their profile and the results of ASSIST-IoT that they use.
- A division of "type of systems to be rated". Here, every respondent category will be assigned to one or more "surveys" that will differ from each other. Based on this classification, each respondent type will be in charge of evaluating the usability of their corresponding results.
- The usability will be measured using the 10 original statements of the SUS instrument (left image below) by marking each of the statements to a specific rating among a list (right image below).
- More statements will be added to the statements depending of the type of result whose scalability is being measured.
- Statistics will be generated, as well as reflections on the usability scale of each identified type of result.



Rating
Best imaginable
Excellent
Good
OK
Poor
Awful
Worst imaginable

Statement

1. I think that I would like to use this product frequently.
2. I found the product unnecessarily complex.
3. I thought the product was easy to use.
4. I think that I would need the support of a technical person to be able to use this product.
5. I found the various functions in the product were well integrated.
6. I thought there was too much inconsistency in this product.
7. I imagine that most people would learn to use this product very quickly.
8. I found the product very awkward to use.
9. I felt very confident using the product.
10. I needed to learn a lot of things before I could get going with this product.

Figure 54. Usability scale

This KPI considers **the same methodology** as KPI 4.4.3 (Section 3.2.2.14), this time applied to the system instead of the interfaces. A minimum of 5 members per pilot were requested to answer these questions, **from 0-10 this time**. Change in the description and range is due to the fact that KPIs were managed by different partners, but inherently are the same. The overall score is computed considering that "negative questions" are inverted (i.e., 2, 4, 6, 8, 10), as lower scores are the desired ones.

Results and outlook

20 different end-users filled in the questionnaire, providing a quantitative value between 1 (strongly disagree) and 5 (strongly agree). The KPI was considered successful if **the score is greater than 70% (7/10)**. As one can see, a 73,9% was obtained, showing a good level of acceptance of the system according to its adopters. More specific numbers about specific technologies are reported in further KPIs, being KPI 1.1.6 (Section 3.4.2.6) the most interesting one for granular data. Here, results are promising but still shows that improvement can be achieved. Specifically, responses are aligned in the sense that the offerings have great interest, but still there are some difficulties in leveraging them (especially when combined), thus requiring the need of experts to fully exploit its capabilities.

Table 121. Survey results of System usability scale

Topic	**Mean value***
1. I think I would like to use ASSIST-IoT platform or a subset of its enablers frequently	9,37
2. I found the product unnecessarily complex (“0” if fully agree with the statement)	3,00 (7,00)
3. I think the outcomes I used from ASSIST-IoT were easy to use	7,68
4. I think I’d need the help of supporting staff to make use of the project outcomes (“0” if fully agree with the statement)	4,10 (5,90)
5. I found the solutions well integrated	7,84
6. I found too many inconsistencies in the products used (“0” if fully agree with the statement)	3,16 (6,84)
7. I imagine most people would learn to use the ASSIST-IoT products very quickly	6,89
8. I felt the solutions awkward to use (“0” if fully agree with the statement)	2,89 (7,11)
9. I felt confident using the solutions	8,53
10. I needed to learn a lot of things before I could get going with the solutions (“0” if fully agree with the statement)	3,26 (6,74)
Mean	7,39 (73,9%)

3.4.2.6. KPI 1.1.6 – Technology acceptance

Table 122. Summary of KPI 1.1.6

Name	**Technology acceptance**				
Description	This KPI will measure the “acceptance” of the technology (ASSIST-IoT as a whole and all the different enablers), drawing from the experiences from both the stakeholders of the project (pilot owners and app developers/IT practitioners) and the Open Call participants. This KPI is very similar to KPI-1.1.3. The main difference is that now the objective is to gather information about usability of the whole platform (architecture, enablers, etc.) while KPI 1.1.3 was specifically addressed to tactile applications.				
Motivation	This KPI helps understanding if the technological implementations are aligned with the expectations of stakeholders and end users.				
Initial target	~~>5~~ >80%	**Score***	84,0%	**Achieved**	Yes
Rationale target selection	(Original target indicated was a typographic error). High target considered aiming at ensuring that the technological proposition is aligned with real needs.				

Measurement period	After the last period of pilot validation activities (M40-M41).
Partner/s responsible	UPV

Measurement methodology

To measure this KPI, the "*Revised Technology Acceptance Model"* will be used. Again, this ancient methodology has now new, modern ways of application that will be explored in ASSIST-IoT. A target value of >5 has been set as a target. The process will be very similar to the previous one:

1. A survey will be prepared, including questions directly inspired from the Revised Technology Acceptance Model, in a very generic way for the whole ASSIST-IoT platform and its enablers.
2. This survey will be circulated to the funded Open Call projects of the first round, around M40 of ASSIST-IoT. Results will be gathered following all ethics and data protection instructions. It is expected that the number of participants here will be larger than for KPI 1.1.3, as all Open Call projects use some part of ASSIST-IoT, and thus are recipients of this survey (while not all of them would be using tactile applications).
3. This survey will be fulfilled by the stakeholders of ASSIST-IoT pilots before the finalisation of the project (M40-M41). Partners requested will be KONECRANES, MFT, CMA CGM, MOSTOSTAL, CIOP-PIB, UPV and TWOTRONIC. A minimum of 5 members per pilot are requested to answer these questions, in a rank **from 0-10**.
4. It is expected that both KPI-1.1.3 will be conducted jointly, answered (or not) depending on the applications that have been used by each consulted entity.

Results and outlook

The number of surveyees depended on the topic under consideration, as some technologies were not used in some of the project pilots. The target score was quite high (80%), but still it has been surpassed with certain margin (84,0%). Insights should be extracted per plane/vertical, but overall the achieved number is quite good. That indicates that the selected technologies were in general aligned with the Industry and novel trends, and that their applicability was useful in the scope of the project pilots.

One takeaway is the potential improvement of the usability of the involved technologies, or rather, their ease of use, which in general had the lowest scores in the different technological areas (aligned with KPI 4.4.3 - Section 3.2.2.14). Besides, expectations were slightly higher than actual feeling after usage, which can be expected. Still, surprising results were obtained with respect to cybersecurity monitoring and DLT, in which reality surpassed the expectations that pilot representatives had on them. In terms of overall system, represented in the final rows, adopters are accepting the proposition, but request more work on its overall usability, giving room to further innovation on top of it.

Finally, specific aspects can be highlighted. First, the expectations of the project GWEN were not fully met, mainly due to the difficulties that posed its use (even though, once working as in Pilot 2, results were very promising). Also, the OpenAPI and the Authorization enablers require more work in contrast to other enablers, although their score was fine. Still, considering the ambitious numbers of technologies and enablers adopted, the figures show a good level of overall acceptance, showing their potential to be integrated in the operational processes of the project's pilots as well as by external stakeholders.

Table 123. Survey results of Technology acceptance

Topic	Mean value*
Device and Edge: GWEN (pilots 1, 2 & 3)	**6,5**
Intention (actual aim of using the application, before having used it)	8,27
Usefulness	6,73
Ease of use	5,67

Post-intention (related to uptaking/recommending it after using it)	5,47
Smart networking and control plane: Smart orchestrator + manageability enablers (all pilots)	**8,5**
Intention (actual aim of using the application, before having used it)	8,68
Usefulness	8,68
Ease of use	8,33
Post-intention (related to uptaking/recommending it after using it)	8,32
Data management plane: Semantic suite (Pilot 2)	**9,1**
Intention (actual aim of using the application, before having used it)	9,4
Usefulness	9,6
Ease of use	8,00
Post-intention (related to uptaking/recommending it after using it)	9,4
Data management plane: LTSE (all pilots)	**8,93**
Intention (actual aim of using the application, before having used it)	9,10
Usefulness	9,00
Ease of use	8,84
Post-intention (related to uptaking/recommending it after using it)	8,79
Data management plane: Edge Data Broker (all pilots)	**8,70**
Intention (actual aim of using the application, before having used it)	9,26
Usefulness	9,00
Ease of use	8,00
Post-intention (related to uptaking/recommending it after using it)	8,53
Applications and services plane: Tactile dashboard, BKPI & PUD (all pilots)	**9,14**
Intention (actual aim of using the application, before having used it)	9,68
Usefulness	9,42
Ease of use	8,68
Post-intention (related to uptaking/recommending it after using it)	8,79
Applications and services plane: Open API enabler (all pilots) *** MR enabler & Video augmentation, considered evaluated as per KPI 1.1.3**	**7,30**
Intention (actual aim of using the application, before having used it)	7,79
Usefulness	7,53
Ease of use	7,00
Post-intention (related to uptaking/recommending it after using it)	6,89
Scalability vertical: FL suite (pilots 2 & 3b)	**9,30**
Intention (actual aim of using the application, before having used it)	9,4
Usefulness	9,3
Ease of use	9,4

Post-intention (related to uptaking/recommending it after using it)	9,1
Security, privacy and trust vertical: IdM & Authz enablers (all pilots)	**8,18**
Intention (actual aim of using the application, before having used it)	8,89
Usefulness	8,74
Ease of use	7,47
Post-intention (related to uptaking/recommending it after using it)	7,63
Security, privacy and trust vertical: Cybersecurity suite (pilots 3a & 3b)	**8,5**
Intention (actual aim of using the application, before having used it)	7,89
Usefulness	9,00
Ease of use	8,66
Post-intention (related to uptaking/recommending it after using it)	8,45
Security, privacy and trust vertical: DLT enablers (all pilots)	**8,41**
Intention (actual aim of using the application, before having used it)	8,14
Usefulness	8,36
Ease of use	8,79
Post-intention (related to uptaking/recommending it after using it)	8,36
Overall ASSIST-IoT platform and enablers	**8,19**
Intention (actual aim of using the application, before having used it)	8,74
Usefulness	8,63
Ease of use	7,32
Post-intention (related to uptaking/recommending it after using it)	8,05
Mean:	**8,40 (84%)**

*** Self-* enablers are not evaluated as are transparent and less intuitive for pilot owners**

3.4.2.7. KPI 1.2.1 – Target customers

Table 124. Summary of KPI 1.2.1

Name	**Target customers**				
Description	This KPI aims at quantifying the number of potential target customers of ASSIST-IoT development				
Motivation	The project is committed to approach as many stakeholders as possible in order to address a sustainable exploitation path beyond ASSIST-IoT lifetime.				
Initial target	500	**Score***	>1999	**Achieved**	Yes
Rationale target selection	The value was identified during the proposal phase. This value represents a well representative range of customers from the 13 companies involved in the project, leading to almost 50 target customers identified by every partner.				
Measurement period	During January – March 2024				
Partner/s responsible	PRO				

Measurement methodology

Project partners with the leadership of the Innovation Manager identifies target customers, users, and beneficiaries for whom our hypothetical business model may create sustainability change for ASSIST-IoT. Both, general ICT target customers aiming at exploiting the ASSIST-IoT platform as a whole, as well as more specific ASSIST-IoT Pilots will be identified by means of data market analyses.

Results and outlook

Considering the market in which the project KERs belong to, the result is the sum of the companies that could make use of them. Of course, numbers could be increased in the future with the adopters of the rest of the KERs and individual innovation elements, but in any case this number shows the innovation potential of the project KERs in their respective markets.

Table 125. Potential customers of the project KERs

KER1	KER4	KER5 and KER7
328 Container terminals in the world	769 OEMs 487 rental car companies	415 Open source IoT and Edge projects

3.4.2.8. KPI 1.2.2 – Business plans for exploitable assets, stakeholders, and key alliances (KVI 7.1)

Table 126. Summary of KPI 1.2.2

Name	**Business plans for exploitable assets, stakeholders, and key alliances**				
Description	This KPI is validated if (and only if) the 100% identified worth-to-pay 4 Key Exploitation Results of the project have defined a clear and sustainable business plan.				
Motivation	The main purpose of the Innovation Management activity is to track the innovations generated in the project, analysing, in the form of exploitable assets, namely Innovation Elements				
Initial target	100%	**Score***	100% (4/4)	**Achieved**	Yes
Rationale target selection	This KPI was clearly agreed during the proposal phase, in order to prove that there are tangible results of the Innovation Management activities				
Measurement period	During January – March 2024				
Partner/s responsible	PRO				

Measurement methodology

The T9.4 Innovation task address the further exploitation of ASSIST-IoT outcomes. 7 Key Exploitable Results were identified and reported in D9.7. Among them, and thanks to the Horizon Results Booster, 4 were selected as the ones with a clear exploitation path. As long as all these 4 KERs provide their business model canvas in D9.7, the KPI will be fulfilled.

Results and outlook

The business models of the project's KERs can be found in D9.7. The target of the project was developing those models for the KERs selected by the Horizon Results Booster (HRB). Following their guidance, different templates were filled, particularly for **KER 1 – TrackGUI App, KER4 – Enhanced Scanner, KER5 – GWEN, and KER7 – ASSIST-IoT platform**, among which one can find the exploitations intentions summary, the exploitation route, among others (see D9.7).

3.4.2.9. KPI 1.2.3 – Addressable market

Table 127. Summary of KPI 1.2.3

Name	**Addressable market**				
Description	This KPI is very similar to the KPI.1.2.1. Whereas the target customers of the former KPI refers to those companies' subject of being recipients of ASSIST-IoT solutions, the latter will be evaluated by estimating with consulting and statistical reports, the number of users that are actually using different IoT platforms that are providing similar services than ASSIST-IoT has been developed.				
Motivation	Project partners need to know the audience size they are committing within the project.				
Initial target	10k users	**Score***	> 400k	**Achieved**	Yes
Rationale target selection	A wider audience is needed for guaranteeing a successful business after project ends. 10k users was assumed from the initial proposal preparation phase as the cornerstone of the project.				
Measurement period	During January – March 2024				
Partner/s responsible	PRO				

Measurement methodology

Research desk making use of the LinkedIn and RocketReach website platforms allow us to identify the number of employees for some of the most representative companies in the three industrial sectors of the project, which in a near future might use some of the ASSIST-IoT development.

Results and outlook

Table 128. Addressable market

Sector	**Number of companies (users) potentially leveraging ASSIST-IoT-related platforms**
Container Terminals	CMA – CGM (2689), EUROGATE Terminals (507), APM Terminals (47114), MSC Terminals (8960)
Construction	Acciona (11898), Vinci France (4702), ACS (9698), Skanska (33953)
Automobile	Mercedes-Benz Group (298000), Volkswagen AG (15407)
Total: 432.928	

3.4.2.10. KPI 1.2.4 – Innovative business models (KVI 8.2)

Table 129. Summary of KPI 1.2.4

Name	**Innovative business models**				
Description	This KPI analyses the proposed business plans of the 4 most promising ASSIST-IoT KERs, and subjectively compared them with other H2020 and HE business plans.				
Motivation	In order to succeed, the KERs of the project have to identify go-to-market strategies sufficiently innovative that elevate companies' efforts beyond a regular business plan.				
Initial target	> 4	**Score***	3	**Achieved**	No
Rationale target selection	The target was selected in the proposal and approved by the European Commission evaluators. The reasoning was to provide >=1 innovative business model per pilot.				
Measurement period	During January – March 2024				

Partner/s responsible	PRO

Measurement methodology

The Innovation Manager requests the list of business models identified for the 4 most promising KERs of the project, which should clearly emphasize their innovative approach with respect to the competence.

Results and outlook

The business models of the project's KERs can be found in D9.7. The target of the project was developing those models for the KERs selected by the Horizon Results Booster (HRB). Following their guidance, different templates were filled, particularly for **KER 1 – TrackGUI App, KER4 – Enhanced Scanner, KER5 – GWEN, and KER7 – ASSIST-IoT platform**, among which one can find the exploitations intentions summary, the exploitation route, the SWOT analysis and the risk assessment, among others (see D9.7). However, due to limited time remaining after the last meeting with HRB (11/3/2024), little time was remaining for providing a valid model for KER5. This will be developed in the following weeks and be incorporated to the pool of business models of the project.

3.4.2.11. KPI 1.2.5 – Technological advantage

Table 130. Summary of KPI 1.2.5

Name	**Technological advantage**				
Description	It is expected that Long-term Operational Expenditures (OPEX) will become the dominant economic trend in NG-IoT future deployments. This KPI evaluates how much would be the OPEX cost of the deployed IoT services on ASSIST-IoT pilots, and compared to current costs (deployment and maintenance).				
Motivation	The consortium was fully aware that the project should not only provide technological advancements, but also advantages in terms of cost with respect to current and well established IoT platforms. The motivation is to prove that ASSIST-IoT is a sustainable and even cheaper solution.				
Initial target	10-15%	**Score***	34%	**Achieved**	Yes
Rationale target selection	At least a 10% of cost reduction should be guaranteed in order to convince a customer to change their platform.				
Measurement period	During January – March 2024				
Partner/s responsible	PRO				

Measurement methodology

This KPI identifies the monthly maintenance cost of the final deployed ASSIST-IoT enablers into project pilots and compares with the total OPEX demanded in case the pilot owner was using a regular public cloud provider. If the cost reduction is greater than 10%, the KPI is fulfilled.

Results and outlook

This KPI is directly related with the previous KPI 4.6.1 Distributed AI costs. To sum up, the results have been obtained for the Pilot 3B are the following:

Before ASSIST-IoT: CAPEX: 5.250 € once + **OPEX / year: (250€ + 250€ + 18.000€)**

After ASSIST-IoT: CAPEX: 7.350 € + **OPEX / year: (350€ + 6.000 €)**.

The difference in OPEX cost of the two alternatives lead to a yearly OPEX reduction of up to 34%. Given an initial target of 10-15%, it was considered that this KPI should be fulfilled.

3.4.2.12. KPI 1.2.6 – Diversification

Table 131. Summary of KPI 1.2.6

Name	**Diversification**				
Description	This KPI aims at verifying that the identified principles and pillar of the project are of interest for their companies.				
Motivation	ASSIST-IoT aims to be a realistic, pilot-driven, NG-IoT platform. To validate ASSIST-IoT features and associated enablers, the project is addressing three main verticals: port logistics; construction, and automotive. However, the scope of ASSSIST-IoT is to become a vertical-agnostic platform, so that any vertical market can apply the functionalities of ASSIST-IoT without significant changes on the overall platform				
Initial target	8	**Score***	8	**Achieved**	Yes
Rationale target selection	The target was selected in the proposal and approved by the European Commission evaluators. The reasoning was to address at least 5 more verticals than the ones of ASSIST-IoT.				
Measurement period	During January – February 2024				
Partner/s responsible	PRO				

Measurement methodology

This KPI addresses the same target as KPI 1.3.7 (Section 3.4.2.19), with identical score (only thing, here the 3 sectors of the project pilots are considered). The methodology is described in that section.

Results and outlook

As aforementioned, results and justification are provided in KPI 1.3.7. These verticals are: 5G, Energy, Smart city, Water management, Agriculture, Maritime logistics, Construction and Automotive.

3.4.2.13. KPI 1.3.1 – IPRs

Table 132. Summary of KPI 1.3.1

Name	**IPRs**				
Description	This KPI represents the number of partners and third parties who are planning to exploit the intellectual property from their own results.				
Motivation	This KPI will evaluate the actual number of innovations that have been extracted from the project results, and are leading to potential Intellectual Property Rights.				
Initial target	≥ 5	**Score***	>7	**Achieved**	Yes
Rationale target selection	The value was agreed in the proposal phase. It was reused from previous experience from project partners.				
Measurement period	During January – March 2024				
Partner/s responsible	PRO				

Measurement methodology

To collect the data for this KPI, ongoing individual exploitation questionnaires, including face-to-face interviews with partners are periodically generated. These activities may result in the generation of several exploitation models, such as licensing, joint ventures, pay-per-service, spin-off, patents, etc. To do so, the different exploitation plans from D9.8 are analysed.

Results and outlook

Once analyzed the individual exploitation plans, it was evident that the KERs are the main sources of exploitation (**KER1 – TrackGUI, KER2 – Workers safety system, KER3 – In-service emission diagnostics, KER4 – Enhanced scanner, KER5 – GWEN, KER6 – Enhanced security center, and KER7 – ASSIST-IoT platform**). The Innovation Elements, on top of which these KERs are constructed, are another source of exploitation (but less studied). In any case, technical development teams and research centres are also willing to further use their results (knowledge, enablers, etc.) in further projects. More information about the individual exploitation plans can be found in Section 4 of D9.8.

3.4.2.14. KPI 1.3.2 – Revenue growth (KVI 8.3.1)

Table 133. Summary of KPI 1.3.2

Name	**Revenue growth**				
Description	Revenue growth refers to the increase in a company's total revenue or income over a specific period, typically calculated quarterly or annually. This KPI is used to reflect that the technological nature of the SMEs involved in the action fosters their growth over time, to which ASSIST-IoT also contributed.				
Motivation	H2020 in general, and ASSIST-IoT in particular, aim at empowering European SMEs in their efforts and challenges towards successful commercialisation of their innovations				
Initial target	15-25%	**Score***	~125%	**Achieved**	Yes
Rationale target selection	As a KVI, it was selected in the proposal and approved by the European Commission evaluators. The reasoning was to prove that SME companies of the project are growing beyond 10% from the start until the end of the project.				
Measurement period	During January – February 2024				
Partner/s responsible	PRO				

Measurement methodology

From the very beginning of the project, a turnover and employee tracking of project's SMEs is being conducted. This KPI will be validated if the ASSIST-IoT SMEs' turnovers from 2020 and 2023 are, in average, increased by at least 15%.

Results and outlook

For computing this KPI, the revenue growth of the participating SMEs in the project has been computed, from the period 2020-2023. For confidentiality reasons, the particular values of the 3 companies (PRODEVELOP, TwoTronic and INFOLYSiS) are not included. Averaging the 3 companies, the revenue has increased by ~91 % (large differences among partners).

3.4.2.15. KPI 1.3.3 – Market share (KVI 8.3.2)

Table 134. Summary of KPI 1.3.3

Name	**Market share**
Description	This KPI will evaluate the market share gained by ASSIST-IoT partners, by comparing their market share analysis before and after ASSIST-IoT commenced started

Motivation	It is foreseen that the innovations that are under development of ASSIST-IoT will allow to reduce reluctance from partners' contacts, letting them achieve relevant market share gains.				
Initial target	15%	**Score***	**NA**	**Achieved**	NA
Rationale target selection	As a KVI, it was selected in the proposal and approved by the European Commission evaluators. The reasoning was to prove that in average for-profit project partners market share have grown beyond 10% from the start until the end of the project.				
Measurement period	During January – March 2024				
Partner/s responsible	PRO				

Measurement methodology

This KPI will evaluate the market share gained by ASSIST-IoT partners, by comparing their market share analysis before and after ASSIST-IoT started.

Results and outlook

Proper value will be computed after project finalization, as final numbers are not yet available and require significant analysis of the respective markets in the current moment (previous market analysis carried out in 2020 is now outdated). This value will be communicated after the final review of the project.

3.4.2.16. KPI 1.3.4 – Return of Investment (RoI)

Table 135. Summary of KPI 1.3.4

Name	**Return of Investment (RoI)**				
Description	This KPI quantifies the RoI of for-profit and non-for-profit organizations of the project.				
Motivation	Like KPI 1.3.2, every R&D action expects some return of investment, in order to continue supporting research in the future.				
Initial target	5-10%	**Score***	> 83%	**Achieved**	Yes
Rationale target selection	From previous experiences, and according to different analysis in economics literature, every company expects about 5-10% returns of their R&D investments.				
Measurement period	During January – March 2024				
Partner/s responsible	PRO				

Measurement methodology

The ROI is measured as a percentage and its calculation is versatile, simple, and easy to understand, based on the equation below:

$$RoI = \frac{Current\ value\ of\ investment\ -\ Cost\ of\ investment}{Cost\ of\ investment}$$

In the above equation, whereas the ***cost of investment*** refers to the total costs of the ASSIST-IoT system, including the deployment of the essential enablers, maintenance, etc., the ***current value of investment*** is the generated value from having **ASSIST-IoT** running at a company. Due to the volatility of the IoT market, the accuracy of a ROI analysis is limited. Therefore, the below steps for better digest the ASSIST-IoT ROI analysis have been followed:

1. **Identify direct and indirect costs for building a new ASSIST-IoT solution**. For example, deploying an ASSIST-IoT platform which allows to enterprise automation (like in Pilot 1) would mean that Terminal Link may not need as many field technicians (fewer salaries to pay) leading to an increase in indirect savings.
2. **Specify the initial cash expenses**. Since an initial cost calculation that encompasses things such as inventory costs, delivery costs, training of staff involved, etc. should be considered. This also affects to the k8s underlying orchestration platform of ASSIST-IoT. Therefore, a comparison between the estimated the cost of current IoT infrastructures and Kubernetes infrastructure should be considered.
3. **Consider the value produced over time.** The quality of ML models of ASSIST-IoT capabilities are expected to improve over time. The data pool increases with time and so does the accuracy and quality of the data.
4. **Make an estimate of possible net cash from the future investment.** This step will require the most time and the best scrutiny of all approximate returns on the part of the platform.

When reflecting about the calculation of the Return of Investment in ASSIST-IoT two viewpoints (depending on for-profit, or non-for-profit organization) have been identified:

a) For non-for-profit organizations (i.e., academia and RTOs): the investment performed by the EC in the project (budget, etc.) vs the benefits extracted from the execution of the action (in terms of publications, position of partners, outcomes, open-source products available, influence, etc.).
b) For for-profit organizations: comparing the resources devoted to the development in the project (personnel, etc.) and the outcome and benefits obtained.

Results and outlook

The cost structure and revenue streams from the business models of the 4 most promising KERs was used as the data for the RoI calculations. They are explained in D9.7. From the results, at least an 83.3% of RoI was estimated for KER4. Thus, the KPI was fulfilled.

Table 136. Results of RoI

KER	Cost structure	Revenue stream	RoI
KER1	28k€ / 3 years	60k€ first year, 30k€ rest	328%
KER4	1.2M€ / 3 years	2.2M€ / 3 years	83,3%
KER5	**Values not provided for this KER**		
KER7	215k€ / 3 years	600k€ / 3 years	179%

3.4.2.17. KPI 1.3.5 – Architecture made available (KVI 1.1)[6]

Table 137. Summary of KPI 1.3.5

Name	**Architecture made available**				
Description	This KPI represents the participation in technological forums and events (webinars, etc.) on the internet to showcase that ASSIST-IoT architecture as a whole has been outputted by the project (as an exploitation result). To collect the data for this KPI, a summary of all communications and meetings that ASSIST-IoT has participated in will be created. This will also include meetings and presentations to show ASSIST-IoT to prospective customers (of the architectures as the baseline of the solution as a whole).				
Motivation	To control and showcase the effort performed in communicating the reference architecture based on enablers fostered by the project.				
Initial target	True	**Score***	True	**Achieved**	Yes

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[6] In the previous deliverable (D8.2), the information related to this KPI was missed as the information of KPI 3.2.5 was filled instead. The information described now is the correct one.

Rationale target selection	A false would not being acceptable from a research and innovation point of view.
Measurement period	Last month of the project (M41)
Partner/s responsible	UPV

Measurement methodology

The measurement means of this KPI will consist of listing the events/forums activities performed with the relevant IoT pillar institutions. Since a continuous monitoring of this activity is performed under the scope of T9.1, the KPI will collect the information from that task.

Results and outlook

The Consortium has extensively promoted the ASSIST-IoT reference architecture, with several types of activities (journal paper, conference papers/keynotes/presentations/workshops/posters, online workshops) generally executed by the Coordination team. Overall, the promotion efforts have been continuous over time, being the following table a non-exhaustive list of all the promotion activities conducted along the execution of the action.

Table 138. Promotion efforts of the architecture

Activity	Justification
Workshop at IoT Week 2022	The IoT Week has been historically one of the main European events related to IoT. The Consortium organized a workshop titled "The ASSIST-IoT approach to NGIoT architecture design and implementation", in which the architecture ("Introduction of ASSIST-IoT as the reference architecture for the NGIoT", presented by the deputy coordinator Ignacio Lacalle - UPV) and some key developments were presented. Info can be found here. It was also presented in two more sessions.
Presentation at NGIoT workshop	The CSA NGIoT organized a workshop for Open Calls potential applicants, where Ignacio Lacalle (UPV) presented the project architecture in the IoT Week 2021 (online, here).
EU-IoT Training Workshops Series	As part of a series of workshops organized by the EUIoT CSA, Prof. Carlos E. Palau (UPV) presented "The ASSIST-IoT Architecture" at the EU-IoT Training Workshops Series: Next Generation IoT Architectures, on Tuesday 9 November 2021. More information here.
BRAINE and ASSIST-IoT joint workshop	These projects organized an online webinar where Ignacio Lacalle (UPV) presented the ASSIST-IoT project and the ASSIST-IoT Open Call, on 14 January 2022.
Conference paper	Dr. Paweł Szmeja (SRIPAS) presented the paper titled "ASSIST-IoT: A Reference Architecture for Next Generation Internet of Things", with lead author Dr. Alejandro Fornés-Leal, on the SOMET 2022 conference in Kitakyushu, Japan.
Conference keynote	Prof. Carlos E. Palau (UPV), project coordinator of ASSIST-IoT, delivered a keynote speech about "Next Generation Tactile IoT – The ASSIST-IoT/aerOS approach" on Tuesday 11 October 2022.
Presentation at ETSI IoT Week 2022	Ignacio Lacalle (UPV) presented "Edge-native paradigm: ASSIST-IoT approach for the next NG-IoT decentralized architecture" scheduled in Session 10, The Role of EDGE in IoT, taking place on Thursday 13 October 2022.

Pitch and poster at TRA2022 Conference	Ignacio Lacalle (UPV) pitched ASSIST-IoT project in the #TRA 2022 at the stand of the European Commission on 14th of November 2022.
Presentation at HiPEAC conference 2023	Ignacio Lacalle (UPV) presented ASSIST-IoT at HiPEAC conference 2023 (17 January 2023, Toulouse, France) as invited project by VEdLIoT at the "AIoT related projects" session.
Poster at EUCEI meeting	As part of the EUCloudEdgeIoT Concertation and Consultation Meeting, 10-11 May 2023, Brussels, Prof. Carlos E. Palau and Dr. Ignacio Lacalle represented the project at a poster session.
Journal paper at Electronics	The ASSIST-IoT architecture has been published with the following reference: Paweł Szmeja, Alejandro Fornés-Leal, Ignacio Lacalle, Carlos E. Palau, Maria Ganzha, Wiesław Pawłowski, Marcin Paprzycki, Johan Schabbink, ASSIST-IoT: A Modular Implementation of a Reference Architecture for the Next Generation Internet of Things, Electronics 2023, 12(4), 854; 8 Feb 2023 https://www.mdpi.com/2079-9292/12/4/854 DOI: https://doi.org/10.3390/electronics12040854
Total: >11	

3.4.2.18. KPI 1.3.6 – Conformance to new techs

Table 139. Summary of KPI 1.3.6

Name	**Conformance to new techs**				
Description	This KPI measures the alignment of ASSIST-IoT technological outcomes (Innovation Elements, exploitable products, global results) with the current trends and de-facto standards in the IoT-edge-cloud and NGIoT fields.				
Motivation	Why is it important to have/mention as KPI (added value)				
Initial target	100%	**Score***	100%	**Achieved**	Yes
Rationale target selection	Targeting a Next-Generation IoT reference architecture, modern technologies complementary/symbiotic to IoT, should be leveraged in the context of the project execution to ensure that the proposed architecture is compatible.				
Measurement period	Last month of the project (M41)				
Partner/s responsible	UPV				

Measurement methodology

First, a list will be elaborated with those current to-be-conforming-with technologies (initiated in D8.2). Afterwards (this document, D8.3), from such a selected set of specific protocols, technologies and standards recently appeared (post 2010), a conformance checking, together with a justification, will be included. Such a list (original and conformed) will be agreed within the Consortium and with the members of the Advisory Board.

Particularly, the measurement means of this KPI will consist of the following:

- Item per item of the following list, an explanatory paragraph will indicate whether (and, if yes, to how extent) or not is ASSIST-IoT conforming with the trending technologies and techniques.
- For those positive cases, links will be added (readme, videos, deliverables, etc.) where the contribution of ASSIST-IoT to those fields will be described.
- This way, it will be straightforward to understand: (1) how much ASSIST-IoT complies with the selected list, (2) how ASSIST-IoT directly contributes to foster and enhance the trending technological lines in the IoT technological field.

Results and outlook

The original list of candidates to meet those *de-facto standard* and research priorities was prepared in D8.2, with a set of actions defined in such document. This list has been refined in the past months, considering also feedback from the Advisory Board:

1. **Contextual IoT and IoT/edge operating systems**: Go beyond "meta" Operating Systems, focusing on semi-autonomous orchestration. In the long run, move from centralised orchestration towards decentralised coordination with AI developments to increase autonomy.
2. **Interoperability, reliability and scalability**: Deploy secure and highly scalable IoT and digital infrastructures with special focus on edge capacity, leveraging on global networking technologies such as IPv6 and 5G
3. **5G/6G**: The deployment of advanced network management and deployment mechanisms and the predominance of virtualization and software-controlled approaches are one of the most relevant topics.
4. **AI/ML, MLOps and data management across IoT deployments**, as fundamental pieces to ensure Data Act and Artificial Intelligence Act and crucial elements for implementing innovative use cases.
5. **Trustworthy AI, lightweight AI/ML and federated ML**: introduction of a variety of techniques, schemas, mechanisms and technologies for federating algorithms and nodes as well as reducing size of models or training data size and quality.
6. **Cloud principles and cloud technologies**, prominently for the management of infrastructure and for orchestrating workloads across the IoT-edge-cloud deployments.
7. **Hardware and sensors**, including energy efficiency and green approaches.
8. **Future-proof security and privacy**: Develop security and privacy by-design to deal with future threats, increasing traceability and trust beyond regulatory compliance.

Table 140. Conformance to new technologies

Item	Justification
1	The project's smart orchestrator includes the option of letting the system decide the optimal place of workloads deployment. Along with self-resource (via enabler supporting K8s' HPA) and self-healing capabilities, the platform is in good position for coping with the current autonomy in orchestration's needs.
2	ASSIST-IoT has semantic interoperability fulfilled thanks to the design and implementation of the semantic suite. Reliability and scalability are tackled thanks to the Cloud Native vision embraced by the project, with K8s in the centre and with a set of self-* enablers.
3	NFV & SDN concepts carefully tighten to 5G have been considered. Virtualization has been fully embraced by the project, with 38/41 technological enablers containerized – going beyond the network realm. Additionally, 3 enablers related to SDN (and 2 with SD-WAN) have been implemented.
4	The project has implemented AI/ML models for networking, service scheduling and provisioning, as well as pilot cases. With respect to data, mechanisms related to semantic, storing, routing and reputation (DLT) have been implemented – no MLOPs.
5	Following with the previous point, a novel FL suite has been implemented for addressing privacy challenges, and frugal techniques have been applied in some of the developed models. Trustworthiness has not been considered.
6	These are one of the pillars of the project, with Cloud Native technologies embraced. Still, IoT and edge are of the same if not higher importance, thus careful selection and dedicated developments were made.
7	The project has designed and implemented its own gateway (apart from some IoT devices for Pilot 2). Aiming at not exceeding consumption of resources, the GWEN is modular and can be extended according to the real needs of the deployments.

8	Apart from dedicated tools related to cybersecurity (adapted to IoT) and access control, the project has implemented a DevSecOps methodology to include security in the different DevOps phases of the project enablers, aiming at being as secure by design as possible.
Total: 100%	

3.4.2.19. KPI 1.3.7 – New verticals identified (KVI 6.2)

Table 141. Summary of KPI 1.3.7

Name	**New verticals identified**				
Description	Whereas KPI.1.2.6 will identify those vertical markets upon which ASSIST-IoT could be adopted without significant changes on the business models (pivoting), this one (KPI.1.3.7) will directly report (in a justified way) all the verticals that have been identified during the project over which ASSIST-IoT could be deployed (providing enough added value). This KPI will be measured drawing from a reasoned justification of those verticals that could be counted as potential market niches for ASSIST-IoT.				
Motivation	Being delivered as a generic, blueprint, reference NGIoT architecture, ASSIST-IoT could be deployed in (virtually) any vertical. While this remains true, this KPI points directly to a deeper reasoning of specific cases in which this could be realized. Drawing from the experience of the partners preparing demonstrators, attending to IoT-related and industrial events (e.g., IoTWeek, TRA2022, among others), it has been noticed that this transfer is feasible and that the expressed needs from ASSIST-IoT's stakeholders are shared in other fields of action.				
Initial target	>= 3	**Score***	>5	**Achieved**	Yes/No
Rationale target selection	A minimum number that ensures that the project is generic enough, having a minimum of 6 if counting the project ones.				
Measurement period	Last month of the project (M41)				
Partner/s responsible	UPV				

Measurement methodology

For measuring this KPI, the team in T8.4 will follow the instructions of the Transferability Analysis document to envisage the application of ASSIST-IoT's technology in other domains. The expected verticals to be documented will contain the following information:

- Sector.
- Specific problems on the sector that might leverage ASSIST-IoT technology.
- ASSIST-IoT enablers, modules, principles or concepts of application.

Results and outlook

Table 142. Preliminary verticals identified – beyond pilot ones

Sector	Specific problem	Potential contribution
5G	Shift from VM-based to Cloud-Native ecosystem is progressing slowly. Incompatibilities with container-based ecosystems.	The MANO framework for 5G is evolving slow. The proposed solution based on Smart Orchestrator (already compatible) could boost the process, considering integration of slicing capabilities.
Energy	Specific interest on energy flexibility use cases, in multi-stakeholder ecosystem. Need of distributed data	Orchestration of services, distributed and efficient data pipelines for IoT devices, cybersecurity

	architectures supported by Cloud/Edge-Native.	enablers, decentralized monitoring and observability capabilities, etc.
Smart city	Availability of several data sources, heterogeneous devices, different stakeholders; all in all, hindering its management and new use cases.	The ASSIST-IoT architecture could flourish in these ecosystems, and, apart from helping the orchestration and monitoring of the infrastructure and services, novel tactile applications could emerge.
Water management	Digitalization and automation of processes is a success factor. Examples like Hidraqua for managing the water mgmt. of Valencia city shows this success.	The extended vertical and properties that bring the ASSIST-IoT architecture and technological features can further enhance current ecosystems, following a similar model applied in Valencia to other cities. Auditing capabilities, based on DLT, could feed novel use cases.
Agriculture	Lack of capabilities for further gain insights and exploit the value of data	The integration of FL paradigm could help gaining and sharing insights among deployments. ASSIST-IoT could provide the data and monitoring needs to that end.
Total: 5		

The NGIoT can be applied to any sector in which the value of distributed data is high. This is a preliminary list considering the Consortium expertise, however, it could be extended to other sectors. Apart from optimizing the resources available and the management of data, novel use cases (based on DLT, FL, tactile applications, etc.) can appear thanks to the implementation of the ASSIST-IoT architecture and NGIoT systems.

3.4.2.20. KPI 1.3.8 – Collaborating IoT Security Projects

Table 143. Summary of KPI 1.3.8

Name	**Collaborating IoT Security Projects**				
Description	This KPI aims at measuring that "collaboration effort", listing the number of joint workshops/webinars in collaboration with IoT security projects/initiatives, together with other ways of collaboration (always including enough endorsement claims).				
Motivation	ASSIST-IoT has as one of its pillars: security and privacy. It is expected that active collaboration will take place with different initiatives and/or projects focused on the merge of IoT with cybersecurity, including privacy, authentication, authorisation, integrity verification and DevSecOps, among others.				
Initial target	10	**Score***	12	**Achieved**	Yes
Rationale target selection	Ambitious target number to collaborate and improve our propositions, as well as influence other projects.				
Measurement period	Last month of the project (M41)				
Partner/s responsible	UPV				

Measurement methodology

This KPI will be measured by listing the number of joint activities performed together with such entities or projects. It is expected that liaison with sister projects and Open Call funded actions will boost this collaboration. The information that will be included is:

- Type of action

- Project with collaboration
- Scope of the collaboration

Results and outlook

Despite not being a cybersecurity project, ASSIST-IoT partners (mainly S21SEC) have been actively considering the outcomes produced within the project for expand the impact in the cybersecurity research and innovation community, as one can see in the table below.

Table 144. Collaborating security projects

Type of action	Project with collaboration	Scope of the collaboration
Communication channels	aerOS	Collaboration under the umbrella of CSA projects. Cross-project open call communication.
Sharing knowledge between projects	EINSTEIN	Technical cooperation in reusing and extending ASSIST-IoT, specifically for the components of OpenAPI, data sovereignty and trust mechanisms (DLT)
Communication channels	Secant	Joint communication for EUCNC 2023
Collaboration in working group, White papers	ECSO	Active participation in the cybersecurity working groups, identification of gaps in cybersecurity domain, contribution to cybersecurity white papers and best practices.
	ENISA	
Workshop	EU-IoT (ICT-56 projects)	Presentation of privacy-preserving techniques in AI & cybersecurity context of FL (IoT-NGIN)
Workshop	IoT-NGIN	Decentralizing IoT Intelligence using Distributed Ledger Technologies
Event	NextSecure	Annual event of S21Sec in which different entities are invited to share their expertise and experience in security areas (some invited entities are Nordex, Thales, Siemens, Basque cybersecurity centre, among others)
MSCA project	AIAS	Collaboration of UPV with external entities in cybersecurity detection, via MSCA programme. Secondments envisioned
Sharing knowledge among both projects	RE4DY	Cybersecurity incident detection and response applied to Data Container Platform, supporting a resilient and sustainable "Data as Product" computing and data space
Sharing knowledge among both projects	IDUNN	Applicability and reuse and expansion of the software modules for incident detection and response. Implementing enhanced cybersecurity resilience focused on orchestration and automation for incident response applied to OT environments.
Sharing knowledge among both projects	ODIN	Cybersecurity incident detection and response applied to networked components in robot operating system environment. Use case modelling and cyber kill chain approach linked with MITRE ATT&CK model in ROS networked scenario
Total: 12		

3.4.2.21. KPI 3.1.1 – Internationally recognized standards supported in ASSIST-IoT solutions

Table 145. Summary of KPI 3.1.1

<table>
<tr><td>Name</td><td colspan="5">Internationally recognized standards supported in ASSIST-IoT solutions</td></tr>
<tr><td>Description</td><td colspan="5">This KPI measures the number of applied existing, well-renowned and market-applied standards in the different components of the ASSIST-IoT. To identify the compliance of this KPI a list of supported standards in different components was prepared. Is considered the fulfilment of this KPI, when the number of <u>standards supported by all software components are over 40</u> at the end of the project.</td></tr>
<tr><td>Motivation</td><td colspan="5">It shows how the ASSIT-IoT solution fulfils and deploys existing the standards.</td></tr>
<tr><td>Initial target</td><td>40</td><td>Score*</td><td>53</td><td>Achieved</td><td>Yes</td></tr>
<tr><td>Rationale target selection</td><td colspan="5">Based on standardisation activities in the research projects and number of technical subjects in the project.</td></tr>
<tr><td>Measurement period</td><td colspan="5">Whole project duration.</td></tr>
<tr><td>Partner/s responsible</td><td colspan="5">OPL</td></tr>
</table>

Measurement methodology

This KPI measures the number of supported/applied existing, well-renowned and market-applied standards in the different components of the ASSIST-IoT. To identify the compliance of this KPI a list of ASSIST-IoT should be conformed, including in this one each of the standards supported by the component. Thus, having this list we can extract a final set of applied standards in ASSIST-IoT.

Results and outlook

Is considered the fulfilment of this KPI, when the number of standards supported by all software components are over 40 at the end of the project. Achieved value is 53. Additional information of them can be seen in D9.4.

3.4.2.22. KPI 3.1.2 – Communications to modify / improve existing standards used in ASSIST-IoT

Table 146. Summary of KPI 3.1.2

<table>
<tr><td>Name</td><td colspan="5">Communications to modify / improve existing standards used in ASSIST-IoT</td></tr>
<tr><td>Description</td><td colspan="5">This KPI.3.1.2 measures the number of identified existing standards where the modification or improvement is required in relation to developed ASSIST-IoT components, enablers or overall architectural design. The list of these standards in relation to ASSIST-IoT components will verify the KPI compliance.</td></tr>
<tr><td>Motivation</td><td colspan="5">To show which existing standards need to be modified.</td></tr>
<tr><td>Initial target</td><td>6</td><td>Score*</td><td>7</td><td>Achieved</td><td>Yes</td></tr>
<tr><td>Rationale target selection</td><td colspan="5">Based on standardisation activities in the different research projects.</td></tr>
<tr><td>Measurement period</td><td colspan="5">Whole project duration.</td></tr>
<tr><td>Partner/s responsible</td><td colspan="5">OPL</td></tr>
</table>

Measurement methodology

This KPI measures the number of identified existing standards where the modification or improvement is required in relation to developed ASSIST-IoT components, enablers or overall architectural design. The list of these standards in relation to ASSIST-IoT components will verify the KPI compliance.

Results and outlook

To fulfil this KPI the number of identified standards should be over 6 at the end of the project. Achieved value is 7 possible modification of existing standards. Additional information of them can be seen in D9.4.

3.4.2.23. KPI 3.1.3 – Recommendations in relevant SDO’s and initiatives

Table 147. Summary of KPI 3.1.3

Name	Recommendations in relevant SDO’s and initiatives				
Description	This KPI.3.1.3 shows number of **activities and performed contributions to different SDO’s and initiatives for recommendations work purposes**. The contributions will be prepared according to relevant ASSSIT-IoT research and development activities in different technical and non-technical subjects.				
Motivation	To shows standardisation contributions performed in the project.				
Initial target	10	**Score***	25	**Achieved**	Yes
Rationale target selection	Based on standardisation contributions in the different research projects.				
Measurement period	Whole project duration.				
Partner/s responsible	OPL				

Measurement methodology

To measure this KPI.3.1.3 we need to count the number of **activities and performed contributions to different SDO’s and initiatives for recommendations work purposes**. The contributions will be prepared according to relevant ASSSIT-IoT research and development activities in different technical and non-technical subjects. The list of activities and contributions were collected.

Results and outlook

The target value of this **KPIs is 10 at the end of the project**. Achieved value is 25 contributions in the project. Additional information of them can be seen in D9.4.

3.4.2.24. KPI 3.1.4 – SDOs and pre-normative initiatives engaged

Table 148. Summary of KPI 3.1.4

Name	SDOs and pre-normative initiatives engaged				
Description	This KPI 3.1.4 is collecting the number of different engagements in SDO’s, and pre-normative initiatives. **All activities will be counted regarding participation in different SDO’s, initiatives and forums for different standardisation subjects**. The active participation in different standardisation working groups, study groups, task forces and their working subjects were included				
Motivation	To show project partners engagements in standardisation activities.				
Initial target	40	**Score***	42	**Achieved**	Yes

Rationale target selection	Based on standardisation activities in the research projects and possible partners involvement.
Measurement period	Whole project duration.
Partner/s responsible	OPL

Measurement methodology

This KPI.3.1.4 is counting the number of different engagements in SDO's, and pre-normative initiatives described in D9.3. All activities will be counted regarding participation in different SDO's, initiatives and forums for different standardisation subjects. The active participation in different standardisation working groups, study groups, task forces and their working subjects were included

Results and outlook

Is considered the fulfilment of this KPI, when the number of **standards supported by all software components are over 40** at the end of the project. Achieved is 42 active project partners' engagements. Additional information of them can be seen in D9.4.

3.4.2.25. KPI 3.1.5 – Identified standards related to ASSIST-IoT activities

Table 149. Summary of KPI 3.1.5

Name	Identified standards related to ASSIST-IoT activities				
Description	This KPI indicates the **identified standards related to different subjects** of ASSIST-IoT solutions (components, enablers, architecture) besides supported standards included in KPI 3.1.1.				
Motivation	To show which standards and reports are relevant in ASSIT-IoT project.				
Initial target	120	**Score***	154	**Achieved**	Yes
Rationale target selection	Based on standardisation activities in the research projects and technical solutions in the project.				
Measurement period	Whole project duration.				
Partner/s responsible	OPL				

Measurement methodology

This KPI measures the identified standards related to different subjects of ASSIST-IoT solutions (components, enablers, architecture) besides supported standards listed below. The analysis of the standards from different SDO's and initiatives in D9.3 was presented and later updated until end of the project. Based on this analysis we can count the number of identified standards and technical reports to evaluate planned KPI value.

Results and outlook

To fulfil this KPI we need to identify at least 120 standards at the end of the project. Achieved value is 154 identified standards. Additional information of them can be seen in D9.4.

3.4.2.26. KPI 3.2.1 – Number of scientific publications

Table 150. Summary of KPI 3.2.1

Name	**Number of scientific publications**

Description	This KPI represents the number of scientific publications.				
Motivation	This is a standard KPI, used in all RIA projects as a typical measure of scientific productivity.				
Initial target	38	**Score***	39	**Achieved**	Yes
Rationale target selection	Estimate based on experiences of project partners; project coordinator and project technical coordinator, in particular.				
Measurement period	Project duration. However, additional publications will actually materialize after the project is completed - publication cycle is long.				
Partner/s responsible	All academic and research partners lead; with remaining partners involvement.				

Measurement methodology

This KPI will be retrieved directly from D9.8 information, counting journal papers, conference papers, white papers and book chapters.

Results and outlook

The total number of achieved publications is 39, according to the last report in impact activities (D9.8). It should be mentioned that at least 5 additional publications are still in different phases of publications, so the total number of scientific contributions can increase in the following months.

3.4.2.27. KPI 3.2.2 – European IoT Platforms compatible and connected to ASSIST-IoT modules

Table 151. Summary of KPI 3.2.2

Name	**European IoT Platforms compatible and connected to ASSIST-IoT modules**				
Description	This KPI measures the practical interoperability of ASSIST-IoT solution with other IoT platforms. Particularly, it will report how many IoT platforms are functioning or have functioned connected to ASSIST-IoT. Open Call participants are expected to play a key role towards this KPI.				
Motivation	ASSIST-IoT focuses one of its verticals in the scalability and interoperability of the technology. For that concern, an Open API, altogether with structured virtualisation and containerisation of the enablers, and a single interface to manage the framework are created. This should help interoperate with other platforms that might wish to leverage any of ASSIST-IoT modules.				
Initial target	4	**Score***	4	**Achieved**	Yes
Rationale target selection	Balanced number to keep a balanced effort.				
Measurement period	Last month of the project (M41)				
Partner/s responsible	UPV				

Measurement methodology

In D8.2, potential interoperability cases that could be reported were:

- IoT platforms by Open Call funded projects that have been connected (interoperability achieved)

- Open IoT platforms available in the open source community that have been connected to ASSIST-IoT (e.g., PIXEL platform, INTER-IoT, IntellIoT, TERMINET, ThingWorx…).
- Explanation of the compatibility of ASSIST-IoT with other IoT platforms even though actual integration has not been tested (limited scope, resources and time of the project).

The measurement means will be to document each of the compatibility cases with, at least, the following information:

- Scope
- IoT Platform integrated
- Functionalities shared (in both ways)
- Lessons learnt

Results and outlook

Table 152. European IoT Platforms connected to ASSIST-IoT

Sector	IoT platform integrated	Functionalities shared	Lessons learnt
IoT	FIWARE – Orion	Used for hosting the contextual data of the Smart orchestrator	Its federated capabilities can be very beneficial to be exploited in further developments to enhance the distributed capabilities of the enabler
IoT	Sensinact	Middleware to process data at the edge, coming from EDB and sending to LTSE (and to Sensinact'S DTT)	The low resources needed by the middleware show it to be very beneficial for interoperability in edge ecosystems
IoT	TheThingsNetwork	Data publishing via EDBE to the Cloud's platform via Internet	The EDB and the devices characteristics of ASSIST-IoT could be seamlessly integrated
5G	OSM MANO	Lifecycle management of services, with OSM focused on NFV and ASSIST-IoT being generalist.	ASISST-IoT platform lacks some sector-specific capabilities (e.g., slicing), still, being better aligned to Cloud Native, in which OSM has room for improvement
Total: 4			

The previous frameworks/platforms could be easily integrated. The ASSIST-IoT open API enabler further extends the possibility in the future.

3.4.2.28. KPI 3.2.3 – Letters of interest to adopt ASSIST-IoT technologies

Table 153. Summary of KPI 3.2.3

Name	**Letters of interest to adopt ASSIST-IoT technologies**				
Description	Towards the end of the project, the partners of T8.4 will work together with T9.4 (Exploitation) to obtain letters of interest from relevant external actors expressing their willingness to adopt ASSIST-IoT technologies in the future. This KPI can be considered a sub-objective of KPI 1.1.2.				
Motivation	As part of communication of the outcomes of the project, is a good way to foster activities in which results are leveraged and/or evolved.				
Initial target	2	**Score***	2	**Achieved**	Yes
Rationale target selection	Moderate number, targeting relevant actors.				

Measurement period	Last month of the project (M41)
Partner/s responsible	UPV

Measurement methodology

The number of letters received (because of effort of promotion, communication, etc.) will be counted, considering only those from entities with certain relevance in the field of IoT (to be assessed by the PCC; stakeholders/companies with portfolio of IoT solutions; European organizations; research groups with participation on IoT competitive projects; etc.).

Results and outlook

At the moment of writing this deliverable, 2 formal letters have been received, fulfilling the KPI. In any case, project partners have also received emails with interest of external users or companies asking for collaboration in specific enablers, which in the future can extend their features or be the base for further agreements between project partners and external actors.

3.4.2.29. KPI 3.2.4 – Research actions including one or several modules developed on ASSIST-IoT

Table 154. Summary of KPI 3.2.4

Name	**Research actions including one or several modules developed on ASSIST-IoT**				
Description	This KPI aims at measuring the pervasiveness of ASSIST-IoT technological outcomes in the research field. In particular, it is the goal of T8.4 participants to tackle new research proposals to request further funds to continue the work over ASSIST-IoT portfolio (as a whole and as per module). This KPI will report about the number of such actions envisioned and tackled.				
Motivation	Important KPI to ensure further research and continuation of the technological outcomes developed in the framework of the project.				
Initial target	2	**Score***	5	**Achieved**	Yes
Rationale target selection	Conservative number, targeting a minimum of contributions (to the scientific realm).				
Measurement period	Last month of the project (M41)				
Partner/s responsible	UPV				

Measurement methodology

In order for an action to be accepted to be counted in this KPI, it needs to include: idea, summary of ambitions, call/program where it has been submitted or that will be submitted. Since there is the risk that such a table might embed privacy concerns or disclosure issues, partners will fulfil the table of results presented below on a voluntary basis. This way, every action reported will be communicated without incurring in any violation of privacy terms.

Results and outlook

A minimum of 5 proposals were written in the past considering the continuation of some of the outcomes from ASSIST-IoT, ensuring the continuation of research and potential increase of the TRL readiness. It should be mentioned that partners do not wish to express the current initiatives under evaluation for sensitivity reasons.

Table 155. Research actions including ASSIST-IoT modules

Type of action	**Name**	**Partner/s**	**Idea**	**Summary of ambitions**	**Call/program**
HE projects	aerOS	UPV, SRIPAS, PRO, S21SEC, INFOLYSIS	A meta operating system to orchestrate the edge-cloud continuum	Cybersecurity, semantic and orchestration capabilities extended	CL4-2021-DATA-01-05
	6G-Cloud	OPL	AI-native and cloud- friendly system architecture atop the continuum	Contributions for cloud continuum architecture	SNS JU
	SAFE-6G	UPV	Orchestration and trustworthiness frameworks in 5G systems	Contributions to security in service mesh capabilities	SNS JU
National projects	HFREMEDI	UPV	Large-scale Big Data system for fleet management and monitoring	Extending current Pilot 3A characteristics with more robustness and Big Data capabilities	Spanish MCIN/ AEI and EU's Next-gen PRTR
Total: 5					

3.4.2.30. KPI 3.2.5 – Industrial actions including one or several modules developed on ASSIST-IoT

Table 156. Summary of KPI 3.2.5

Name	**Industrial actions including one or several modules developed on ASSIST-IoT**				
Description	This KPI aims at measuring the pervasiveness of ASSIST-IoT technological outcomes in the private/industrial field. In particular, the idea is to achieve the inclusion of one or some ASSIST-IoT modules in the innovation lines / innovation policies / product portfolio / improvement route of private actors related (or not) to the verticals of the project (being the subject a partner of ASSIST-IoT or not). The task T9.4 is in charge of dealing with the Innovation Elements of the project as well as with the Key Exploitable Results and the business analysis of ASSIST-IoT outcomes.				
Motivation	This KPI aims at measuring how those activities have transpired into actual inclusion of ASSIST-IoT technology as operational parts of private companies in their day-to-day business. To ensure further use and continuation of the technological outcomes developed in the framework of the project.				
Initial target	2	**Score***	3	**Achieved**	Yes
Rationale target selection	Conservative number, targeting a minimum of contributions (to the industrial realm).				
Measurement period	Last month of the project (M41)				
Partner/s responsible	UPV				

Measurement methodology

Every industrial action (see definition above) performed by private partners of the Consortium or detected from outsider entities will be logged and described considering:

- ASSIST-IoT enabler, principle or asset reutilized and to which extent (fully, partially, conceptually…).
- How it contributes to the company/product/innovation/investment line.
- Company and its business scope.
- Expectations for medium-long term.

Results and outlook

The following table summarizes all those actions that project partners have been willing to share. After project finalization, it is expected that partners make further use of the produced outcomes, mainly in the form of P2P contracts for tech transfer with local Industries.

Table 157. Industrial actions including ASSIST-IoT modules

Enabler/ principle/ asset	Company	Business type	Contribution	Expectations
KER1 - Edge Tactile application (TrackGUI)	CMACGM/ MFT	Maritime logistics	Enhances the logistic operations from CHE drivers, thanks to the real-time assignments and instructions	Optimization of operations, with further optimization of AI support
KER4 – Enhanced scanner	TWOT customer (cannot disclose company)	Automotive	Reduces the processing time, thus reducing the time needed for customers to be in premises	Extending the capacity of the garage operators to be with more customers per day, improving efficiency
Tactile dashboard	Different maritime authorities	Maritime logistics	Implementation of the tactile dashboard as central framework for presenting different dashboards to operators	Integration in real operation, with granular access and presentation of valuable information
Total: 3				

3.4.2.31. KPI 3.2.6 – Number of cyber-security fairs/congresses attended

Table 158. Summary of KPI 3.2.6

Name	Number of cyber-security fairs/congresses attended				
Description	KPI measures participation of consortium members in cyber-security related events				
Motivation	Since security is a part of the DevSecOps methodology, participation in cyber-security related events is an appropriate avenue to disseminate project achievements.				
Initial target	8	**Score***	9	**Achieved**	Yes
Rationale target selection	Based on experiences (from past projects) of project coordinator and technical coordinator.				
Measurement period	Project duration. However, some activities, involving presentations of pertinent project results may take place after project completion.				
Partner/s responsible	8Bells as lead and other partners as support.				

Measurement methodology

Information gathered from partners contributing to the security, privacy and trust vertical. The list is extracted from the Impact deliverables and internal project information. It should be mentioned that, because of the scope of the project, partners target conferences and fairs that involve different aspects of IoT & ICT technologies, not only cybersecurity. The list below includes some of those in which cybersecurity-related sessions were attended.

Results and outlook

Table 159. Cybersecurity fairs/events attended/organized

Partner	Fain/conference	Session/s
UPV	IoT Solutions World Congress 2023	Several interactive sessions related to cybersecurity
S21SEC	RootedCON 2023	The computer security conference born with the purpose of promoting the exchange of knowledge between members of the security community. It includes training activities and courses, besides presentations
S21SEC	NextSecure	Cybersecurity event/fair organized by S21Sec, with active participation in different sessions
S21SEC	Basque Open Industry 2023	Industrial Cybersecurity: Strategic initiatives and challenges of cybersecurity
S21SEC	BeDigital	Session with different talks devoted to cybersecurity
SRIPAS, UPV	World Forum of IoT 2023	Although not only about cybersecurity, different workshops and special sessions were carried out and attended by ASSIST-IoT partners
SRIPAS, UPV	World Forum of IoT 2022	
UPV, CERTH, ICCS, PRO	IoT Week 2022	
SRIPAS	INISTA 2023	
Total: 9		

3.4.2.32.KPI 3.3.1 – Communication and community building activities organised/co-organised

Table 160. Summary of KPI 3.3.1

Name	**Communication and community building activities organised/co-organised**				
Description	This KPI determines the number of events organised/co-organised/attended by ASSIST-IoT such as workshops, webinars, events, open trials etc. To identify the compliance of this KPI, WP9 closely monitors and documents the activities performed.				
Motivation	This KPI represents how extrovert is the ASSIST-IoT project. In order to better understand the progress and the success of the communication process the following table summarises this type of communication and community building activities during M1-M40 period.				
Initial target	12 activities	**Score***	17	**Achieved**	Yes
Rationale target selection	This is the KPI measurement (as per DoA) that we estimate as sufficient for addressing the project's impact objectives and ambitions in the specific category.				
Measurement period	M1-M40				

Partner/s responsible	INFOLYSiS

Measurement methodology

INFOLYSiS collects and categorizes all the organized and co-organised events (Workshops-Webinars-Special Sessions-Call for papers) by ASSIST-IoT project. There is also a list with all events attended/participated by the partners available at the website (Events organised/organised: https://assist-iot.eu/workshops-presentations-and-trials/, Events in which partners actively participated or attended: https://assist-iot.eu/past-events/). Details are also provided in D9.8 (Sections 2 and 5).

Results and outlook

The table below summarises the organized and co-organised events (Workshops-Webinars-Special Sessions) by ASSIST-IoT project. In total 17 events have been organised and the initial set target has been well met, highlighting the impactful activities performed by ASSIST-IoT in the organisation/co-organisation of various events with other projects/associations/initiatives. More details on the exact events are also provided in D9.8 (Sections 2 and 5).

Table 161. Community building activities organized or co-organized

Items	Justification
11	Organised activities
6	Co-organised activities
Total: 17	

In addition, 101 events have been noted as events in which ASSIST-IoT partners participated with an activity (paper, presentation, panel discussion etc.) or attended by ASSIST-IoT partners (https://assist-iot.eu/past-events/)

3.4.2.33. KPI 3.3.2 – Subscribers to ASSIST-IoT communication channels and related activities

Table 162. Summary of KPI 3.3.2

Name	**Subscribers to ASSIST-IoT communication channels and related activities**				
Description	This KPI determines the number of visitors, subscribers and followers in ASSIST-IoT communication channels. To identify the compliance of this KPI, WP9 closely monitors and documents the visitors/followers/subscribers of ASSIST-IoT communication channels on a quarterly basis through the release of Statistical Dashboards per social media channel.				
Motivation	This KPI represents the success of the actions in task T9.1. It has been closely monitored during this period by periodically checking the number of visitors/followers/subscribers to the different channels and social media accounts of ASSIST-IoT. The reason for monitoring this KPI is for measuring, in an indirect way, the magnitude of the audience reached through the use of ASSIST-IoT communication channels.				
Initial target	2000 (website visitors and social media followers/subscribers)	**Score***	11,405	**Achieved**	Yes
Rationale target selection	This is the KPI measurement (as per DoA) that we estimate as sufficient for addressing the project's impact objectives and ambitions in the specific category of communication channels and targeted audience as visitors/followers.				

Measurement period	M1-M40
Partner/s responsible	INFOLYSiS

Measurement methodology

It has been closely monitored during this period by periodically checking the number of visitors/followers/subscribers to the different channels and social media accounts of ASSIST-IoT. Standard tools are being used (those proportionated by the channels themselves: e.g., historic info of the profile) alongside other means like Google Analytics (GA4 – compliant with European legislation and data privacy). On a quarterly basis, statistical dashboards were issued by INFOLYSIS (using Google Data Studio/Looker Studio), for evaluating and monitoring the impact created. These dashboards along with Google Analytics have been use for calculating the score of this KPI.

Results and outlook

The table below summarizes the audience reached (as website visitors and as social media followers) by the ASSIST-IoT communication channels.

Table 163. Subscribers to ASSIST-IoT communication channels and website visitors

Items	**Justification**
9,864	Website unique visitors
1,541	Social media followers/subscribers (LinkedIn: 788, Facebook: 114, X/Twitter: 425, Instagram: 169, YouTube: 45)
Total: 11,405	

The number of 11,405 visitors/followers has been reached at the end of M40, overpassing by far the DoA set target of 2000. This result proves really well how efficient was the use of all communication channels and how impactful were the activities performed and communicated. The accumulated audience was also very interactive since all activities received also a high number of likes, sharing and engagement as is shown in the related KPIs further below. More details are also provided in D9.8 (Sections 2 and 5) where the related statistical dashboards are also presented.

3.4.2.34. KPI 3.3.3 – Online communications (news, posts, articles)

Table 164. Summary of KPI 3.3.3

Name	**Online communications (news, posts, articles)**				
Description	This KPI determines the number of posts and news communicated through the website and social media. To identify the compliance of this KPI, WP9 closely monitors and documents the news communicated.				
Motivation	Aims at ensuring a minimum number of communication contributions to the ASSIST-IoT online channels. Important to keep an engaged community and keep continuously informed ASSIST-IoT audience of all channels. Both the website and social media channels provide continuously updated information on a weekly basis.				
Initial target	600	**Score***	1976	**Achieved**	Yes
Rationale target selection	This KPI measurement, as outlined in the DOA, is sufficient to address the project's impact objectives and ambitions within the specified category. The target set is a sufficient to prove the efficient online communications in the form of news, posts and articles				
Measurement period	M1-M40				

Partner/s responsible	INFOLYSiS

Measurement methodology

The responsible partner closely monitors the posting activities and articles from both internal and external stakeholders in order to assess the visibility of the project and retrieve feedback. Dedicated dashboards have also been created to provide information on the social media management to the members of the consortium on a quarterly basis. Details are also provided in D9.8 (Section 5)

Results and outlook

The number of 1976 online communication news/posts/articles have been reached at the end of M40, overpassing by far the DoA set target of 600. The reached target proves the impactful content continuously communicated to the targeted audience through ASSIST-IoT communication channels. This communication was both constant (on a weekly basis) but also versatile (different content per channel, addressing different types of audience). Details are also provided in D9.8 (Section 5) were also links to statistical dashboards are provided for calculating the posts made by each social media channel.

Table 165. Online communications performed

Items	Justification
197	News posts (https://assist-iot.eu/blog/)
19	Articles (https://assist-iot.eu/articles/)
1760	Social media posts (LinkedIn: 433, Facebook: 438, X/Twitter: 493, Instagram: 396). Links of statistical dashboards available at D0.9 section 5.
Total: 1976	

3.4.2.35. KPI 3.3.4 – Online traffic attracted (website, social media)

Table 166. Summary of KPI 3.3.4

Name	**Online traffic attracted (website, social media)**				
Description	This KPI determines the number of visitors and persons reached/engaged with the online communication activities of ASSIST-IoT website and social media. To identify the compliance of this KPI, WP9 closely monitors and documents the number of visitors/persons reached/engaged on a quarterly basis.				
Motivation	This metric determines the visibility of the project and how impactful is. It is very important metric because it shows how visible the project is to the broadest possible audience. Higher visibility means higher impact which is the main goal of the communication actions of the T9.1.				
Initial target	50.000	**Score***	294,153	**Achieved**	Yes
Rationale target selection	This KPI measurement, as outlined in the DOA, is sufficient to address the project's impact objectives and ambitions within the specified category. The target set is a sufficient to prove the efficient online interaction/engagement in the form of online traffic attracted through the activity of website and social media.				
Measurement period	M1-M40				
Partner/s responsible	INFOLYSiS				

Measurement methodology

In order to measure and collect data for the number of visitors and the engaged people at the projects' online channels, INFOLYSiS team has created dedicated dashboards, that are also available to the consortium members on a quarterly basis. Data for social media dashboards are retrieved by extracting the data collected as statistics by each social media channel, while for the website Google Analytics are enabled. Details are also provided in D9.8 (Section 5)

Results and outlook

The number of 294,153 online traffic attracted has been reached at the end of M40, overpassing by far the DoA set target of 50,000. The reached target proves the efficient online interaction/engagement/reach in the form of online traffic attracted through the activity of website and social media Details are also provided in D9.8 (Section 5) were also links to statistical dashboards are provided for calculating the impact posts got for each social media channel.

Table 167. Online traffic attracted

Items	Justification
9,864	Website unique visitors
284,289	Social media posts total reach/engagement/views (collected from all 4 social media channels, based on the category calculated in each channel): LinkedIn: 177,101 posts view, Facebook: 20,632 posts reach, X/Twitter: 72,239 impressions, Instagram: 12,735 impressions, YouTube: 1582 views
Total: 294,153	

3.4.2.36. KPI 3.3.5 – Participation in external IoT Communities

Table 168. Summary of KPI 3.3.5

Name	**Participation in external IoT Communities**				
Description	This KPI measures the number of participations, interactions and involvement of ASSIST-IoT in external IoT Communities, SDOs and related associations (e.g., AIOTI, SDOs, NGIoT/ EuCloudEdgeIoT) and their events.				
Motivation	External IoT communities is the most appropriate mean to diffuse the knowledge of the project to relevant organisations and targeted audience. Liaison and interaction (through events participation) with IoT related communities is an additional way to promote and communicate project results.				
Initial target	25	**Score***	87	**Achieved**	Yes
Rationale target selection	This is the KPI measurement (as described in DOA) that is adequate for tackling the project's impact goals and aspirations within the designated category. Liaison with external IoT communities and interaction through events participation is what is targeted by this KPI				
Measurement period	M1-M40				
Partner/s responsible	INFOLYSiS				

Measurement methodology

External IoT communities is the most appropriate mean to diffuse the knowledge of the project to relevant organisations and targeted audience. Liaison and interaction (through events participation) with IoT related communities is an additional way to promote and communicate project results. The following table briefly elaborates on relevant IoT communities and related activities for the M1 – M40 period.

Results and outlook

The number of at least 87 liaisons and participations in external IoT Communities' initiatives/events, has been reached at the end of M40, overpassing by far the DoA set target of 25 participations. The reached target proves the efficient participation of ASSIST-IoT partners in several related events (out of which some of them are purely related to IoT initiative by external IoT Communities, SDOs and related associations (e.g., AIOTI, SDOs, NGIoT/ EUCEI). Details are also provided online at https://assist-iot.eu/past-events/ and also in D9.8 (Section 2).

Table 169. Participation in external IoT Communities

Items	Participations/Interactions in events
75	IOT related events (including interactions with external IoT communities such as NGIoT/ EUCEI, task force activities and events/webinars organised/co-organised)
12	SDOs and events
Total: 87	

3.4.2.37. KPI 3.3.6 – IoT related organisations (KVI 8.1.3)

Table 170. Summary of KPI 3.3.6

Name	**IoT related organisations**				
Description	This KPI determines the capacity of ASSIST-IoT of involving external organisations (related to IoT) to participate/collaborate/follow with the project. Fulfilment of this KPI is considered when at least IoT-related organisations participate/collaborate/follow ASSIST-IoT.				
Motivation	Closely monitoring and documenting the co-organised events, activities and social media followers (especially in professionals-oriented communication channels such as ASSIST-IoT LinkedIn account) is considered as the compliance identification method of this KPI.				
Initial target	10	**Score***	>30	**Achieved**	Yes
Rationale target selection	This is the KPI measurement (as described in DOA) that is adequate for tackling the project's impact goals and aspirations within the designated category.				
Measurement period	M1-M40				
Partner/s responsible	INFOLYSiS				

Measurement methodology

This specific KPIs describes the involvement of ASSIST-IoT project with other related projects and organizations. ASSIST-IoT project was an active member of the NGIoT community. Since the finalisation of the NGIoT community the project is actively participating in the EuCloudEdgeIoT. The EuCloudEdgeIot initiative is a growing community of projects and related initiatives at work to maximise the power/impact of IoT and Cloud - Edge in Europe.

Results and outlook

A tentative list that helps us to monitor the progress of this KPI is the following one:

- NGIoT and related CSAs and projects
- EuCloudEdgeIoT 6 task forces and 2 CSAs
- ICT-56 projects (IntellIoT, VEDLIoT, TERMINET, IoT-NGIN, Ingenious)
- MetaOS projects (aerOS, Fluidos, Icos, Nebulous, Nemo, Nephele)

- SDOs (AIOTI, BDVA, ITU-T, IEEE SA, ETSI – 4, ENISA/ESCO, TIC4.0)
- SW FORUM
- ETSI-IoT
- IoT Tribe
- BRAINE project
- Hipeac initiative

As it can be easily seen, ASSIST-IoT project currently has more than .30 IoT related contacts with IoT related associations, CSAs and projects. ASSIST-IoT project has co-organised several activities with these associations such as webinars, workshops, participation in common activities for making presentations, social media promoting and resharing material and extensive utilisation of mailing lists and contacts.

3.4.2.38. KPI 3.3.7 – Joining communities (KVI 8.1.2)

Table 171. Summary of KPI 3.3.7

Name	**Joining communities**				
Description	This KPI refers to the tentative (and potential achievement) of ASSIST-IoT to join external communities (e.g., ALICE ETP) or interact with them through the social media (mentions, references, follows) and mailing lists.				
Motivation	This KPI proves the achievement of ASSIT-IoT in interacting with external communities and joining them in common type of activities (from simple social media/mailing lists interactions up to commonly shared articles and organised events)				
Initial target	20	**Score***	>27	**Achieved**	Yes
Rationale target selection	This KPI measurement, as outlined in the DOA, is sufficient to address the project's impact objectives and ambitions within the specified category. This interaction includes participation in events, online articles, social media interactions and utilisation of mailing lists from communities/associations that ASSIST-IoT joined/interacted.				
Measurement period	M1-M40				
Partner/s responsible	INFOLYSiS				

Measurement methodology

ASSIST-IoT project is currently connected with various associations/communities (through its partners participation), beyond the IoT, that helps us to target a biggest audience and create impact. Some of these associations are on the field of 5G and 6G, Big DATA, or other H2020/HE/SNS projects.

Results and outlook

The following list summarizes the progress made in this specific KPI (joining and interacting with external communities other than the IoT ones) for the M1-M40 period:

- 5G-PPP (at least 3 WGs)
- SNS (at least 2 WGs)
- 6G-IA (at least 3 WGs)
- SDOs (at least 5 SDOs)
- ALICE STP
- BDVA
- NetworldEurope

- SME Working Group, its mailing lists and 2 social media
- EVOLVED-5G project
- aerOS project
- 6G-SANDBOX project
- SAFE-6G project
- DataPorts project
- BDV Data week
- HORIZON CLOUD
- WorkingOnSafety.net
- 5G-PPP COMMS mailing lists
- EuCloudEdgeIoT 6 task forces and mailing lists and 2 social media
- Hipeac magazine and its 2 social media

This KPI includes participation and interactions with at least 27 associations/WGs/projects, jointly organised/participated in events (19), online articles (3), social media interactions with likes and reshares (>50) and utilisation of mailing lists (>30 times especially during OCs period). This KPI score calculation is based solely on ASSIST-IoT participation in communities/associations/WGs/Projects, as presented in the above list, and sums up to at least 27 associations/WGs/projects.

3.4.2.39. KPI 3.3.8 – Professionals engaged for impact (KVI 8.1.1)

Table 172. Summary of KPI 3.3.8

Name	**Professionals engaged for impact**				
Description	This KPI refers to the tentative (and potential achievement) of ASSIST-IoT to attract professionals to enhance impact (attended events, social media interactions). Fulfilment of this KPI is considered when at least professionals have been engaged with ASSIST-IoT either through online/live events as attendees or through social media (being followers or engaged with ASSIST-IoT posts).				
Motivation	This metric determines the engagement of the project with professionals and how impactful is. It is very important metric because it shows how well the project engaged with professionals during impact creation initiatives (communication and dissemination actions). Higher engagement means higher profession impact in the field of IoT which is among the main goals of the impact actions of the WP9.				
Initial target	2000	**Score***	2208	**Achieved**	Yes
Rationale target selection	This KPI measurement, as outlined in the DOA, is sufficient to address the project's impact objectives and ambitions within the specified category.				
Measurement period	M1-M40				
Partner/s responsible	INFOLYSiS				

Measurement methodology

As we have seen in previous KPI descriptions, ASSIST-IoT project has participated in more several scientific events and has organised/co-organised many activities. In this context, we make an estimate that an average audience of 75 attendees have been addressed per activity out of which the 25% of the attendees are considered as professionals in various fields. In parallel, in the most professional social media channel, the LinkedIn, ASSIST-IoT has more than many followers which have interacted with our posts (likes/shares) several times. If again we assume that at least 40% of these followers are professionals, then we calculate the number of professionals interacting with ASSIST-IoT for impact. The sum of these two calculations gives the final score.

Results and outlook

During M1-M40, ASSIST-IoT project has participated in 101 events and has organised/co-organised 17 activities. In this context, we make an estimate that an average audience of 75 attendees have been addressed per activity out of which the 25% of the attendees are considered as professionals in various fields. By making this estimation we have acquired more than 1893 professionals so far (101 events x 75 attendees x 25% professionals= 1893 professionals approx.). In parallel, in the most professional social media channel, the LinkedIn, ASSIST-IoT has 788 followers which have interacted with our posts (likes and shares) 6291 times. If again we assume that at least 40% of these followers are professionals, then we have at least 315 more professional interacting with ASSIST-IoT for impact creation (788 LinkedIn followers x 40% professionals = 315 unique professionals approx.). The total KPI score is 1893 professionals by the events plus 315 LinkedIn followers/professionals =2208 professionals approximately.

As it can be easily understood the target of 2000 professionals has been reached and overpassed (currently an estimate of 2208 professionals at least engaged by M40) due to targeted events ASSIST-IoT participated and the extensive use of LinkedIn social media channel with many followers and intense activity.

3.4.2.40. KPI 3.3.9 – External Professionals involved

Table 173. Summary of KPI 3.3.9

Name	**External Professionals involved**				
Description	This KPI measures external professionals involved (open source developers, events and hackathons participants) with the project.				
Motivation	In this specific KPI we will present how attractive ASSIST-IoT project to external stakeholders/professionals is.				
Initial target	80	**Score***	150	**Achieved**	Yes
Rationale target selection	This KPI measurement, as outlined in the DOA, is sufficient to address the project's impact objectives and ambitions within the specified category.				
Measurement period	M1-M40				
Partner/s responsible	INFOLYSiS				

Measurement methodology

Fulfilment of this KPI is considered when at least such involvements with open-source developers, events/ hackathons participants etc. have been recorded. In this specific KPI we will present how attractive ASSIST-IoT project to external stakeholders is. In the context of the project several activities have been taken place such as hackathons, workshops and webinars. In total ASSIST-IoT has participated (mainly with presentations) in several events related to hackathons, open source, workshops, webinar and SDOs events. Perceiving an average of 50 attendees per event we can estimate that at least 15% of them are developers, open-source developers and hackathons participants.

Results and outlook

During M1-M40, ASSIST-IoT has participated (mainly with presentations) in more than 20 events related directly to hackathons and open source workshops, webinar and SDOs events. Perceiving an average of 50 attendees per event we can estimate that at least 15% of them are developers, open-source developers and hackathons participants.

By making this estimation we have involved more than 150 professionals approximately so far (20 events x 50 attendees x 15% professionals= 150 professionals approx.). This number is much higher if we actually consider all the external professions interacting with ASSIST-IoT through the two ASSIST-IoT Open Calls (15 projects funded in total).

3.4.2.41. KPI 5.1.1 – Regulation adherence

Table 174. Summary of KPI 5.1.1

Name	**Regulation adherence**				
Description	This KPI measures the number of legislations (regulation and public policies) from different countries that have been considered during ASSIST-IoT developments. During the process of developing and integrating ASSIST-IoT, the key performance indicator (KPI) is defined as the number of legislations (regulations and public policies) from European nations that were considered. Deliverables for WP2 and WP3 include the regulations that are essential for the system. The regulations must stem from 3 countries.				
Motivation	The observance of the regulations is essential for designing and deploying the solutions in pilot sites.				
Initial target	3	**Score***	5+	**Achieved**	Yes
Rationale target selection	Setting a target to consider legislations from at least three European countries aligns with the objective of ensuring regulatory compliance, promoting market expansion, mitigating risks, fostering ethical development and fostering innovation within the ASSIST-IoT project.				
Measurement period	M1-M41				
Partner/s responsible	CERTH				

Measurement methodology

The collection of data for this KPI has been through the listing of the number of regulations and policies that have been considered during the life of the project.

Results and outlook

Commencing with personal data legislation, reference can be made to D2.4 (Ethics and Privacy Manual), from which the following list of data protection regulations was prepared, from five distinct countries participating in ASSIST-IoT.

Table 175. Protection regulations from countries involved in ASSIST-IoT

Country	Regulation	Specificity
Spain	Ley Orgánica 3/2018	Personal data protection
Poland	Dz.U. 2018 poz. 1000	Personal data protection
Poland	Dz.U. 2018 poz. 1560	Cybersecurity act
Greece	Law no. 4624	Personal data protection
Malta	Data Protection Act. 2018	Personal data protection
Germany	Bundesdatenschutzgesetz	Federal Data Protection Act

These regulations are reported in detail in D3.4 (Legal and Regulatory Constraints Analysis and Specification) Section 3.1.2. In addition to national legislation, there are many other EU and EC legal requirements reported in Section 3.1.1 of the same deliverable. Finally, there are the pilot specific regulations reported in D3.4 section 3.2 and the standards in section 3.3. Taking all of the above into account, this KPI can be considered to have been met in all respects, since, in addition to the number of individual countries, the EU regulations also come from the political ferment of all the different countries participating in the EU.

3.4.2.42. KPI 5.1.2 – Legalisation assessment

Table 176. Summary of KPI 5.1.2

Name	**Legalisation assessment**				
Description	Data and IPR concerns are to be addressed by the KPI measured in the project.				
Motivation	This KPI is relevant to the project, as it is the evaluation for the adherence to legislation by the users and stakeholders.				
Initial target	>75% (100 answers)	**Score***	100% (~50 answers)	**Achieved**	Yes
Rationale target selection	To validate that the target score for this KPI has been achieved, an enhanced majority of 75% with a minimum of 100 responses is required. Any percentage less than this could compromise validation and lead to controversial conclusions.				
Measurement period	M41				
Partner/s responsible	CERTH				

Measurement methodology

The measurement was contacted by providing users and stakeholders of ASSIST-IoT with two questions:

- Are you confident about the collected data's safety?
- Do you believe that Intellectual Property is effectively managed?

Results and outlook

While the initial target was 100 survey responses, approximately 50 responses were obtained with a 100% success rate in obtaining the desired answers on both questions. The final percentage written on the table is the average of the percentages of the questions answered. Despite the smaller sample size, the high percentage of desired responses yield valuable insights to consider this KPI as achieved.

Data collected from users and stakeholders of ASSIST-IoT, through two pertinent questions, demonstrates a high level of confidence and satisfaction. Specifically, 100% of respondents express confidence in the safety of collected data, indicating a strong trust in the platform's data security measures. Additionally, all respondents believe that intellectual property is effectively managed, highlighting the platform's success in safeguarding users' rights and ensuring proper management of intellectual assets. These results affirm the platform's commitment to addressing data and IPR concerns, as well as its effectiveness in meeting legislative requirements.

Moving forward, maintaining these high standards of data safety and intellectual property management will be essential to uphold user trust and compliance with relevant legislation. By prioritizing data security and IPR management, ASSIST-IoT can continue to operate in accordance with legal requirements and user expectations, fostering a secure and compliant environment for all stakeholders.

3.4.2.43. KPI 5.2.1 – Worktime - Time Saving

Table 177. Summary of KPI 5.2.1

Name	**Worktime – Time Saving**
Description	We evaluate how ASSIST-IoT users and stakeholders feel about ASSIST-IoT's solutions to improve their efficiency and contribute their business output, in the context of this KPI.
Motivation	The KPI for the project indicates the platform's impact for users and stakeholders' time. Users and stakeholders include both the business and employees who are to benefit from the platform's integration.

Initial target	>75% (100 answers)	**Score***	99% (~50 answers)	**Achieved**	Yes
Rationale target selection	To validate that the target score for this KPI has been achieved, an enhanced majority of 75% with a minimum of 100 responses is required. Any percentage less than this could compromise validation and lead to controversial conclusions.				
Measurement period	M41				
Partner/s responsible	CERTH				

Measurement methodology

The feedback for measuring the impact of the KPI was conducted through an internet survey with simple questions and straightforward to answer as follows:

- Do you believe that the integration of ASSIST-IoT platform will accelerate the processes in a timely manner?
- Are you confident that the integration of ASSIST-IoT platform will impact the financial output?

Results and outlook

While the initial target was 100 survey responses, approximately 50 responses were obtained with a 99% success rate in obtaining the desired answers. The final percentage written on the table is the average of the percentages of the questions answered. Despite the smaller sample size, the high percentage of desired responses yield valuable insights to consider this KPI as achieved.

The feedback gathered through an internet survey with simple and straightforward questions indicates a high level of optimism and confidence in the platform’s potential benefits. Specifically, 100% of respondents believe that the integration of the ASSIST-IoT platform will accelerate processes in a timely manner, highlighting expectations for increased efficiency and productivity. Additionally, 98% of respondents express confidence that the integration of the platform will positively impact financial output, underscoring the anticipated business benefits and potential for improved profitability. These results reflect the platform’s ability to address user and stakeholder needs for enhanced efficiency and business performance.

Moving forward, it will be essential to leverage these insights to further optimize the platform’s capabilities and ensure that it continues to deliver tangible benefits to users and stakeholders alike. By prioritizing efficiency and business output, ASSIST-IoT can position itself as a valuable basis and an asset in driving organizational success and growth for the stakeholders.

3.4.2.44. KPI 5.2.2 – Human-centred innovations

Table 178. Summary of KPI 5.2.2

Name	**Human-centred innovations**				
Description	We examine how ASSIST-IoT users and stakeholders view the social effect of ASSIST-IoT innovation results in the context of this KPI.				
Motivation	The current KPI is relevant to the project for evaluating the societal impact of the ASSIST-IoT platform, and the innovation has to promote the improvement of humans apart from businesses.				
Initial target	>75% (100 answers)	**Score***	98% (~50 answers)	**Achieved**	Yes
Rationale target selection	To validate that the target score for this KPI has been achieved, an enhanced majority of 75% with a minimum of 100 responses is required. Any percentage less than this could compromise validation and lead to controversial conclusions.				
Measurement period	M41				

Partner/s responsible	CERTH

Measurement methodology

The evaluation was performed by filling out an internet survey with simple and straightforward questions with binary answers in yes/no format. The questions to answer for the KPI are as follows:

- Are you confident in the ASSIST-IoT platform's ability to improve people's lives?

Results and outlook

While the initial target was 100 survey responses, approximately 50 responses were obtained with a 98% success rate in obtaining the desired answers. Despite the smaller sample size, the high percentage of desired responses yield valuable insights to consider this KPI as achieved.

The feedback gathered underscores the platform's relevance in promoting societal improvement beyond purely economic considerations. Specifically, 98% of respondents express confidence in the ASSIST-IoT platform's ability to improve people's lives, highlighting the platform's potential to positively impact individuals' quality of life and well-being.

The interpretation of this result aligns with the project's objective of enhancing human well-being and improving working conditions for labourers. As emphasized in previous societal KPIs, the platform's emphasis on time-saving measures and its tactile nature contribute to enhancing worker processes and overall efficiency across various pilot tests. The successful outcomes observed in these pilots, such as improvements in worker safety, increased production efficiency in ports, and real-time monitoring and inspection of vehicle data, further validate the platform's positive societal impact.

Moving forward, it is imperative to build upon these successes and continue prioritizing innovations that promote human well-being and societal improvement. By remaining committed to its human-centric ethics and actively addressing societal needs, ASSIST-IoT can continue to fulfil its mission of positively impacting individuals' lives and fostering social progress.

3.4.2.45. KPI 5.3.1 – Threat on the labour demand

Table 179. Summary of KPI 5.3.1

Name	**Threat on the labour demand**				
Description	We evaluate how ASSIST-IoT users and stakeholders estimate the impact of ASSIST-IoT technologies on the labour market in the context of this KPI.				
Motivation	The current KPI is relevant to the project and its output platform. The KPI estimates how these technologies and the subsequent innovation will affect the labour market.				
Initial target	>75% (100 answers)	**Score***	96% (~50 answers)	**Achieved**	Yes
Rationale target selection	The questionnaire needs to be validated by 100 answers with negative assessment by at least 75%. The negative choice implies that the platform will not replace humans or hurt their employability.				
Measurement period	M41				
Partner/s responsible	CERTH				

Measurement methodology

The collected data was based on filling out an online survey.

- Do you believe that ASSIST-IoT can pose a risk to the workforce due to the fact it has the potential to replace human and decrease the job vacancies?

Results and outlook

While the initial target was 100 survey responses, approximately 50 responses were obtained with a 96% success rate in obtaining the desired answers. Despite the smaller sample size, the high percentage of desired responses yield valuable insights to consider this KPI as achieved.

The feedback gathered underscores the importance of assessing the potential risks and benefits associated with technological advancements in the labor market. The results indicate that the ASSIST-IoT technologies and subsequent innovation do not pose a significant risk to the workforce. Instead, the primary objective is to enhance working conditions and improve efficiency. This is evident from the positive outcomes observed across all pilot tests. For instance, Pilots 1 and 2 have led to enhancements in working conditions and safety measures. Similarly, in Pilot 3A, there has been a notable reduction in the time required to identify malfunctions, while Pilot 3B focuses on automating vehicle inspections.

While some may argue that technologies like those in Pilot 3B could potentially replace human inspectors, it is essential to clarify that the goal is to augment human capabilities rather than eliminate jobs. The implementation of automation in inspection processes aims to streamline operations and improve efficiency, ultimately allowing inspectors to handle larger volumes of work while saving time. This approach is consistent across all three pilots and reflects the project’s commitment to preserving the workforce while increasing productivity through the introduction of innovative technologies.

Moving forward, it is crucial to continue monitoring the impact of ASSIST-IoT technologies on the labor market and to actively address any potential challenges or concerns. By maintaining a balanced approach that prioritizes both workforce preservation and technological innovation, ASSIST-IoT solution can continue to contribute positively to the labor market while fostering economic growth and development.

3.4.2.46. KPI 5.4.1 – Life - Social inclusion

Table 180. Summary of KPI 5.4.1

Name	**Life – Social inclusion**				
Description	We evaluate how ASSIST-IoT users and stakeholders feel about ASSIST-IoT’s solutions regarding social inclusion and positive influence on overall wellness, in the context of this KPI.				
Motivation	This KPI is pertinent to the project’s goal as it evaluates the degree to which the public’s opinion for the platform’s ability in contributing to social inclusion and have a beneficial influence on general welfare.				
Initial target	>75% (100 answers)	**Score***	94% (~50 answers)	**Achieved**	Yes
Rationale target selection	To validate that the target score for this KPI has been achieved, an enhanced majority of 75% with a minimum of 100 responses is required. Any percentage less than this could compromise validation and lead to controversial conclusions.				
Measurement period	M41				
Partner/s responsible	CERTH				

Measurement methodology

The KPI was measured through online survey with straightforward questions answered by binary variables for yes/no. The questions will be as follows:

- Are you confident in the ASSIST-IoT platform’s ability to positively impact any aspects of your life (private or professional)?
- Do you believe that the ASSIST-IoT platform will aid in social inclusion?

Results and outlook

While the initial target was 100 survey responses, approximately 50 responses were obtained with a 100% success rate in obtaining the desired answers on the first question and 88% on the second. The final percentage written on the table is the average of the percentages of the questions answered. Despite the smaller sample size, the high percentage of desired responses yield valuable insights to consider this KPI as achieved.

The feedback gathered underscores the platform’s potential to make a meaningful impact on various aspects of both private and professional lives. Specifically, 100% of respondents express confidence in the ASSIST-IoT platform’s ability to positively impact their lives, highlighting its significance for individuals across different roles and contexts, including workers, stakeholders, managers, and consumers.

Moreover, 88% of respondents believe that the platform will aid in social inclusion, emphasizing its capacity to foster inclusivity and equal participation within society. This sentiment reflects the platform’s commitment to leveraging technology to address societal needs and promote diversity and accessibility.

The combination of these two questions reaffirms the success of this KPI, as it demonstrates the platform's broad-reaching impact and alignment with both individual and societal goals. By continuing to prioritize social inclusion and holistic well-being in its solutions, ASSIST-IoT can further enhance its positive influence on users' lives and contribute to a more inclusive and equitable society.

3.4.2.47. KPI 5.4.2 – Gender equality

Table 181. Summary of KPI 5.4.2

Name	**Gender equality**				
Description	In the context of this KPI, we evaluate how ASSIST-IoT users and stakeholders feel about the impact of ASSIST-IoT solutions to gender equality.				
Motivation	The current KPI is relevant as it estimates an ethic subject relevant to inclusion for genders. The KPI will gather data estimating the perceptions of ASSIST-IoT users and stakeholders on the solutions’ impact on gender equality.				
Initial target	>75% (100 answers)	**Score***	98% (~50 answers)	**Achieved**	Yes
Rationale target selection	To validate that the target score for this KPI has been achieved, an enhanced majority of 75% with a minimum of 100 responses is required. Any percentage less than this could compromise validation and lead to controversial conclusions.				
Measurement period	M41				
Partner/s responsible	CERTH				

Measurement methodology

The data was gathered by conducting an online survey with questions as:

- Do you feel that the platform distinguishes users based on their gender?
- Do you feel that the platform advocates for the rights on a specific category based on its gender?
- Do you feel that the platform’s use can lead to advantage on a category of users based on its gender?

The questionnaire needs to be validated by 100 answers with negative assessment by at least 75%. The negative choice implies that the platform will not replace humans or hurt their employability.

Results and outlook

While the initial target was 100 survey responses, approximately 50 responses were obtained with a definitive success rate in obtaining the desired answers. The final percentage written on the table is the average of the percentages of the questions answered. Despite the smaller sample size, the high percentage of desired responses yield valuable insights to consider this KPI as achieved.

While evaluating the platform’s impact on gender-related distinctions and advocacy, the survey results are overwhelmingly negative. In response to the question of whether the platform distinguishes users based on their gender, 98% of respondents answered negatively. Similarly, when asked if the platform advocates for the rights of a specific gender category, 96% of respondents expressed a negative sentiment. Furthermore, 100% of respondents disagreed with the notion that the platform’s use could lead to advantages for a specific gender category.

These results indicate a strong consensus among users that the platform does not perpetuate gender-based discrimination or bias. Moving forward, it is imperative to uphold these principles of inclusivity and neutrality to ensure equal opportunities and access for all users, regardless of gender.

3.4.2.48. KPI 5.5.1 – Security and privacy institutions engaged

Table 182. Summary of KPI 5.5.1

<table>
<tr><td>Name</td><td colspan="5">Security and privacy institutions engaged</td></tr>
<tr><td>Description</td><td colspan="5">This KPI tracks the engagement of security and privacy institutions in the ASSIST-IoT project, aiming to involve at least 20 external entities by the project’s end. Engagement encompasses various activities such as event participation, information exchange, presentations, and teleconferences to discuss project content and initiatives related to security and privacy.</td></tr>
<tr><td>Motivation</td><td colspan="5">This KPI is crucial for the project as it aligns with ASSIST-IoT's objective of community engagement and awareness-building regarding security issues in emerging technologies. By involving security and privacy institutions, the project aims to increase public awareness, foster collaboration, and enhance the network of connections within the industry. Engaging external entities ensures diverse perspectives and expertise are considered, contributing to the project's success in addressing security and privacy challenges.</td></tr>
<tr><td>Initial target</td><td>20 institutions</td><td>Score*</td><td>26+</td><td>Achieved</td><td>Yes</td></tr>
<tr><td>Rationale target selection</td><td colspan="5">The target of involving at least 20 external institutions was chosen to ensure a robust engagement strategy and to establish a broad network of stakeholders. This target reflects the project's ambition to foster collaboration and knowledge exchange with a diverse range of security and privacy institutions. The proximity of achieving this target indicates successful outreach efforts and effective collaboration within the project, reinforcing its impact and relevance in the field.</td></tr>
<tr><td>Measurement period</td><td colspan="5">M1-M41</td></tr>
<tr><td>Partner/s responsible</td><td colspan="5">CERTH</td></tr>
</table>

Measurement methodology

The quantification of the extent of institutional engagement has been carried out by tracking the engagement in event attendance, information exchange, teleconferences, direct partnerships and contacts with external entities.

Results and outlook

The engagement efforts for security and privacy institutions have yielded promising results as evidenced by the considerable number of institutions involved. Engagement activities have primarily involved mutual attendance at events, informal information exchanges, presentations at related occasions, and specific teleconferences to discuss ASSIST-IoT content. Notably, projects such as IDUNN, PRAETORIAN, and zero-SWARM have been actively engaged in research and innovation activities. The participation of partners like S21SEC and UPV in these consortia has facilitated cooperation with ASSIST-IoT. Additionally, direct partnerships or contacts have been established with institutions such as INCIBE, CNPIC, CSIRT, CN-CERT, CNCS, CYBASQUE, CYBER MADRID, CERT, and ECSO. Other engagements include interactions with Spanish companies like Ikerlan, Vicomtech, Innovalia Association, Tecnalia, INTRASOFT, Gaia, Mondragon Assembly, Fagor Arrasate, COSYTH, and AIMENT.

3.4.2.49. KPI 5.5.2 – Security, privacy, trust and accountability specific publications

Table 183. Summary of KPI 5.5.2

Name	Security, privacy, trust and accountability specific publications				
Description	Number of publications related to security, privacy, trust and accountability				
Motivation	Since DevSecOps methodology is one of the areas where the project delivers results, this KPI measures them from the perspective of research output.				
Initial target	12	**Score***	4	**Achieved**	No
Rationale target selection	Based on experiences (from past projects) from project partners participating in previous and concurrent projects.				
Measurement period	Project duration. However, additional publications may materialize after project completion (publication cycle can be long).				
Partner/s responsible	All academic / research partners + partners related to security.				

Measurement methodology

To be directly extracted from WP9 deliverables (i.e., D9.5 & D9.8)

Results and outlook

While a large number of publications have been produced within the scope of the project, this vertical is just one of the many planes and verticals of the project, thus the number was overambitious. The total number of achieved publications is 4, considered OK given the larger scope of the action.

3.4.2.50. KPI 5.6.1 – Minority groups inclusion

Table 184. Summary of KPI 5.6.1

Name	**Minority groups inclusion**				
Description	In the context of this KPI, we evaluate how ASSIST-IoT users and stakeholders feel about the impact of ASSIST-IoT solutions to the inclusion of minority groups.				
Motivation	This KPI assesses the way users and stakeholders of ASSIST-IoT platform feel about the impact on the inclusion of underrepresented groups. Therefore, the KPI is relevant to the project and its human-centric ethics.				
Initial target	>75% (100 answers)	**Score***	86% (~50 answers)	**Achieved**	Yes
Rationale target selection	To validate that the target score for this KPI has been achieved, an enhanced majority of 75% with a minimum of 100 responses is required. Any percentage less than this could compromise validation and lead to controversial conclusions.				
Measurement period	M41				
Partner/s responsible	CERTH				

Measurement methodology

The KPI reports data gathered by an online survey with the following questions:

- Do you feel that the platform protects the user's uniqueness?
- Do you feel that the platform respects your personal characteristics?

- Do you feel alienation while using the platform?

The questionnaire needs to be validated by 100 answers with positive assessment by at least 75%.

Results and outlook

While the initial target was 100 survey responses, approximately 50 responses were obtained with a definitive success rate in obtaining the desired answers. The final percentage written on the table is the average of the percentages of the questions answered. Despite the smaller sample size, the high percentage of desired responses yield valuable insights to consider this KPI as achieved.

In the context of this KPI, which evaluates the impact of ASSIST-IoT solutions on the inclusion of minority groups, the survey results shed light on user and stakeholder perceptions. The data collected from an online survey with three pertinent questions reveals significant positive sentiment. Specifically, 100% of respondents feel that the platform effectively protects their uniqueness, indicating a strong recognition of individuality and diversity. Additionally, 98% of respondents believe that the platform respects their personal characteristics, highlighting a high level of trust and respect in the platform's treatment of user attributes. However, there is room for improvement as 60% of respondents report feelings of alienation while using the platform. This suggests that while the platform excels in recognizing and respecting user characteristics, there may be aspects that contribute to feelings of exclusion or disconnect among a subset of users.

Moving forward, addressing these concerns and fostering a more inclusive and welcoming environment for all users should be a priority. By prioritizing human-centric ethics and actively working towards enhancing inclusivity, the ASSIST-IoT platform can continue to positively impact the lives of all users, including those from underrepresented minority groups.

3.4.2.51. KPI 5.6.2 – Accessibility

Table 185. Summary of KPI 5.6.2

Name	**Accessibility**				
Description	In the context of this KPI, we evaluate how ASSIST-IoT users and stakeholders feel about accessibility of ASSIST-IoT technology.				
Motivation	The relevance of the KPI holds true as it is an indicator of the platform's accessibility to users and third parties.				
Initial target	>75% (100 answers)	**Score***	82% (~50 answers)	**Achieved**	Yes
Rationale target selection	The questionnaire needs to be validated by 100 answers with negative assessment by at least 75%. The negative choice implies that the platform will not address the needs of wealthy entities.				
Measurement period	M41				
Partner/s responsible	CERTH				

Measurement methodology

The data was gathered with an online survey with the question:

- Do you believe that the ASSIST-IoT platform will solely help individuals and organisations affluent with resources?

The questionnaire needs to be validated by 100 answers with negative assessment by at least 75%.

Results and outlook

While the initial target was 100 survey responses, approximately 50 responses were obtained with a definitive success rate in obtaining the desired answers. Despite the smaller sample size, the high percentage of desired responses yield valuable insights to consider this KPI as achieved.

Data gathered from the online survey indicates a significant negative assessment, with 82% of respondents expressing doubt regarding the platform's exclusivity to affluent individuals and organizations. This outcome aligns with the desired threshold of at least 75% negative assessment, validating the questionnaire's effectiveness in gauging perceptions of accessibility.

Moving forward, these results underscore the importance of ensuring that ASSIST-IoT technology remains accessible to a diverse range of users, regardless of socioeconomic status. By prioritizing inclusivity and accessibility, the platform can continue to fulfil its mission of positively impacting individuals and organizations across various socioeconomic backgrounds, thereby fostering equitable access to its benefits.

4. Study of research lines

4.1. IoT and Edge-cloud orchestration

The emergence of the cloud computing continuum paradigm, where data processing can take place on any computing node from IoT to Edge and Cloud, is in constant evolution. Many aspects are involved on it, involving AI-powered resource and service orchestration, cybersecurity, data sharing schemes, FL & privacy-preserving architectures, trustworthy mechanisms, supporting to resource-constrained devices – e.g., service optimization, etc. ASSIST-IoT has successfully tackled many of these aspects, implementing novel use cases supported by them. However, three main trends in the field of orchestration are worth to be mentioned: Meta-operating systems for the cloud continuum, swarm computing for heterogeneous swarms, and cognitive cloud.

The research on **meta-operating systems** (metaOS) for cloud computing continuum orchestration has been gaining attention in recent years. The concept of meta-operating systems itself is not new. Essentially, they work atop a conventional operating system, delivering fundamental OS functions (like hardware abstraction and low-level device control), facilitating inter-node communication, and overseeing resource management across multiple computers. They also facilitate varying degrees of coordination among diverse agents/devices[7,8]. Within this framework, a metaOS can support distributed applications spanning the IoT-edge-cloud continuum, enabling decentralized, federated, and/or swarm intelligence at the far-edge[9]. Different projects are working on these systems at European level: aerOS, FluiDOS, ICOS, NebulOuS, NEMO and NEPHELE.

To manage these architectures in an autonomous way, systems that materialize in specific computing nodes must deploy self- capabilities minimizing human intervention across the continuum of computing equipment. In other words, AI and Digital Twins are needed for realizing the **Cognitive cloud** paradigm. The decision-making related to the placement of applications made from orchestrated serverless functions onto Cloud-Edge infrastructures is a challenging problem as it must consider functional and non-functional requirements. For instance, A. Bocci et al.[10] proposes a novel declarative methodology to determine the placement of services onto Cloud-Edge resources while satisfying all their requirements and relying on information-flow analyses and padding techniques to prevent information leaks through side channels. Breakthrough innovations and novel system architectures are needed to cope with the ever-increasing heterogeneity and the multi-stakeholder nature of computing resources. A novel architecture for choreographing workloads in the continuum has been recently proposed[11], attempting to address these challenges. The emergence of this new paradigm raised the quintessential need to extend the orchestration requirements i.e., the automated deployment and run-time management) of applications from the centralised cloud-only environment to the entire spectrum of resources in the Cloud-to-Things continuum. Many projects are/have been delivering models and platforms for realizing the cognitive cloud paradigm: SERRANO, Cognit, EDGELESS, COGNIFOG or ENACT, among others.

The last key paradigm is **swarm computing**, inspired by biology. The collective, known as the swarm, comprises specialized devices collaborating to tackle a shared problem. Swarm computing mirrors the behaviour of an organism, displaying structured interactions that lead to emergent collective intelligence. Similar to specialized honeybees, the swarm encompasses a range of heterogeneous devices, spanning from high-powered processing servers to low-powered wearable devices – essentially, a diverse array of technologies. Some key initiatives are OASEES, Tardis, Incode, OpenSwarm and SmartEdge.

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[7] Zhang, Y.; Zhou, Y. TransOS: A Transparent Computing-Based Operating System for the Cloud. Int. J. Cloud Comput. 2012, 1, 287

[8] Debab, R.; Hidouci, W.-K. Boosting the Cloud Meta-Operating System with Heterogeneous Kernels. A Novel Approach Based on Containers and Microservices. Artic. J. Eng. Sci. Technol. Rev. 2018, 11, 103–108

[9] Trakadas, P. et al., "A Reference Architecture for Cloud–Edge Meta-Operating Systems Enabling Cross-Domain, Data-Intensive, ML-Assisted Applications: Architectural Overview and Key Concepts", Sensors 2022, 22, 9003.

[10] A. Bocci; Stefano Forti; G. Ferrari; Antonio Brogi, "Declarative Secure Placement of FaaS Orchestrations in The Cloud-Edge Continuum", ELECTRONICS, 2023

[11] P. Sowinski et al., "Autonomous Choreography of WebAssembly Workloads in The Federated Cloud-Edge-IoT Continuum", ARXIV-CS.DC, 2023

All these initiatives share similarities, although key differences can be found. For instance, cognitive cloud focuses more on services placement and scheduling on top of the continuum, while swarms rather target the joint work of the involved nodes to addressing specific services/functions. In turn, metaOS can support the former paradigms by having dedicated services available at edge computing node, while providing many additional features. The work of having a unified taxonomy is very important, effort that is currently being carried out by the European Initiative EUCEI, and also proposed in some research papers[12]. The ASSIST-IoT project also participates in this initiative, which apart from the taxonomy, will deliver a high-level architecture of building blocks, where the experience of ASSIST-IoT can help (initial concept can be seen in Figure 55). A building block devoted to orchestration has been depicted, including concepts such as scheduling, deployment/smart allocation, scalability, load balancing, migration, decision support systems, lifecycle management, embracing also the differentiation between high-level and low-level orchestration. Similarly to the principles envisioned for data spaces (for data sharing in distributed, multi-stakeholder ecosystems), properties like trustworthiness, security and data sovereignty, ecosystem of data (no central data storage capabilities), standardized interoperability, value adding apps, data markets, open development process, re-use of existing technologies, contribution to standardization[13] are crucial so that the involved stakeholders sharing and using - in this case the infrastructure – are key for the later adoption of these paradigms, or a combination of them.

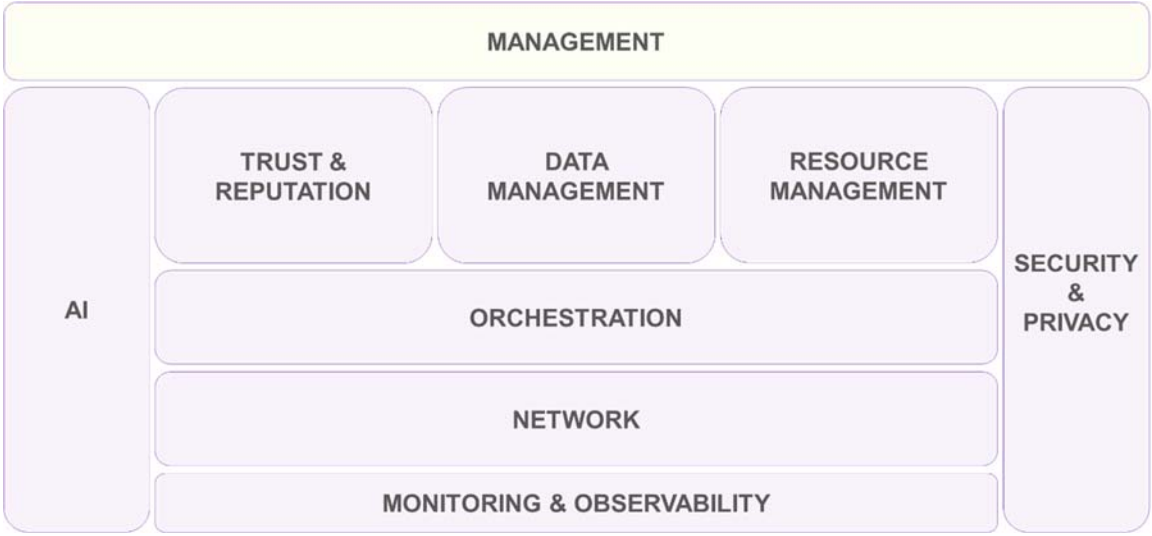

Figure 55. EUCEI building blocks

4.2. Tactile Internet & MR applications

Mixed Reality (MR) applications aim to combine Virtual and Augmented Reality features creating an environment where virtual and real world are merged, while physical and digital objects are interacted with each other in real-time. To achieve this, haptic, auditory and visual data management is required in order to provide the user with the required information from the environment, especially, reassuring low latency[14]. Thus, the use of Tactile Internet is essential for MR applications, which based on the International Telecommunication Union – Telecommunication Standardization Sector (ITU-T), is explained as "*extremely low latency, in combination with high availability, reliability and security*" enhancing the communication and interaction of users and technologies in remote environments. Tactile Internet as the evaluation of Internet of Things (IoT) provides

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[12] Amjad Ullah; Tamas Kiss; József Kovács; Francesco Tusa; James Deslauriers; Huseyin Dagdeviren; Resmi Arjun; Hamed Hamzeh, "Orchestration in The Cloud-to-Things Compute Continuum: Taxonomy, Survey and Future Directions", ARXIV-CS.DC, 2023

[13] International Data Space Association, Reference Architecture Model, v.3.0: https://internationaldataspaces.org/wp-content/uploads/IDS Reference-Architec ture-Model-3.0-2019.pdf

[14] Minopoulos, G., & Psannis, K. E. (2022). Opportunities and challenges of tangible XR applications for 5G networks and beyond. IEEE Consumer Electronics Magazine.

both machine-to-machine and human-to-machine communication in real-time reaching a wide range of commercial, societal, and industrial applications.

The aforementioned combination of technologies applies in various fields, which are constantly evolving elaborating state-of-the-art technologies operating in (almost) real-time. In construction sites, MR and Tactile Internet are used for health and safety regulations and alerts. In health applications, remote surgeries are developed, where the latency rate, reliability and robustness are critical aspects and determine the life of the patient. As for the smart manufacturing, using MR for mainly robot remote manipulation facilitates the industry's process reassuring the user's safety. Finally, in mining fields, MR along with Tactile Internet offer real time supervision and control of the mining operations without risking any human life as well as assisting with decision making.

However, the implementation of Tactile Internet in MR applications creates multiple challenges. When it comes to wireless data transmission, MR and Tactile Internet are regarded as extremely delicate technologies. For the user experience to be seamless and uninterrupted, strict network requirements must be met. The next generation networks are anticipated to meet the stringent requirements of both technologies in terms of latency, delay, and data rate, thereby enabling the full potential of their widespread implementation to be unveiled. Particularly in industries, such as healthcare operations and smart manufacturing, Tactile Internet implementation necessitates responsive connections, high reliability, and minimal latency creating new algorithms and mechanisms to ensure security and privacy while maintaining nearly 100% availability of communication services[15].

Finally, within Next Generation Internet of Things (NGIoT) society and practises, is facilitated the development of IoT-based solutions supporting the human-centric and sustainable digital transition. These solutions work, also, in harmony with other rapidly advancing technological fields, such as cloud, edge, artificial intelligence, 5G telecommunications networks and services, cybersecurity, and blockchain[16]. Thus, tactile Internet and MR applications have the necessary room to develop and be reinforced in order to enable real-time and remote applications while enhancing reliability, security, and latency rates and addressing challenges arising from the critical nature of the solutions.[17]

4.3. Future trends on data management

Data management is an aspect of Cloud-Edge-IoT (CEI) systems that remains challenging. In the recent work of EUCloudEdgeIoT Task Force 3, the current data management pain points were highlighted, using, among others, the lessons learned in ASSIST-IoT. Data and service catalogues will certainly form the backbone of future CEI systems, allowing one to manage the complexity of data formats, sources, and protocols. Here, ASSIST-IoT's Semantic Repository enabler is a valuable contribution – although it is not a full data catalogue, it is very universal and may be extended in the future. In any case, several trends are still under evolution, among which we can highlight the following ones:

- **Data spaces.** One of the most interesting innovation areas at this moment, data spaces are places where value is generated around data through voluntary sharing in an environment of sovereignty, trust and security. The data space enables you to determine who accesses what data and under what conditions, thus facilitating the deployment of different use cases to meet different business needs. The data space functions as an open and heterogeneous environment of providers and consumers of data products, with no dominant players and no disproportionate barriers to entry and exit. Europe is strongly supporting the creation of common spaces for different areas (e.g., Industrial, Green deal, Mobility, Health, Financial, Energy, Agriculture, Skills, Public Administration), and fostering their use.
- **Data fabrics.** A data fabric is a comprehensive solution designed to streamline end-to-end data integration and management within an organization. It encompasses various components including architecture, data management and integration software, and a shared data environment. At its core, a

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[15] Tychola, K. A., Voulgaridis, K., & Lagkas, T. (2023). Tactile IoT and 5G & beyond schemes as key enabling technologies for the future metaverse. Telecommunication Systems, 84(3), 363-385.

[16] https://www.ngiot.eu/

data fabric aims to provide a unified and cohesive approach to handling data across different systems, applications, and sources. It allows organizations to seamlessly connect, access, and manage data throughout its lifecycle, from ingestion and storage to processing, analysis, and dissemination.

- **Data interoperability** is still a major challenge, still investigated in a new wave of EU-funded projects (e.g., SmartEdge). **Semantic technologies** were cemented as the dominant approach to interoperability and are used by standards such as FIWARE and W3C's Web of Things. It is clear, however, that more work is needed to make these solutions more scalable to support a wider range of use cases. It should be highlighted that portability and scalability are one of the more distinctive features of ASSIST-IoT's Semantic Annotation and Semantic Translation enablers, making them interesting for further research.
- Finally, **message brokers** are evolving to support a wider variety of topologies, services, and underlying protocols. Next-generation messaging and streaming protocols like NATS and Zenoh have the much-needed innovation in technology that will likely make them a more attractive choice than MQTT in the near future.

All in all, there is still the need to break data silos, to fully exploit the value from available data. For that to be possible, there should be willingness to share them, in trusted ecosystems, and with enough technological enablers to break any potential adoption barrier, especially from the technical perspective.

4.4. Privacy and trust

In recent times, blockchain technology has emerged as a crucial element in several approaches aimed at creating a secure, confidential, and dependable environment. Blockchain serves as an unalterable ledger, commonly operating without a central repository or authority. It represents a novel trend in safeguarding shared information across multiple networked organizations. The key advantages of blockchain include decentralization, reliability, openness, confidentiality, and non-repudiation. The ledger is upheld by numerous network nodes, resulting in a decentralized network architecture. Through a consensus mechanism, trust can be established without the intervention of a trusted intermediary. Once data is uploaded onto the blockchain, its segments, or blocks, become challenging to modify, ensuring non-repudiation. Blockchain validates and stores data using interconnected cryptographic blocks, updates data through consensus processes, and executes and modifies data via smart contracts. The entire network collaborates to reach a consensus on the latest block to be appended to the blockchain.

Utilizing hash algorithms presents a profound impact on privacy concerns, particularly in managing vast datasets within blockchain technology. Hashing facilitates data organization through a process that aligns information based on a specific correspondence, providing a fixed-length value regardless of the input size. Consequently, this irreversibility inherent in hash operations ensures data integrity during transmission, enabling parties to detect tampering through hash value comparison. Furthermore, the collision-resistant nature of hash functions enhances data security, although the computational infeasibility of finding collision messages doesn't entirely rule out their existence. Additionally, the problem-friendliness aspect of hash functions underpins critical blockchain mechanisms like Proof of Work (PoW), ensuring consensus and decentralization, thereby mitigating trust-related issues[18].

Trust within blockchain ecosystems is primarily upheld by consensus mechanisms designed to ensure decentralization and reliability without reliance on centralized entities. PoW, PoS, DPoS, and PBFT represent diverse approaches to consensus, each with unique characteristics and implications. PoW, for instance, leverages computational work to secure transactions, whereas PoS emphasizes stakeholding as a determinant for block validation. DPoS introduces a governance layer to stakeholder involvement, enhancing decentralization and efficiency. PBFT, on the other hand, focuses on fault tolerance through state machine replication, ensuring system resilience against Byzantine faults. Each consensus model embodies distinct advantages and limitations, underscoring the complexity and significance of trust mechanisms in blockchain networks.

The DLT enablers of ASSIST-IoT embody a dual focus on privacy and trust, addressing critical aspects of data integrity and reputation management within distributes systems. Through cryptographic techniques, sensitive

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[18] Ma, Y., Sun, Y., Lei, Y. et al. A survey of blockchain technology on security, privacy, and trust in crowdsourcing services. World Wide Web 23, 393–419 (2020)

information remains confidential, fostering trust among users in the authenticity and reliability of the data. This approach not only enhances privacy by safeguarding data from unauthorized access but also instils confidence in the integrity of the entire system.

Present research on utilizing Blockchain in IoT applications is still in its early phases. The majority of the projects are proof-of-concept studies. Building benchmarks for these apps and having real-world bigger implementations are both intriguing. Benchmarks can assist in the development of more efficient IoT applications utilizing Blockchain. The decentralization of blockchain technology is its distinguishing feature. The blockchain has far-reaching consequences for research and practice. At the same time, blockchain's development and acceptance of the IoT have been fraught with several challenges. The first major unresolved challenge is how to assess blockchain performance. The performance varies depending on the number of nodes, consensus methods, network circumstances, and other factors. Enhancing blockchain performance to align with IoT application requirements remains a significant area of research[19].

4.5. Cybersecurity and AI

A security operations center (SOC) is at the core of a well-structured cybersecurity strategy. It's more than just a room filled with screens and security experts; it is the focal point of a complex defence mechanism. The SOC team is primarily tasked with identifying, analysing, and responding to cybersecurity incidents and threats in real time, swiftly and efficiently. The SOC team's purpose is simple: Protect and maintain the organization's digital assets and sensitive data and ensure business continuity. The increased interconnectedness of systems in a network has also increased exposure to various cyberthreats as more systems are connected online. While digital transformation provides convenience, it has expanded the attack surface and avenues for exploitation. A security operations center is vital for executing an organization's overall cybersecurity strategy. The SOC acts as the main hub for monitoring, assessing, and defending against cyberattacks through coordinated efforts.

There are 4 basic tools that are essential for a SOC team. These tools collect, correlate, and analyse data, arming the SOC team with real-time monitoring and threat detection capabilities.

Log collection and management tool

To perform any security analysis, you need to obtain the relevant information first. Logs are the best source of information regarding various activities taking place in your network. However, millions of logs are generated by multiple devices across the network every day. A log management tool can automate the entire process of log collection, parsing, and analysis. It is usually included in a SIEM solution.

Security information and event management (SIEM)

One of the most fundamental technologies that forms the core of a SOC is a SIEM tool. Logs collected across the organization's network provide a wealth of information that has to be analysed for abnormal behaviour. A SIEM platform aggregates log data from heterogeneous sources, examines it to detect any possible attack patterns, and quickly raises an alert if a threat is found. A SIEM solution provides a holistic view of your enterprise network.

Vulnerability management

Cybercriminals mainly target and exploit vulnerabilities that might already be present in your network to infiltrate your systems, so the SOC team must scan and monitor the organization's network periodically for any vulnerabilities. Upon discovery, they have to address the vulnerability quickly before it can be exploited.

Endpoint detection and response (EDR)

EDR tools continuously monitor various endpoints, collect data from them, and analyse the information for any suspicious activities and attack patterns. If a threat has been identified, the EDR tool will contain the threat and immediately alert the security team. EDR tools can also be integrated with cyber threat intelligence, threat hunting, and behaviour analytics to detect malicious activities faster.

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[19] Alzoubi YI, AI-Ahmad A, Kahtan H, Jaradat A. Internet of Things and Blockchain Integration: Security, Privacy, Technical, and Design Challenges. Future Internet.2022; 14(7):216

From the point of view of technologies, these are used to empower a security operations center to keep the organization informed, vigilant, and well-prepared in the battle against cyberattacks:

User and entity behaviour analytics

This kind of tools use machine learning techniques to process data collected from various network devices and develop a baseline of normal behaviour for every user and entity in the network. These technologies analyse logs coming from various network devices on a daily basis. If any event deviates from the baseline, it is flagged as an anomaly and is further analysed for potential threats

Cyber threat hunting

Conventional detection methods are reactive; threat hunting, on the other hand, is a proactive strategy. It is useful in detecting threats that are often missed by conventional security tools. Threat hunters proactively search through the network for any hidden threats to prevent potential attacks. If any threat is detected, they collect information about the threat and pass it on to the concerned teams so appropriate action can be taken immediately.

Threat Intelligence

Threat intelligence is evidence-based knowledge of threats that have occurred or will occur shared by different organizations. With threat intelligence, the SOC team can gain valuable insights into various malicious threats and threat actors, their objectives, signs to look out for, and how to mitigate the threats.

AI can monitor, analyse detect, and respond to cyber threats in real time. As AI algorithms analyse massive amounts of data to detect patterns that are indicative of a cyberthreat, it can also scan the entire network for weaknesses to prevent common kinds of cyber-attacks. AI can assist human security professionals by analysing vast amounts of data, recognizing patterns, and creating insights based on large volumes of security data. This could take hours, sometimes weeks to complete with traditional security processes.

AI systems ban be trained to detect potential cyber threats, identify new attack vectors, and safeguard your company’s sensitive data. The three top benefits to using AI driven cybersecurity tools include:

- Quickly analysing large amounts of data.
- Detecting anomalies and vulnerabilities.
- Automating repetitive processes.

The potential of leveraging AI in cybersecurity is virtually endless. The speed and accuracy of threat detection and response is as close to real-time as possible. AI can help minimize the impact of a ransomware attack by flagging suspicious behaviour to your security team as soon as possible. And finally, AI makes cybersecurity operations more efficient through automation, freeing up your security team’s valuable time and resources to work on other, more important tasks.

4.6. AI trends

The integration of Artificial Intelligence (AI) into the fabric of the edge-cloud continuum and next-generation Internet of Things (IoT) promises a transformative impact on various industries, from healthcare to manufacturing and beyond. As AI capabilities evolve, particularly within the framework of cognitive cloud computing, the landscape of resource allocation and service scheduling undergoes significant shifts. However, amidst the promises lie challenges that AI must overcome to fully realize its potential in these domains.

The edge-cloud continuum represents a distributed computing architecture where computation and data storage are performed closer to the data source while also leveraging the capabilities of centralized cloud infrastructure. With the proliferation of edge computing devices and heterogeneous cloud infrastructures, the task of dynamically allocating resources to meet diverse application requirements becomes increasingly complex. AI-driven approaches, such as reinforcement learning and evolutionary algorithms, offer promising avenues for tackling this challenge by enabling adaptive resource management strategies tailored to specific use cases and performance objectives.

As the number of edge devices and IoT sensors continues to grow, AI algorithms must contend with scalability issues. Edge devices often have limited computational power, memory, and energy resources, posing challenges for deploying complex AI models. Furthermore, the dynamic nature of edge environments requires AI algorithms to adapt to varying resource constraints and fluctuations in their capabilities.

In some scenarios, edge devices often collect sensitive data, raising concerns about privacy and security. AI algorithms operating in the cognitive cloud must adhere to privacy regulations and implement robust security measures to safeguard data integrity and confidentiality. Federated learning and edge-based encryption techniques can mitigate these risks by preserving data privacy while still enabling collaborative AI model training.

Edge environments experience dynamic fluctuations in workload demand due to factors such as user mobility, device failures, and environmental changes. AI-based workload prediction models can anticipate these variations and dynamically allocate resources to meet evolving demands, thereby optimizing resource utilization and minimizing latency.

In edge-cloud continuum environments, AI algorithms must prioritize tasks based on their QoS requirements, such as response time, throughput, and reliability. Advanced scheduling techniques, including service-level agreements (SLAs) and admission control policies, can ensure that critical tasks receive preferential treatment while still meeting overall performance objectives. A practical example would be the need for some edge devices to process data in real time. Therefore, the implementation of AI in the edge-cloud continuum could provide the ability to make the decision to process that same data directly at the edge rather than requiring it to be processed in the cloud to reduce latency and achieve the desired QoS.

In brief, optimizing resource utilization across the edge-cloud continuum requires effective orchestration of computing, storage, and networking resources. Some factors have to be taken into account very carefully such as proximity, resource availability and cost constrains.

4.7. B5G & 6G

Currently, 5G NSA networks were already installed in many countries and full 5G is under deployment. In comparison to previous PLMN networks releases the 5G is characterized by: better separation between control plane (CP) and user plane (UP). The network functions (NFs) in 5G was refactored into individual micro-services and core network (5GC) was completely based on Web Services what is called Service-Based Architecture (SBA) but SBA concept is reduced to core network. Unfortunately, 5G is still not easy to integrate with systems other than 3GPP-defined access networks.

The new generation 6G network is not fully defined yet however this network will be characterized by[20,21]:

- **Extremely high bandwidth**: One of the main objectives of 6G networks will be to provide even higher data throughput than 5G. Data transfer speeds can be even faster, allowing faster downloads and uploads, oriented on high-quality streaming video, virtual reality, cloud gaming, etc.
- **Ultra-low latency**: The 6G network data latency will be minimised, allowing for instantaneous information exchange, which is crucial for advanced applications such as autonomous vehicles and remote surgery.
- **Extreme reliability**: 6G will be reliable even in the most demanding conditions, which means providing connectivity even in areas where connectivity may be difficult, such as areas with high device density or during natural disasters.
- **Sustainability:** A 6G network should also be more energy and environmentally sustainable than 5G. Implemented in 6G technologies should take into consideration environmental constraints and reduce energy consumption and greenhouse gas emissions. The Sustainable Development Goals also mean using proper resources to keep 6G CAPEX and OPEX low.

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[20] X. An, J. Wu, W. Tong, P. Zhu and Y. Chen, "6G Network Architecture Vision," 2021 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit), Porto, Portugal, 2021, pp. 592-597

[21] Mahmood, Nurul & Alves, Hirley & Alcaraz López, Onel & Shehab, Mohammad & Moya Osorio, Di-ana Pamela & Latva-aho, Matti. (2020). Six Key Features of Machine Type Communication in 6G. 1-5

- **Artificial Intelligence usage:** The 6G network concept also assumes deeper integration of Artificial Intelligence. Intelligent network management, allows resource optimisation another usage area are advanced AI applications such as machine learning on Edge Computing or based on AI augmented reality.
- **Augmented reality and haptic support**: 6G network will enable even more advanced applications based on virtual and augmented reality. Using 6G will be possible, for example, to generate more realistic experiences in AR/VR, and support haptic interactions that allow users e.g.to feel tactile sensations in the digital world.

Future mobile networks will be very dynamic, complex and based on fast platforms. Current network architecture for both 4G and 5G is fixed and developed for dedicated task. The 6G network architecture is will be dynamic and can be optimized based on user requirements. A detailed comparison of 5G and 6G network parameters is provided in Table 186Table 186.

Table 186. 5G vs 6G networks comparison.

Technology	Data rate	End-to-end latency	Highest spectral efficiency	Network mobility support	fmax	extended reality (XR) support	Services	Deployment	Antenna Architecture	AI
5G	≈20 GBPS	10 ms	30 bps/Hz	Up to 500 km/h	90 Hz	Partial	VR, AR	2D terrestrial	Massive MIMO	Partial
6G	≈1 TBPS	1 ms	100 bps/Hz	Up to 1000 km/h	10 Hz	Full	Tactile	3D: non-terrestrial	Intelligent surface	Full

In 6G all functional network domains should be migrated to the “cloud model” such as core network, RAN or Edge. This model will allow the 6G network to be built as a system of service oriented, allowing on-demand implementation of network functions and finally achieve a balance between flexibility and performance.

One of the tasks for 6G networks will be to provide global coverage, for this purpose it will be possible to connect terrestrial networks (e.g. PLMN, Fixed Networks) and as well as non-terrestrial networks (e.g. such as satellite and underwater networks). The concept, known as Network of Networks (NoN), uses sub-networks such as: RAN, WAN, Internet etc. to provide flexible 6G connectivity. The future telemedicine, haptics and autonomous vehicle applications are expected to use long packets with very high reliability and high data rates. These requirements (real time IoT) are in opposition to the actually used short packets used in IoT that are implemented by 5G networks. Another limitation of 5G networks in the next-generation IoT area is that the connectivity density of 106/km2 is too low. One of the most interesting technologies from the IoT point of view in the 6G network is the integration of wireless information and energy transfer (WIET). WIET means longer battery life for wireless devices and even support for battery-free devices. Edge computing allows cloud computing services to be implemented closer to the final user. It ensures better security of processed data and reduces data processing delay[22]. Upcoming 6G networks will integrate current infrastructure 5G and IoT via edge computing equipment, thus supporting the execution of AI algorithms on the Mobile Edge Computing (MEC) side.

Other authors also report[23] that by 2025, up to 75 billion of IoT devices will be connected to the Internet. Another report, according to the research conducted by IoT Analytics defines number of connected global devices IoT will grow 12% per year, from 16,7 billion in 2023 to 29,7 billion in 2030. From this perspective, 6G will be a significant factor enabling the development of future IoT networks and applications. The 6G network will provide full coverage and can integrate all functions, including data acquisition, transmission edge computation and security. Therefore, new 6G technology will be intensively studied for IoT services deployment.

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[22] Mahmood, Nurul & Alves, Hirley & Alcaraz López, Onel & Shehab, Mohammad & Moya Osorio, Diana Pamela & Latva-aho, Matti. (2020). Six Key Features of Machine Type Communication in 6G. 1-5

[23] T. Cagenius, G. Mildh, G. Rune, J. Vikberg, M. Wahlqvist and P. Willars, "6G Network Architecture – A Proposal for Early Alignment in *Ericsson Technology Review*, vol. 2023, no. 11, pp. 2-7, October 2023

5. Conclusion

This deliverable reports all the activities carried out in the scope of WP8. Apart from finalizing the gathering of (technical, pilot and process) KPIs, additional sections have been devoted to providing the rest of inputs of the work package, primarily those from Task 8.4. First and foremost, almost all the KPIs have met the minimum target expected at the moment of their formalization, with small deviations already reported (e.g., some cybersecurity-related KPIs were targeting overambitious values from a project that is targeting several aspects, not only related to that particular field).

Besides, a methodology for transferability of project results have been designed, considering inputs from existing analysis. It includes different actions, like the preparation of surveys for identifying adoption barriers and technical acceptance of the proposed solutions, an analysis of the transferability of the project main results, a set of transferability steps pointing to the project examples for its pilots, and feedback gather from adopters (i.e., Open callers). Additional feedback can be found in the particular KPIs where surveys were distributed. Finally, a summary of further research lines has been included as part of the assessment activities.

A. Replicability assessment results

In the following pages are presented the results coming from the AIOTI's RSA tools over the ASSIST-IoT KERs.

Alliance for IoT
and Edge Computing
Innovation

Replicability & Scalability assessment tool

Project name	*ASSIST-IoT - TrackGUI*
Contact name	*Eduardo Garro*
email	egarro@prodevelop.es
Pilot/experimentation location (s)	*Birzebugga, Malta*

Technical dimension - 11 Questions (T1-T11)

This assessment dimension would determine if a project result/solution is replicable or scalable from a technical point of view.

Use case / Solution description: ? Please explain in a concise manner what you will deliver (max 200 words)

The main result is a mobile application that is not available in the market yet. It will be available to download from the most common mobile marketlace, and will allow container terminal stakeholders to securely connect to the most common Terminal Operating Systems (TOS), Navis N4. and obtain guides about where the trucks have to go just after entering into the port. It can also support AI-based guiding routes as well as real-time telemetry data from the cranes when trucks are close enough. These optional features would allow for adaptable implementation costs according to the real customer needs and dedicated resources, and offers a big added value for each single customer.

T1: Openess of components: Component provides interfaces that could allow easy integration in other environments

☐ Easy to integrate in another evironment **2 points**

☑ Difficult to integrate in another environment without expert support **1 point**

☐ Impossible to integrate in another environment **0 point**

On the one hand, the mobile App interface will be able to be downloaded from any marketplace, which is a plus. However, the integration with the container terminal IT systems is not as straightforward, and will need some extra integration efforts between the customer and provider.

T2: Interoperability of components - Standardized device communication API: Provides application developers with uniform and transparent access to physical devices and wearables. (e.g. SCRAL, LinkSmart)

☑ Standardized API available **1 point**

☐ No API available **0 point**

Developers could access the REST API, as long as they have enough credentials.

T3: Standardized Data Modeling: Allows IoT syntactic and semantic interoperability (e.g. OGC SensorThings API), Standardized Data model available

☑ Standardized Data Model **1 point**

☐ Proprietary Data Model **0 point**

The telemetry data collected is translated to the TIC 4.0 standard, which has been assumed as the de-facto standard for container terminals digitalization.

T4: IoT Platform interoperability : Allows the integration with other IoT platforms (e.g. oneM2M, FIWARE, Azzure, ..., see SCoDIHNet platform catalogue)

☐ Component is running on one of the IoT platforms	**1 point**
☑ Component is running on a proprietary platform	**0 point**

The system does not use any classical IoT platform, but the generated data can be accesssed by the APIs of those platforms if needed.

T5: Modularity: Referred to modular IoT architecture that can be customized for a diverse range of applications or, in general, to a design principle that subdivides a system into smaller parts called modules, which can be independently created, modified, replaced, or exchanged with other modules or between different systems

☑ Components have been designed with several modules	**1 point**
☐ Components have been designed in one single module	**0 point**

The backend data management of the system makes use of ASSIST-IoT enablers, which, by default, are considered as plug-and-play encapsulated modules.

T6: Compatibility with legacy infrastructure and equipment: The solution is using legacy network infrastructure (5G, Sigfox, Lora, NB-IoT, …) and devices

☑ The solution is using legacy infrastructure	**1 point**
☐ The solution is using proprietary infrastructure	**0 point**
☑ The solution is using legacy devices	**1 point**
☐ The solution is using proprietary devices	**0 point**

The mobile app connects to two different kind of Siemens IoT devices (IoT2040 and IoT2050). As long as the container terminal is managed with this kind of devices, the system shall be fully compatible.

T7: Updates & Maintenance: Components should evolve to add new functionalities or to correct bugs, this could be made could be easily remotely or need intervention of experts

☐ Components updated and maintained by the integrator	**1 point**
☑ Maintenance and updates need expert intervention	**0 point**

While the tools used are well-known in the software industry, they cannot be modified by any external user unless he/she is previously familiarized with them.

T8: Standards Compliance: Many standards have been developed for IoT and communication, interoperability could only become a reality if components are compliant to one or the other standards

☑ Components are compliant to a standard	**1 point**
☐ Components are cot compliant to any standard	**0 point**

[Elaboration text]

T9: Communication/Cloud infrastructure: : Data generated by IoT need to be stored and manipulated before feeding the end user application. This topic targets the communication protocol used to send out data to the cloud data centre. There are several types of protocol available (Sigfox, LoRa, 4G, 5G, RF, NFC, …) which need to offer interoperability

☑ Components compliant with a communication protocol standard	**1 point**
☐ Components use a proprietary communication	**0 point**

The data is sent by the IoT and servers to internet. Hence, any communication protocol with internet access should be OK.

T10: Exploitation potential/applicability to industrial relevant environment: In order to contribute to the Digitalisation of the European Industry (Digital Europe Program) through the Digital Innovation Hubs, a component should be used for use cases addressing industry whatever it is

☑ Components able to be used in an industrial environment	**1 point**	*The KER is addressing explicitly container terminals, hence will be used at a logistic industrial environment.*
☐ Components not usable in an industrial environment	**0 point**	

T11: Technology Readiness Level: A method to estimate the technology maturity of the solution

○ TRL 1 – Basic principles observed	**1 point**	*During the project, the app was tested and validated at Malta Freeport Terminal.*
○ TRL 2 – Technology concept formulated	**2 points**	
○ TRL 3 – Experimental proof of concept	**3 points**	
○ TRL 4 –Technology validated in lab	**4 points**	
○ TRL 5 – Technology validated in relevant environement	**5 points**	
● TRL 6 – Technology demonstrated in relevant environement	**6 points**	
○ TRL 7 – System prototype demonstration in operational environment	**7 points**	
○ TRL 8 – System complete and qualified	**8 points**	
○ TRL 9 – Actual system proven in operational environment	**9 points**	

Data dimension - 6 Questions (D1-D6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a "Data" point of view

D1: Compatibility with data privacy rules: Data provided by IoT and used by applications should be under the European regulation. IoT are providing basic information but also videos, pictures or human sensors data that fall under GDPR

☑ Components are not collecting personal data	**1 point**	*We are just collecting machines data, not explicitly drivers' data.*
☐ Components are collecting personal data but respect the GDPR	**0 point**	

D2: Data Modelling: Data modelling is the process of creating a visual representation of either a whole information system or parts of it to communicate connections between data points and structures. Data modelling employs standardized schemas and formal techniques. This provides a common, consistent, and predictable way of defining and managing data resources across an organization, or even beyond. A number of tools are available to support the methodology (Erwin Data Modeller, Enterprise Architect, ER/Studio, Open ModelSphere, …)

☐ A data modelling tool has been used	**1 point**	*[Elaboration text]*
☑ No data modelling tool has been used	**0 point**	

D3: Data Security: Data security is the practice of protecting digital information from unauthorized access, corruption, or theft throughout its entire lifecycle. It encompasses Encryption, Data erasure, Data masking and data resiliency

☐ Component is implementing Data encryption	**1 point**	*[Elaboration text]*	
☐ Component is implementing Data erasure	**1 point**		
☐ Component is implementing Data masking	**1 point**		
☐ Component is implementing Data resilience	**1 point**	☑ No security implemented	**0 point**

D4: Data Quality: Data quality measures the condition of data, relying on factors such as how useful it is to the specific purpose, completeness, accuracy, timeliness (e.g., is it up to date?), consistency, validity, and uniqueness.

☐ Component is implementing Data completeness control	**1 point**
☑ Component is implementing Data accuracy control	**1 point**
☑ Component is implementing Data timeliness ontrol	**1 point**
☐ Component is implementing Data consistency control	**1 point**
☑ Component is implementing Data validity control	**1 point**
☐ Component is implementing Data uniqueness control	**1 point**
☐ No Data Quality implemented	**0 point**

[Elaboration text]

D5: Data Assets Management: Data assets management (DAM) has the objective to Acquiring, monitoring, using, optimizing, and exploiting data assets to generate value. DAM encompasses Accessibility, compliance and Risk management.

☐ Component is providing Data asset catalogue	**1 point**
☑ Component is compliant with all relevant regulation	**1 point**
☐ Component is implementing the relevant security strategy	**1 point**
☐ No DAM implemented	**0 point**

[Elaboration text]

D6: Data Relevance: Data relevance is a measure of the impact of specific data on decisions or actions by the user. Collecting irrelevant data contributes to information "overload" and complicates decision-making

☑ Component is able to select relevant data	**1 point**
☐ Component is only using specific collected data	**0 point**

[Elaboration text]

Market dimension - 8 Questions (M1-M8)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

M1: Market analysis: A market analysis provides information about industries, customers, competitors, and other market variables. You can also determine the relationship between supply and demand for a specific product or service. Based on these insights, you can make more informed decisions about possible marketing strategies.

☑ A market analysis has been conducted	**1 point**
☐ No market analysis conducted yet	**0 point**

It can be seen in D9.7 deliverable

M2: Demand analysis: Demand analysis is a research done to estimate or find out the customer demand for a product or service in a particular market. Demand analysis process needs to be done in a structured manner for a particular market and affects the business strategy and decisions. Some of the steps which are to be followed for the analysing the demand are: Market selection, Product/service category analysis, understanding business parameters, understanding the competitors and partner trends

☑ A Demand analysis has been conducted	**1 point**
☐	**0 point**

It can be seen in D9.7 deliverable

☐ No Demand analysis conducted yet	0 point

M3: Business model: The term business model refers to a company's plan for making a profit. It identifies the products or services the business plans to sell, its identified target market, and any anticipated expenses. There are a number of Business models but for a manufacturer which is responsible for sourcing raw materials and producing finished products by leveraging internal labor, machinery, and equipment. A manufacturer may make custom goods or highly replicated, mass produced products. A manufacturer can also sell goods to distributors, retailers, or directly to customers

☑ A Business model has been developed	1 point
☐ No Business model available yet	0 point

It can be seen in D9.7 deliverable

M4: Stakeholder needs analysis: A stakeholder analysis is a project management tool used to identify the project’s stakeholders, issues they care about and how they will be impacted by the project

☑ A Stakeholder needs analysis has been conducted	1 point
☐ No Stakeholder needs analysis conducted yet	0 point

It can be seen in D9.7 deliverable

M5: IPR analysis: Intellectual property (IP) rights aim to stimulate innovation by enabling inventors to appropriate the returns on their investments

☐ A IPR analysis has been conducted	1 point
☑ No IPR analysis conducted yet	0 point

[Elaboration text]

M6: IP strategy for your solution: An IP strategy is a plan for you to develop, grow, leverage and monetize your portfolio of IP assets

☐ An IP strategy is in place	2 points
☐ An IP strategy has been defined	1 point
☑ There is no specific IP strategy defined yet	0 point

[Elaboration text]

M7: Solution validated in the market: Market validation includes reviewing your solution with your market (customers and prospects)

☐ Your solution is generating revenues	2 points
☐ Your solution is deployed at (prospect) customer site	1 point
☑ Your solution has not been deployed at customer site	0 point

[Elaboration text]

M8: Business Readiness Level: A method to estimate the business maturity of the solution

○ BRL 1 – Concept	1 point
○ BRL 2 – Problem-solution fit	2 points

[Elaboration text]

○ BRL 3 – Build team and plan	3 points
○ BRL 4 – Customer definition	4 points
○ BRL 5 – Hypothesis testing	5 points
○ BRL 6 – Minimum viable product	6 points
● BRL 7 – Feedback	7 points
○ BRL 8 – Scale	8 points
○ BRL 9 – Fully embedded business	9 points

Acceptation dimension - 6 Questions (A1-A6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

A1: End-user interface design/usability: User interface design is responsible for a product's appearance, interactivity, usability, behaviour, and overall feel. UI design can determine whether a user has a positive experience with a product

☑ A focus group has been conducted	1 point
☑ A user test has been conducted	1 point
☑ A pilot/experiment has been conducted	1 point

[Elaboration text]

A2: Implementation instructions and documentation: Product documentation is a type of technical documentation that explains almost everything there is to know about a product or piece of software.

☐ Product specifications and system requirements available	1 point
☐ Instructions for product setup, installation, and configuration available	1 point
☑ Specific use case instructions available	1 point
☐ Troubleshooting info available	1 point
☐ User documentation and answers to frequently asked questions available	1 point

[Elaboration text]

A3: Adoption by DIHs: The use case/solution will be well accepted by the DIHs if the component answers to the end user needs, is easy to use, to modify, to maintain and cost effective

☐ The use case / Solution is well-known from DIHs	1 point
☑ The use case / Solution is unknown from DIHs	0 point

[Elaboration text]

A4: User experience: User Experience refers to the feeling users experience when using a product, application, system, or service. It is a broad term that can cover anything from how well the user can navigate the product, how easy it is to use, how relevant the content displayed is etc.

☑ UX testing has been conducted	1 point
☐ UX testing has not been conducted yet	0 point

[Elaboration text]

A5: Language: In European projects, user Interface (UI) are usually designed using the English language. In the case of replicability, it is obvious that the UI has to be adapted to the targeted country (even outside Europe).

☐ The solution is already supported other languages	2 points

[Elaboration text]

☑ The solution could use other languages	1 point
☐ The solution can't use other languages easily	0 point

A6: Societal readiness: The Societal Readiness Level https://innovationsfonden.dk/sites/default/files/2019-03/societal_readiness_levels_-_srl.pdf is a way of assessing the level of societal adaptation of, for instance, a particular social project, a technology, a product, a process, an intervention, or an innovation (whether social or technical) to be integrated into society. There are 9 levels (SRL) which help to qualify the solution, which one fits the best with your case:

○ SRL 1 – identifying problem and identifying societal readiness	1 point
○ SRL 2 – formulation of problem, proposed solution(s) and potential impact, expected societal readiness; identifying relevant stakeholders for the project.	2 points
○ SRL 3 – initial testing of proposed solution(s) together with relevant stakeholders.	3 points
○ SRL 4 – problem validated through pilot testing in relevant environment to substantiate proposed impact and societal readiness	4 points
○ SRL 5 – proposed solution(s) validated, now by relevant stakeholders in the area	5 points
● SRL 6 – solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact	6 points
○ SRL 7 – refinement of project and/or solution and, if needed, retesting in relevant environment with relevant stakeholders	7 points
○ SRL 8 – proposed solution(s) as well as a plan for societal adaptation complete and qualified	8 points
○ SRL 9 – actual project solution(s) proven in relevant environment	9 points

Regulation/Policy dimension - 3 Questions (R1-R3)

The European Commission and Member states are elaborating a policy strategy that give a long term vision of the evolution of Europe that are translated into laws. It addresses Environment, economy, health, democracy, ...).

The European Union is based on the rule of law. This means that every action taken by the EU is founded on treaties that have been approved democratically by its members. EU laws help to achieve the objectives of the EU treaties and put EU policies into practice. There are several EU acts that are applying to European citizens and industries. There are a number of regulations addressing the digital sectors that all products need to respect.

R1: EU regulation compliance: Looking to the EUR-Lex tool (https://eur-lex.europa.eu), there are 633 regulations that are application to the digital sector

☐ Checking the compliance with the European Regulation has been conducted	1 point
☑ No check of the compliance with the European Regulation has been conducted	0 point

[Elaboration text]

R2: National regulation Compliance: At national level there are also specific laws that are not against European legislation but that could bring additional constraints.

☐ Checking the compliance with the National Regulation has been conducted	1 point
☑ No check of the compliance with the National Regulation has been conducted	0 point

[Elaboration text] In the case checking has been made, which countries have been investigated ?

R3: EU Policy support: The political strategy of this Commission is to set Europe on a path to successfully achieving climate neutrality by 2050, shaping our digital future, strengthening our unique social market economy, building a Union of prosperity, and making Europe stronger in the world. 6 priorities have been identified, when one your solutions to contributing to:

☑ A European Green Deal	1 point	☑ A Europe fit for the digital age	1 point
☑ An economy that works for people	1 point	☑ A stronger Europe in the world	1 point
☐ Promoting our European way of life	1 point	☐ A new push for European democracy	1 point

Alliance for IoT
and Edge Computing
Innovation

Replicability & Scalability assessment tool

Project name	*ASSIST-IoT: Worker's safety*
Contact name	*Dymarski Piotr*
email	P.Dymarski@mostostal.waw.pl
Pilot/experimentation location (s)	*Warsaw, Masovian, Poland*

Technical dimension - 11 Questions (T1-T11)

This assessment dimension would determine if a project result/solution is replicable or scalable from a technical point of view.

Use case / Solution description: ? Please explain in a concise manner what you will deliver (max 200 words)

Assist-IoT solution tested within the Smart Safety of Workers Pilot provides a complete solution for OSH supervision and reporting including solutions utilising Mixed Reality technology. The systems allows for automatic and real-time detection of construction worker's slips, trips and falls conducted by location and acceleration measuring tools. Furthermore ASSIST-IoT solution supports health and safety inspection by automatizing worker identification and providing ways for effective permission checking for OSH reporting via an IoT system in a way which guarantees secured and unchangeable data.it automates the monitoring of the use of required PPE based on software that takes advantage of machine learning models. The location system helps prevent unwarranted access to dangerous areas and to minimize the reaction time in case of a health emergency

T1: Openess of components: Component provides interfaces that could allow easy integration in other environments

☑ Easy to integrate in another evironment	**2 points**	*Developed components use open APIs, industry-standard protocols (MQTT, HTTP, gRPC), and languages. The solution is packaged as Docker containers and Helm charts allowing for easy deployment in many environments. Data processing is based on RDF and uses standardized ontologies, allowing for extensibility.*
☐ Difficult to integrate in another environment without expert support	**1 point**	
☐ Impossible to integrate in another environment	**0 point**	

T2: Interoperability of components - Standardized device communication API: Provides application developers with uniform and transparent access to physical devices and wearables. (e.g. SCRAL, LinkSmart)

☐ Standardized API available	**1 point**	*Device access is custom, prepared specifically for each device type.*
☑ No API available	**0 point**	

T3: Standardized Data Modeling: Allows IoT syntactic and semantic interoperability (e.g. OGC SensorThings API), Standardized Data model available

☑ Standardized Data Model	**1 point**	*All data is exchanged in RDF with standard serializations (Turtle, JSON-LD). The used ontologies are W3C Recommendations (SOSA/SSN) or otherwise widely used in industry applications (OM2).*
☐ Proprietary Data Model	**0 point**	

T4: IoT Platform interoperability : Allows the integration with other IoT platforms (e.g. oneM2M, FIWARE, Azzure, ..., see SCoDIHNet platform catalogue)

☑ Component is running on one of the IoT platforms	**1 point**
☐ Component is running on a proprietary platform	**0 point**

ASSIST-IoT is itself an IoT platform, therefore it is not running on any other existing platform. It is highly interoperable with other platforms (e.g., via MQTT and the semantic data models).

T5: Modularity: Referred to modular IoT architecture that can be customized for a diverse range of applications or, in general, to a design principle that subdivides a system into smaller parts called modules, which can be independently created, modified, replaced, or exchanged with other modules or between different systems

☑ Components have been designed with several modules	**1 point**
☐ Components have been designed in one single module	**0 point**

The solution consists of many, largely independent modules (ASSIST-IoT enablers). The modules can be easily replaced, modified, or added. The base layer of module interoperability is described in T1.

T6: Compatibility with legacy infrastructure and equipment: The solution is using legacy network infrastructure (5G, Sigfox, Lora, NB-IoT, …) and devices

☑ The solution is using legacy infrastructure	**1 point**
☐ The solution is using proprietary infrastructure	**0 point**
☑ The solution is using legacy devices	**1 point**
☐ The solution is using proprietary devices	**0 point**

The solution reuses already existing infrastructure technologies (5G, Wi-Fi, Bluetooth Low Energy, UWB) and devices that are already on the market (e.g., the smartwatch is the Pine64 PineTime).

T7: Updates & Maintenance: Components should evolve to add new functionalities or to correct bugs, this could be made could be easily remotely or need intervention of experts

☑ Components updated and maintained by the integrator	**1 point**
☐ Maintenance and updates need expert intervention	**0 point**

The components can be modified and reconfigured easily using the Smart Orchestrator, part of the ASSIST-IoT reference architecture. The level of configurability is very high and allows for, e.g., replacing specific container images.

T8: Standards Compliance: Many standards have been developed for IoT and communication, interoperability could only become a reality if components are compliant to one or the other standards

☑ Components are compliant to a standard	**1 point**
☐ Components are cot ompliant to any standard	**0 point**

The solution heavily relies on wireless communication standards (BLE, UWB, 5G, Wi-Fi), network protocols (HTTP, gRPC, MQTT), serializations, and ontologies.

T9: Communication/Cloud infrastructure: : Data generated by IoT need to be stored and manipulated before feeding the end user application. This topic targets the communication protocol used to send out data to the cloud data centre. There are several types of protocol available (Sigfox, LoRa, 4G, 5G, RF, NFC, …) which need to offer interoperability

☑ Components compliant with a communication protocol standard	**1 point**
☐ Components use a proprietary communication	**0 point**

Networking: 4G/5G, Wi-Fi, Ethernet
Protocols: MQTT (mainly), HTTP

T10: Exploitation potential/applicability to industrial relevant environment: In order to contribute to the Digitalisation of the European Industry (Digital Europe Program) through the Digital Innovation Hubs, a component should be used for use cases addressing industry whatever it is

☑ Components able to be used in an industrial environment	**1 point**
☐ Components not usable in an industrial environment	**0 point**

The system prototype was successfully demonstrated in an operational environment of a construction site of the Polish construction company Mostostal Warszawa SA.

T11: Technology Readiness Level: A method to estimate the technology maturity of the solution

○ TRL 1 – Basic principles observed	**1 point**
○ TRL 2 – Technology concept formulated	**2 points**
○ TRL 3 – Experimental proof of concept	**3 points**
○ TRL 4 –Technology validated in lab	**4 points**
○ TRL 5 – Technology validated in relevant environement	**5 points**
● TRL 6 – Technology demonstrated in relevant environement	**6 points**
○ TRL 7 – System prototype demonstration in operational environment	**7 points**
○ TRL 8 – System complete and qualified	**8 points**
○ TRL 9 – Actual system proven in operational environment	**9 points**

The individual technologies (and the system) were demonstrated in the relevant environment of an active construction site in Warsaw, Poland. The people participating in the trials did not perform construction activities at the same time, and thus this was a relevant and not an operational environment.

Data dimension - 6 Questions (D1-D6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a "Data" point of view

D1: Compatibility with data privacy rules: Data provided by IoT and used by applications should be under the European regulation. IoT are providing basic information but also videos, pictures or human sensors data that fall under GDPR

☐ Components are not collecting personal data	**1 point**
☑ Components are collecting personal data but respect the GDPR	**0 point**

Collecting personal data is necessary to realize the designed use cases. The system respects the GDPR regulation and was designed to minimized the privacy risks by, e.g., processing as much data as possible on the edge, or by anonymizing the data early.

D2: Data Modelling: Data modelling is the process of creating a visual representation of either a whole information system or parts of it to communicate connections between data points and structures. Data modelling employs standardized schemas and formal techniques. This provides a common, consistent, and predictable way of defining and managing data resources across an organization, or even beyond. A number of tools are available to support the methodology (Erwin Data Modeller, Enterprise Architect, ER/Studio, Open ModelSphere, …)

☑ A data modelling tool has been used	**1 point**
☐ No data modelling tool has been used	**0 point**

The system is based on semantic technologies and the tool Protege with git-based source control were used to manage the data models.

D3: Data Security: Data security is the practice of protecting digital information from unauthorized access, corruption, or theft throughout its entire lifecycle. It encompasses Encryption, Data erasure, Data masking and data resiliency

☑ Component is implementing Data encryption	**1 point**
☑ Component is implementing Data erasure	**1 point**
☑ Component is implementing Data masking	**1 point**
☑ Component is implementing Data resilience	**1 point**
☐ No security implemented	**0 point**

Encryption: encrypted communication over the network. Erasure: data on edge nodes is erased after being process and never retained or transmitted elsewhere. Masking: pseudonymous or random IDs are used where possible. Resilience: the system is resilient to node loss and records information

D4: Data Quality: Data quality measures the condition of data, relying on factors such as how useful it is to the specific purpose, completeness, accuracy, timeliness (e.g., is it up to date?), consistency, validity, and uniqueness.

☑ Component is implementing Data completeness control	1 point
☑ Component is implementing Data accuracy control	1 point
☑ Component is implementing Data timeliness ontrol	1 point
☐ Component is implementing Data consistency control	1 point
☑ Component is implementing Data validity control	1 point
☑ Component is implementing Data uniqueness control	1 point
☐ No Data Quality implemented	0 point

The various data quality checks are enforced on many layers, but most prominently in processing the semantic data in the system. OWL2 ontologies serve as the primary mechanism for validation, along with custom checks implemented in SPARQL. Additionally, JSON Schema is used to ensure the quality of non-semantic data in the system.

D5: Data Assets Management: Data assets management (DAM) has the objective to Acquiring, monitoring, using, optimizing, and exploiting data assets to generate value. DAM encompasses Accessibility, compliance and Risk management.

☑ Component is providing Data asset catalogue	1 point
☐ Component is compliant with all relevant regulation	1 point
☐ Component is implementing the relevant security strategy	1 point
☐ No DAM implemented	0 point

The ASSIST-IoT Semantic Repository enabler is used as the data asset catalogue in the solution.

D6: Data Relevance: Data relevance is a measure of the impact of specific data on decisions or actions by the user. Collecting irrelevant data contributes to information “overload” and complicates decision-making

☑ Component is able to select relevant data	1 point
☐ Component is only using specific collected data	0 point

The data is transmitted and processed very selectively, with dynamic filters and routing rules implemented in, e.g., the Edge Data Broker enabler, Location Processing enabler, Workplace safety controlller.

Market dimension - 8 Questions (M1-M8)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

M1: Market analysis: A market analysis provides information about industries, customers, competitors, and other market variables. You can also determine the relationship between supply and demand for a specific product or service. Based on these insights, you can make more informed decisions about possible marketing strategies.

☑ A market analysis has been conducted	1 point
☐ No market analysis conducted yet	0 point

An intital market analysis was conducted including current market and barreiers of entry (WP3).

M2: Demand analysis: Demand analysis is a research done to estimate or find out the customer demand for a product or service in a particular market. Demand analysis process needs to be done in a structured manner for a particular market and affects the business strategy and decisions. Some of the steps which are to be followed for the analysing the demand are: Market selection, Product/service category analysis, understanding business parameters, understanding the competitors and partner trends

☑ A Demand analysis has been conducted	1 point
	0 point

An intital demand analysis was conducted, including customer and end users identification.

☐ No Demand analysis conducted yet	0 point	

M3: Business model: The term business model refers to a company's plan for making a profit. It identifies the products or services the business plans to sell, its identified target market, and any anticipated expenses. There are a number of Business models but for a manufacturer which is responsible for sourcing raw materials and producing finished products by leveraging internal labor, machinery, and equipment. A manufacturer may make custom goods or highly replicated, mass produced products. A manufacturer can also sell goods to distributors, retailers, or directly to customers

☑ A Business model has been developed	1 point	*Business model consisting of* customer needs identification, value proposition definition and more *was created. (WP9)*
☐ No Business model available yet	0 point	

M4: Stakeholder needs analysis: A stakeholder analysis is a project management tool used to identify the project’s stakeholders, issues they care about and how they will be impacted by the project

☑ A Stakeholder needs analysis has been conducted	1 point	*This was conducted as part of the business model.*
☐ No Stakeholder needs analysis conducted yet	0 point	

M5: IPR analysis: Intellectual property (IP) rights aim to stimulate innovation by enabling inventors to appropriate the returns on their investments

☑ A IPR analysis has been conducted	1 point	D9.6: "The BIP and IE plus FIP tables allow to derive a number of innovation maps, where each IE, FIP and BIP will be cross-linked among themselves, and with the partners owning them."
☐ No IPR analysis conducted yet	0 point	

M6: IP strategy for your solution: An IP strategy is a plan for you to develop, grow, leverage and monetize your portfolio of IP assets

☑ An IP strategy is in place	2 points	D9.6: "The BIP and IE plus FIP tables allow to derive a number of innovation maps, where each IE, FIP and BIP will be cross-linked among themselves, and with the partners owning them."
☑ An IP strategy has been defined	1 point	
☑ There is no specific IP strategy defined yet	0 point	

M7: Solution validated in the market: Market validation includes reviewing your solution with your market (customers and prospects)

☐ Your solution is generating revenues	2 points	*During the pilot action the solution was validated at a example end user site (Mostostal Warszawa)*
☑ Your solution is deployed at (prospect) customer site	1 point	
☐ Your solution has not been deployed at customer site	0 point	

M8: Business Readiness Level: A method to estimate the business maturity of the solution

● BRL 1 – Concept	1 point	*Due to the research nature of the project a business concept, model or strategy were not developed.*
○ BRL 2 – Problem-solution fit	2 points	

○ BRL 3 – Build team and plan	3 points
○ BRL 4 – Customer definition	4 points
○ BRL 5 – Hypothesis testing	5 points
○ BRL 6 – Minimum viable product	6 points
○ BRL 7 – Feedback	7 points
○ BRL 8 – Scale	8 points
○ BRL 9 – Fully embedded business	9 points

Acceptation dimension - 6 Questions (A1-A6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

A1: End-user interface design/usability: User interface design is responsible for a product's appearance, interactivity, usability, behaviour, and overall feel. UI design can determine whether a user has a positive experience with a product

☑ A focus group has been conducted	**1 point**
☑ A user test has been conducted	**1 point**
☑ A pilot/experiment has been conducted	**1 point**

During the developemnt of the UI for a smartwatch and a tablet, the insight of end user (construction company i.e. Mostostal Warszawa) was taken into account. They helped generate ideas and gave feedback. The UI was then tested during and tested after the pilot actions.

A2: Implementation instructions and documentation: Product documentation is a type of technical documentation that explains almost everything there is to know about a product or piece of software.

☑ Product specifications and system requirements available	**1 point**
☑ Instructions for product setup, installation, and configuration available	**1 point**
☑ Specific use case instructions available	**1 point**
☑ Troubleshooting info available	**1 point**
☑ User documentation and answers to frequently asked questions available	**1 point**

Implementation instructions and documentation for the enablers are publically available, where is documentation for setup and troubleshooting were created for internal use for the consortium partners.

A3: Adoption by DIHs: The use case/solution will be well accepted by the DIHs if the component answers to the end user needs, is easy to use, to modify, to maintain and cost effective

☐ The use case / Solution is well-known from DIHs	**1 point**
☑ The use case / Solution is unknown from DIHs	**0 point**

[Elaboration text]

A4: User experience: User Experience refers to the feeling users experience when using a product, application, system, or service. It is a broad term that can cover anything from how well the user can navigate the product, how easy it is to use, how relevant the content displayed is etc.

☑ UX testing has been conducted	**1 point**
☐ UX testing has not been conducted yet	**0 point**

UX was tested and evaluated during the pilot in Warsaw.

A5: Language: In European projects, user Interface (UI) are usually designed using the English language. In the case of replicability, it is obvious that the UI has to be adapted to the targeted country (even outside Europe).

☑ The solution is already supported other languages	**2 points**

During the pilot in Warsaw UI in both Polish and

☐ The solution could use other languages	1 point	*English was demonstrated.*
☐ The solution can't use other languages easily	0 point	

A6: Societal readiness: The Societal Readiness Level https://innovationsfonden.dk/sites/default/files/2019-03/societal_readiness_levels_-_srl.pdf is a way of assessing the level of societal adaptation of, for instance, a particular social project, a technology, a product, a process, an intervention, or an innovation (whether social or technical) to be integrated into society. There are 9 levels (SRL) which help to qualify the solution, which one fits the best with your case:

○ SRL 1 – identifying problem and identifying societal readiness	1 point
○ SRL 2 – formulation of problem, proposed solution(s) and potential impact, expected societal readiness; identifying relevant stakeholders for the project.	2 points
○ SRL 3 – initial testing of proposed solution(s) together with relevant stakeholders.	3 points
○ SRL 4 – problem validated through pilot testing in relevant environment to substantiate proposed impact and societal readiness	4 points
○ SRL 5 – proposed solution(s) validated, now by relevant stakeholders in the area	5 points
● SRL 6 – solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact	6 points
○ SRL 7 – refinement of project and/or solution and, if needed, retesting in relevant environment with relevant stakeholders	7 points
○ SRL 8 – proposed solution(s) as well as a plan for societal adaptation complete and qualified	8 points
○ SRL 9 – actual project solution(s) proven in relevant environment	9 points

Regulation/Policy dimension - 3 Questions (R1-R3)

The European Commission and Member states are elaborating a policy strategy that give a long term vision of the evolution of Europe that are translated into laws. It addresses Environment, economy, health, democracy, ...).

The European Union is based on the rule of law. This means that every action taken by the EU is founded on treaties that have been approved democratically by its members. EU laws help to achieve the objectives of the EU treaties and put EU policies into practice. There are several EU acts that are applying to European citizens and industries. There are a number of regulations addressing the digital sectors that all products need to respect.

R1: EU regulation compliance: Looking to the EUR-Lex tool (https://eur-lex.europa.eu), there are 633 regulations that are application to the digital sector

☑ Checking the compliance with the European Regulation has been conducted	1 point	*Both general legal regulations related to ASSIST-IoT pursuits and pilot-specific regulations were analysed.*
☐ No check of the compliance with the European Regulation has been conducted	0 point	

R2: National regulation Compliance: At national level there are also specific laws that are not against European legislation but that could bring additional constraints.

☑ Checking the compliance with the National Regulation has been conducted	1 point	*National Regulations have been take in consideration e.g. regulations related to work safety.*
☐ No check of the compliance with the National Regulation has been conducted	0 point	

R3: EU Policy support: The political strategy of this Commission is to set Europe on a path to successfully achieving climate neutrality by 2050, shaping our digital future, strengthening our unique social market economy, building a Union of prosperity, and making Europe stronger in the world. 6 priorities have been identified, when one your solutions to contributing to:

☐ A European Green Deal	1 point	☑ A Europe fit for the digital age	1 point
☐ An economy that works for people	1 point	☐ A stronger Europe in the world	1 point
☐ Promoting our European way of life	1 point	☐ A new push for European democracy	1 point

Alliance for IoT and Edge Computing Innovation

Replicability & Scalability assessment tool

Project name	*ASSIST-IoT: In-Service emission diagnostic*
Contact name	*Klaus SCHUSTERITZ*
email	kschust4@ford.com
Pilot/experimentation location (s)	*Pilot 3A "Fleet emission monitoring" Valenica, Spain*

Technical dimension - 11 Questions (T1-T11)

This assessment dimension would determine if a project result/solution is replicable or scalable from a technical point of view.

Use case / Solution description: ? Please explain in a concise manner what you will deliver (max 200 words)

Manufacturers of vehicles with internal combustion engines face an increasing stringency of emission related regulations. At the same time, affordable technical solutions to ensure a precise close to real-time fleet wide emission distribution monitoring over vehicle lifetime in the cost sensitive automotive environment are missing.

Ideally, car manufactures are in the position to gather emission related data close to real time, with a sufficient accuracy over vehicle lifetime, respecting the cost sensitive automotive environment. This would enable OEMs to understand the emission distribution of a whole vehicle fleet and act accordingly in a later step.

T1: Openess of components: Component provides interfaces that could allow easy integration in other environments

☐ Easy to integrate in another evironment — **2 points**

☑ Difficult to integrate in another environment without expert support — **1 point**

☐ Impossible to integrate in another environment — **0 point**

As car manufactures have highly heterogeneous vehicle topologies, at least expert support is needed to integrate the results of Pilot 3A into different vehicle platforms.

T2: Interoperability of components - Standardized device communication API: Provides application developers with uniform and transparent access to physical devices and wearables. (e.g. SCRAL, LinkSmart)

☐ Standardized API available — **1 point**

☑ No API available — **0 point**

Due to the research nature of Pilot 3A, the focus was shifted to technical aspects rather than reuseability aspects.

T3: Standardized Data Modeling: Allows IoT syntactic and semantic interoperability (e.g. OGC SensorThings API), Standardized Data model available

☐ Standardized Data Model — **1 point**

☑ Proprietary Data Model — **0 point**

Due to the research nature of Pilot 3A, the focus was shifted to technical aspects rather than reuseability aspects.

T4: IoT Platform interoperability : Allows the integration with other IoT platforms (e.g. oneM2M, FIWARE, Azzure, …, see SCoDIHNet platform catalogue)

☑ Component is running on one of the IoT platforms	**1 point**
☐ Component is running on a proprietary platform	**0 point**

Results of Pilot 3A are not limited to a certain IoT platform.

T5: Modularity: Referred to modular IoT architecture that can be customized for a diverse range of applications or, in general, to a design principle that subdivides a system into smaller parts called modules, which can be independently created, modified, replaced, or exchanged with other modules or between different systems

☑ Components have been designed with several modules	**1 point**
☐ Components have been designed in one single module	**0 point**

Pilot 3A was created using different hardware and software modules.

T6: Compatibility with legacy infrastructure and equipment: The solution is using legacy network infrastructure (5G, Sigfox, Lora, NB-IoT, …) and devices

☑ The solution is using legacy infrastructure	**1 point**
☐ The solution is using proprietary infrastructure	**0 point**
☑ The solution is using legacy devices	**1 point**
☐ The solution is using proprietary devices	**0 point**

It was one of the key aspects of Pilot 3A, to interface with legacy vechicle infrastructure and devices, to allow a cost efficient implementation.

T7: Updates & Maintenance: Components should evolve to add new functionalities or to correct bugs, this could be made could be easily remotely or need intervention of experts

☐ Components updated and maintained by the integrator	**1 point**
☑ Maintenance and updates need expert intervention	**0 point**

Due to the complex nature of the topic and the implication on vehicle homologation, an expert intervention is needed.

T8: Standards Compliance: Many standards have been developed for IoT and communication, interoperability could only become a reality if components are compliant to one or the other standards

☐ Components are compliant to a standard	**1 point**
☑ Components are cot ompliant to any standard	**0 point**

Due to the research nature of Pilot 3A, the focus was shifted to technical aspects rather than reuseability aspects.

T9: Communication/Cloud infrastructure: : Data generated by IoT need to be stored and manipulated before feeding the end user application. This topic targets the communication protocol used to send out data to the cloud data centre. There are several types of protocol available (Sigfox, LoRa, 4G, 5G, RF, NFC, …) which need to offer interoperability

☑ Components compliant with a communication protocol standard	**1 point**
☐ Components use a proprietary communication	**0 point**

Standards implemented in ASSIST-IoT are used.

T10: Exploitation potential/applicability to industrial relevant environment: In order to contribute to the Digitalisation of the European Industry (Digital Europe Program) through the Digital Innovation Hubs, a component should be used for use cases addressing industry whatever it is

☑ Components able to be used in an industrial environment	**1 point**
☐ Components not usable in an industrial environment	**0 point**

Componetes (still in prototype phase) are intended to work in an industrial environment.

T11: Technology Readiness Level: A method to estimate the technology maturity of the solution

○ TRL 1 – Basic principles observed	**1 point**
○ TRL 2 – Technology concept formulated	**2 points**
○ TRL 3 – Experimental proof of concept	**3 points**
● TRL 4 –Technology validated in lab	**4 points**
○ TRL 5 – Technology validated in relevant environement	**5 points**
○ TRL 6 – Technology demonstrated in relevant environement	**6 points**
○ TRL 7 – System prototype demonstration in operational environment	**7 points**
○ TRL 8 – System complete and qualified	**8 points**
○ TRL 9 – Actual system proven in operational environment	**9 points**

Technology validated in a real-life vehicle and considering a simulated lab environment for fleet volume

Data dimension - 6 Questions (D1-D6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a “Data” point of view

D1: Compatibility with data privacy rules: Data provided by IoT and used by applications should be under the European regulation. IoT are providing basic information but also videos, pictures or human sensors data that fall under GDPR

☑ Components are not collecting personal data	**1 point**
☐ Components are collecting personal data but respect the GDPR	**0 point**

Personal data which is necessary for functionality (e.g. vehicle location, VIM id) will be handled to respect GDPR in every aspect.

D2: Data Modelling: Data modelling is the process of creating a visual representation of either a whole information system or parts of it to communicate connections between data points and structures. Data modelling employs standardized schemas and formal techniques. This provides a common, consistent, and predictable way of defining and managing data resources across an organization, or even beyond. A number of tools are available to support the methodology (Erwin Data Modeller, Enterprise Architect, ER/Studio, Open ModelSphere, …)

☐ A data modelling tool has been used	**1 point**
☑ No data modelling tool has been used	**0 point**

Due to the research nature of Pilot 3A, the focus was shifted to technical aspects rather than reuseability aspects.

D3: Data Security: Data security is the practice of protecting digital information from unauthorized access, corruption, or theft throughout its entire lifecycle. It encompasses Encryption, Data erasure, Data masking and data resiliency

☑ Component is implementing Data encryption	**1 point**
☑ Component is implementing Data erasure	**1 point**
☐ Component is implementing Data masking	**1 point**
☑ Component is implementing Data resilience	**1 point**
☐ No security implemented	**0 point**

ASSIST-IoT Identification/Authentification enablers are used within Pilot 3A. Data at the edge is removed periodically. Data is encrypted when travelling from vehicles to cloud.

D4: Data Quality: Data quality measures the condition of data, relying on factors such as how useful it is to the specific purpose, completeness, accuracy, timeliness (e.g., is it up to date?), consistency, validity, and uniqueness.

☐ Component is implementing Data completeness control	1 point
☑ Component is implementing Data accuracy control	1 point
☑ Component is implementing Data timeliness ontrol	1 point
☑ Component is implementing Data consistency control	1 point
☑ Component is implementing Data validity control	1 point
☐ Component is implementing Data uniqueness control	1 point
☐ No Data Quality implemented	0 point

Data quality aspects are a part of Pilot 3A, but need to be enhanced if the results of Pilot 3A are being used within series production.

D5: Data Assets Management: Data assets management (DAM) has the objective to Acquiring, monitoring, using, optimizing, and exploiting data assets to generate value. DAM encompasses Accessibility, compliance and Risk management.

☐ Component is providing Data asset catalogue	1 point
☐ Component is compliant with all relevant regulation	1 point
☐ Component is implementing the relevant security strategy	1 point
☑ No DAM implemented	0 point

No DAM implemented, focus was solely on technical aspects. This could be interesting for the future.

D6: Data Relevance: Data relevance is a measure of the impact of specific data on decisions or actions by the user. Collecting irrelevant data contributes to information “overload” and complicates decision-making

☑ Component is able to select relevant data	1 point
☐ Component is only using specific collected data	0 point

A main focus of Pilot 3A is to select relevant data and discard irrelevant data already on the edge.

Market dimension - 8 Questions (M1-M8)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

M1: Market analysis: A market analysis provides information about industries, customers, competitors, and other market variables. You can also determine the relationship between supply and demand for a specific product or service. Based on these insights, you can make more informed decisions about possible marketing strategies.

☑ A market analysis has been conducted	1 point
☐ No market analysis conducted yet	0 point

Market analysis was part of ASSIST-IoT.

M2: Demand analysis: Demand analysis is a research done to estimate or find out the customer demand for a product or service in a particular market. Demand analysis process needs to be done in a structured manner for a particular market and affects the business strategy and decisions. Some of the steps which are to be followed for the analysing the demand are: Market selection, Product/service category analysis, understanding business parameters, understanding the competitors and partner trends

☑ A Demand analysis has been conducted	1 point
	0 point

Demand analysis was part of ASSIST-IoT.

☐ No Demand analysis conducted yet	0 point

M3: Business model: The term business model refers to a company's plan for making a profit. It identifies the products or services the business plans to sell, its identified target market, and any anticipated expenses. There are a number of Business models but for a manufacturer which is responsible for sourcing raw materials and producing finished products by leveraging internal labor, machinery, and equipment. A manufacturer may make custom goods or highly replicated, mass produced products. A manufacturer can also sell goods to distributors, retailers, or directly to customers

☐ A Business model has been developed	**1 point**
☑ No Business model available yet	**0 point**

Pilot 3A is a reseach project only. Business model is done independently with the results provided in this project.

M4: Stakeholder needs analysis: A stakeholder analysis is a project management tool used to identify the project’s stakeholders, issues they care about and how they will be impacted by the project

☑ A Stakeholder needs analysis has been conducted	**1 point**
☐ No Stakeholder needs analysis conducted yet	**0 point**

Part of ASSIST-IoT.

M5: IPR analysis: Intellectual property (IP) rights aim to stimulate innovation by enabling inventors to appropriate the returns on their investments

☐ A IPR analysis has been conducted	**1 point**
☑ No IPR analysis conducted yet	**0 point**

No IPR analysis conducted yet.

M6: IP strategy for your solution: An IP strategy is a plan for you to develop, grow, leverage and monetize your portfolio of IP assets

☐ An IP strategy is in place	**2 points**
☐ An IP strategy has been defined	**1 point**
☑ There is no specific IP strategy defined yet	**0 point**

Research project only, specific IP strategy might follow later on.

M7: Solution validated in the market: Market validation includes reviewing your solution with your market (customers and prospects)

☐ Your solution is generating revenues	**2 points**
☐ Your solution is deployed at (prospect) customer site	**1 point**
☑ Your solution has not been deployed at customer site	**0 point**

Research project only.

M8: Business Readiness Level: A method to estimate the business maturity of the solution

○ BRL 1 – Concept	**1 point**
○ BRL 2 – Problem-solution fit	**2 points**

Research project in early stage.

● BRL 3 – Build team and plan	3 points
○ BRL 4 – Customer definition	4 points
○ BRL 5 – Hypothesis testing	5 points
○ BRL 6 – Minimum viable product	6 points
○ BRL 7 – Feedback	7 points
○ BRL 8 – Scale	8 points
○ BRL 9 – Fully embedded business	9 points

Acceptation dimension - 6 Questions (A1-A6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

A1: End-user interface design/usability: User interface design is responsible for a product's appearance, interactivity, usability, behaviour, and overall feel. UI design can determine whether a user has a positive experience with a product

☐ A focus group has been conducted	1 point
☑ A user test has been conducted	1 point
☑ A pilot/experiment has been conducted	1 point

Basic UI is part of Pilot 3A.

A2: Implementation instructions and documentation: Product documentation is a type of technical documentation that explains almost everything there is to know about a product or piece of software.

☑ Product specifications and system requirements available	1 point
☐ Instructions for product setup, installation, and configuration available	1 point
☑ Specific use case instructions available	1 point
☑ Troubleshooting info available	1 point
☐ User documentation and answers to frequently asked questions available	1 point

Documentation as part of ASSIST-IoT deliverables only. Information scattered, but available.

A3: Adoption by DIHs: The use case/solution will be well accepted by the DIHs if the component answers to the end user needs, is easy to use, to modify, to maintain and cost effective

☐ The use case / Solution is well-known from DIHs	1 point
☑ The use case / Solution is unknown from DIHs	0 point

Research project only. If intruduced to series production, user experience has to be focused.

A4: User experience: User Experience refers to the feeling users experience when using a product, application, system, or service. It is a broad term that can cover anything from how well the user can navigate the product, how easy it is to use, how relevant the content displayed is etc.

☐ UX testing has been conducted	1 point
☑ UX testing has not been conducted yet	0 point

Research project only. If intruduced to series production, user experience has to be focused.

A5: Language: In European projects, user Interface (UI) are usually designed using the English language. In the case of replicability, it is obvious that the UI has to be adapted to the targeted country (even outside Europe).

☑ The solution is already supported other languages	2 points

Research project only. If intruduced to series *production, user experience has to be focused.*

☑ The solution could use other languages — **1 point**

☐ The solution can't use other languages easily — **0 point**

A6: Societal readiness: The Societal Readiness Level https://innovationsfonden.dk/sites/default/files/2019-03/societal_readiness_levels_-_srl.pdf is a way of assessing the level of societal adaptation of, for instance, a particular social project, a technology, a product, a process, an intervention, or an innovation (whether social or technical) to be integrated into society. There are 9 levels (SRL) which help to qualify the solution, which one fits the best with your case:

○ SRL 1 – identifying problem and identifying societal readiness	**1 point**
○ SRL 2 – formulation of problem, proposed solution(s) and potential impact, expected societal readiness; identifying relevant stakeholders for the project.	**2 points**
○ SRL 3 – initial testing of proposed solution(s) together with relevant stakeholders.	**3 points**
● SRL 4 – problem validated through pilot testing in relevant environment to substantiate proposed impact and societal readiness	**4 points**
○ SRL 5 – proposed solution(s) validated, now by relevant stakeholders in the area	**5 points**
○ SRL 6 – solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact	**6 points**
○ SRL 7 – refinement of project and/or solution and, if needed, retesting in relevant environment with relevant stakeholders	**7 points**
○ SRL 8 – proposed solution(s) as well as a plan for societal adaptation complete and qualified	**8 points**
○ SRL 9 – actual project solution(s) proven in relevant environment	**9 points**

Regulation/Policy dimension - 3 Questions (R1-R3)

The European Commission and Member states are elaborating a policy strategy that give a long term vision of the evolution of Europe that are translated into laws. It addresses Environment, economy, health, democracy, ...).

The European Union is based on the rule of law. This means that every action taken by the EU is founded on treaties that have been approved democratically by its members. EU laws help to achieve the objectives of the EU treaties and put EU policies into practice. There are several EU acts that are applying to European citizens and industries. There are a number of regulations addressing the digital sectors that all products need to respect.

R1: EU regulation compliance: Looking to the EUR-Lex tool (https://eur-lex.europa.eu), there are 633 regulations that are application to the digital sector

☑ Checking the compliance with the European Regulation has been conducted — **1 point**

☐ No check of the compliance with the European Regulation has been conducted — **0 point**

Part of ASSIST-IoT project.

R2: National regulation Compliance: At national level there are also specific laws that are not against European legislation but that could bring additional constraints.

☑ Checking the compliance with the National Regulation has been conducted — **1 point**

☐ No check of the compliance with the National Regulation has been conducted — **0 point**

Part of ASSIST-IoT project, preliminary check was conducted for Germany.

R3: EU Policy support: The political strategy of this Commission is to set Europe on a path to successfully achieving climate neutrality by 2050, shaping our digital future, strengthening our unique social market economy, building a Union of prosperity, and making Europe stronger in the world. 6 priorities have been identified, when one your solutions to contributing to:

☑ A European Green Deal	**1 point**	☑ A Europe fit for the digital age	**1 point**
☐ An economy that works for people	**1 point**	☐ A stronger Europe in the world	**1 point**
☐ Promoting our European way of life	**1 point**	☐ A new push for European democracy	**1 point**

Alliance for IoT and Edge Computing Innovation

Replicability & Scalability assessment tool

Project name	*ASSIST-IoT - Enhanced Scanner*
Contact name	*Lambis Tassakos*
email	lambis.tassakos@gmail.com
Pilot/experimentation location (s)	*TwoTronic GmbH, Ellgau, Germany*

Technical dimension - 11 Questions (T1-T11)

This assessment dimension would determine if a project result/solution is replicable or scalable from a technical point of view.

Use case / Solution description: ? Please explain in a concise manner what you will deliver (max 200 words)

Supporting the imense pressure for process digitalisation of many automotive post-sales business cases we were investigating novel technologies to enhance a next generation digital vehicles scaner by using key innovation project results. Certified vehicle images (DLT), Federated-Learning AI-framework, scalable software structures for fast deployment and adaptive interfaces to existing customer IT-systems based on web-technologies promises a solid ground for an enhanced scanner architecture

T1: Openess of components: Component provides interfaces that could allow easy integration in other environments

☑ Easy to integrate in another evironment **2 points**

☐ Difficult to integrate in another environment without expert support **1 point**

☐ Impossible to integrate in another environment **0 point**

Keeping a clear interaction architecture within a hybrid computing environment facilitates the integration of multiple customer environments balancing the computational needs according to the individual business cases.

T2: Interoperability of components - Standardized device communication API: Provides application developers with uniform and transparent access to physical devices and wearables. (e.g. SCRAL, LinkSmart)

☐ Standardized API available **1 point**

☑ No API available **0 point**

no relevant for this pilot

T3: Standardized Data Modeling: Allows IoT syntactic and semantic interoperability (e.g. OGC SensorThings API), Standardized Data model available

☑ Standardized Data Model **1 point**

☐ Proprietary Data Model **0 point**

The pilot use case uses standarised interfaces for interoperatability (e.g. Windows- & Ubunty OS-functionalities, SQL-level for data storage, standard packaging protocols for fast transmissions of large data volumes as required for colour, high-resolution images, JPEC-format).

T4: IoT Platform interoperability : Allows the integration with other IoT platforms (e.g. oneM2M, FIWARE, Azzure, ..., see SCoDIHNet platform catalogue)

☑ Component is running on one of the IoT platforms	**1 point**
☐ Component is running on a proprietary platform	**0 point**

The integration results support many different cloud-platforms

T5: Modularity: Referred to modular IoT architecture that can be customized for a diverse range of applications or, in general, to a design principle that subdivides a system into smaller parts called modules, which can be independently created, modified, replaced, or exchanged with other modules or between different systems

☑ Components have been designed with several modules	**1 point**
☐ Components have been designed in one single module	**0 point**

with interfaces for modulare provision of single web-based services

T6: Compatibility with legacy infrastructure and equipment: The solution is using legacy network infrastructure (5G, Sigfox, Lora, NB-IoT, …) and devices

☑ The solution is using legacy infrastructure	**1 point**
☐ The solution is using proprietary infrastructure	**0 point**
☑ The solution is using legacy devices	**1 point**
☐ The solution is using proprietary devices	**0 point**

Using standard PC-environment with all standard HW and SW- legacy standards possibilities

T7: Updates & Maintenance: Components should evolve to add new functionalities or to correct bugs, this could be made could be easily remotely or need intervention of experts

☑ Components updated and maintained by the integrator	**1 point**
☐ Maintenance and updates need expert intervention	**0 point**

with basic IT-knowledge of web architectures and additional development of administration tools. However using several standard technologies it facilitates the components management

T8: Standards Compliance: Many standards have been developed for IoT and communication, interoperability could only become a reality if components are compliant to one or the other standards

☑ Components are compliant to a standard	**1 point**
☐ Components are cot compliant to any standard	**0 point**

No special protocols but communication standards are being used

T9: Communication/Cloud infrastructure: : Data generated by IoT need to be stored and manipulated before feeding the end user application. This topic targets the communication protocol used to send out data to the cloud data centre. There are several types of protocol available (Sigfox, LoRa, 4G, 5G, RF, NFC, …) which need to offer interoperability

☑ Components compliant with a communication protocol standard	**1 point**
☐ Components use a proprietary communication	**0 point**

No special protocols but communication standards are being used

T10: Exploitation potential/applicability to industrial relevant environment: In order to contribute to the Digitalisation of the European Industry (Digital Europe Program) through the Digital Innovation Hubs, a component should be used for use cases addressing industry whatever it is

☑ Components able to be used in an industrial environment	**1 point**
☐ Components not usable in an industrial environment	**0 point**

The key innovation elements can be used in industrial relevant environments. Integrating these elements into an existing product line as pilot, they have shown their potential for futher exploitation with simple adaptions.

T11: Technology Readiness Level: A method to estimate the technology maturity of the solution

○ TRL 1 – Basic principles observed	**1 point**
○ TRL 2 – Technology concept formulated	**2 points**
○ TRL 3 – Experimental proof of concept	**3 points**
○ TRL 4 –Technology validated in lab	**4 points**
○ TRL 5 – Technology validated in relevant environement	**5 points**
○ TRL 6 – Technology demonstrated in relevant environement	**6 points**
● TRL 7 – System prototype demonstration in operational environment	**7 points**
○ TRL 8 – System complete and qualified	**8 points**
○ TRL 9 – Actual system proven in operational environment	**9 points**

The pilot system is running in parallel within a real market environment with real evaluation possibilites of end users in their everyday operations.

Data dimension - 6 Questions (D1-D6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a “Data” point of view

D1: Compatibility with data privacy rules: Data provided by IoT and used by applications should be under the European regulation. IoT are providing basic information but also videos, pictures or human sensors data that fall under GDPR

☐ Components are not collecting personal data	**1 point**
☑ Components are collecting personal data but respect the GDPR	**0 point**

Vehicle license plates anonymisation and person face pixelation support the respect of existing GDPR-rules during the pilot

D2: Data Modelling: Data modelling is the process of creating a visual representation of either a whole information system or parts of it to communicate connections between data points and structures. Data modelling employs standardized schemas and formal techniques. This provides a common, consistent, and predictable way of defining and managing data resources across an organization, or even beyond. A number of tools are available to support the methodology (Erwin Data Modeller, Enterprise Architect, ER/Studio, Open ModelSphere, …)

☑ A data modelling tool has been used	**1 point**
☐ No data modelling tool has been used	**0 point**

The basic data structure of the pilot and the use case are vehicle images. Using a standard jpec-format for processing, storage and transmission overall within an organisation it can be accessed via all standard tools for the corresponding functionality

D3: Data Security: Data security is the practice of protecting digital information from unauthorized access, corruption, or theft throughout its entire lifecycle. It encompasses Encryption, Data erasure, Data masking and data resiliency

☑ Component is implementing Data encryption	**1 point**
☐ Component is implementing Data erasure	**1 point**
☑ Component is implementing Data masking	**1 point**
☑ Component is implementing Data resilience	**1 point**
☐ No security implemented	**0 point**

For both ASSIST-IoT specific part of the overall system architecture as well as for the specific business part several data protection mechanims are applied. Also the Identification and the Authentification enablers are used. DLT-based scans protection has also been applied.

D4: Data Quality: Data quality measures the condition of data, relying on factors such as how useful it is to the specific purpose, completeness, accuracy, timeliness (e.g., is it up to date?), consistency, validity, and uniqueness.

☐ Component is implementing Data completeness control	1 point
☐ Component is implementing Data accuracy control	1 point
☐ Component is implementing Data timeliness control	1 point
☑ Component is implementing Data consistency control	1 point
☑ Component is implementing Data validity control	1 point
☐ Component is implementing Data uniqueness control	1 point
☐ No Data Quality implemented	0 point

To validate AI-based results several visualisation possibilities are being applied to support the final user to review and validate the resulted vehicle appraisal data. No special automated data accuracy or completeness control is applied.

D5: Data Assets Management: Data assets management (DAM) has the objective to Acquiring, monitoring, using, optimizing, and exploiting data assets to generate value. DAM encompasses Accessibility, compliance and Risk management.

☑ Component is providing Data asset catalogue	1 point
☐ Component is compliant with all relevant regulation	1 point
☐ Component is implementing the relevant security strategy	1 point
☐ No DAM implemented	0 point

The pilot inspection results can be manually reviewed and set the base for a vehicle exterior appraisal procedured. Depending on the expected AI-proposals accuracy this could be used manually or automatically by transferring the data results to special vehicle appraisal systems according to the business case.

D6: Data Relevance: Data relevance is a measure of the impact of specific data on decisions or actions by the user. Collecting irrelevant data contributes to information "overload" and complicates decision-making

☑ Component is able to select relevant data	1 point
☐ Component is only using specific collected data	0 point

There is the user-definable selection of pictures with existing damage proposals. This heavily supports the added value of the data relevance of the resulting scanner usage but heavily depends on the expected AI-performance. Millions of unnecessary images can be cut already on the edge-level

Market dimension - 8 Questions (M1-M8)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

M1: Market analysis: A market analysis provides information about industries, customers, competitors, and other market variables. You can also determine the relationship between supply and demand for a specific product or service. Based on these insights, you can make more informed decisions about possible marketing strategies.

☑ A market analysis has been conducted	1 point
☐ No market analysis conducted yet	0 point

it was part of ASSIST-IoT, see D9.7

M2: Demand analysis: Demand analysis is a research done to estimate or find out the customer demand for a product or service in a particular market. Demand analysis process needs to be done in a structured manner for a particular market and affects the business strategy and decisions. Some of the steps which are to be followed for the analysing the demand are: Market selection, Product/service category analysis, understanding business parameters, understanding the competitors and partner trends

☑ A Demand analysis has been conducted	1 point
☐	0 point

It was part of ASSIST-IoT

☐ No Demand analysis conducted yet	0 point

M3: Business model: The term business model refers to a company's plan for making a profit. It identifies the products or services the business plans to sell, its identified target market, and any anticipated expenses. There are a number of Business models but for a manufacturer which is responsible for sourcing raw materials and producing finished products by leveraging internal labor, machinery, and equipment. A manufacturer may make custom goods or highly replicated, mass produced products. A manufacturer can also sell goods to distributors, retailers, or directly to customers

☑ A Business model has been developed	**1 point**
☐ No Business model available yet	**0 point**

The pilot 3b project is within growing market segments of automotive organisations. A business model has been developed for a next generation digital scanner with enhanced properties for several sub-segments

M4: Stakeholder needs analysis: A stakeholder analysis is a project management tool used to identify the project's stakeholders, issues they care about and how they will be impacted by the project

☑ A Stakeholder needs analysis has been conducted	**1 point**
☐ No Stakeholder needs analysis conducted yet	**0 point**

It is part of ASSIST-IoT

M5: IPR analysis: Intellectual property (IP) rights aim to stimulate innovation by enabling inventors to appropriate the returns on their investments

☐ A IPR analysis has been conducted	**1 point**
☑ No IPR analysis conducted yet	**0 point**

[Elaboration text]

M6: IP strategy for your solution: An IP strategy is a plan for you to develop, grow, leverage and monetize your portfolio of IP assets

☐ An IP strategy is in place	**2 points**
☐ An IP strategy has been defined	**1 point**
☑ There is no specific IP strategy defined yet	**0 point**

The major stakeholder here is a SME with limited IPR-protection capabilities. Although there is already IPRs, develped outside the project, only a strategic parthernship with a strong industrial partner could provide the benefits of an IPR-strategy

M7: Solution validated in the market: Market validation includes reviewing your solution with your market (customers and prospects)

☐ Your solution is generating revenues	**2 points**
☑ Your solution is deployed at (prospect) customer site	**1 point**
☐ Your solution has not been deployed at customer site	**0 point**

During the pilot evaluation phase some pilot customers have been evolved in various means

M8: Business Readiness Level: A method to estimate the business maturity of the solution

○ BRL 1 – Concept	**1 point**
○ BRL 2 – Problem-solution fit	**2 points**

Using the MVP of the pilot 3b we are testing the market feedback with selected early adaptors of the most relevant market

○ BRL 3 – Build team and plan	3 points
○ BRL 4 – Customer definition	4 points
○ BRL 5 – Hypothesis testing	5 points
● BRL 6 – Minimum viable product	6 points
○ BRL 7 – Feedback	7 points
○ BRL 8 – Scale	8 points
○ BRL 9 – Fully embedded business	9 points

Acceptation dimension - 6 Questions (A1-A6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

A1: End-user interface design/usability: User interface design is responsible for a product's appearance, interactivity, usability, behaviour, and overall feel. UI design can determine whether a user has a positive experience with a product

☑ A focus group has been conducted	1 point
☑ A user test has been conducted	1 point
☑ A pilot/experiment has been conducted	1 point

The evaluation phase of the pilot is used for first experiments with first users. More experiments shall be executed in the upcoming time. UI has been dedicatably developed for the pilot.

A2: Implementation instructions and documentation: Product documentation is a type of technical documentation that explains almost everything there is to know about a product or piece of software.

☑ Product specifications and system requirements available	1 point
☐ Instructions for product setup, installation, and configuration available	1 point
☐ Specific use case instructions available	1 point
☐ Troubleshooting info available	1 point
☐ User documentation and answers to frequently asked questions available	1 point

The relevant requirements have been captured and described in the WP3. No explicit user documentation and frequently asked questions documents do currently exist for final users.

A3: Adoption by DIHs: The use case/solution will be well accepted by the DIHs if the component answers to the end user needs, is easy to use, to modify, to maintain and cost effective

☐ The use case / Solution is well-known from DIHs	1 point
☑ The use case / Solution is unknown from DIHs	0 point

[Elaboration text]

A4: User experience: User Experience refers to the feeling users experience when using a product, application, system, or service. It is a broad term that can cover anything from how well the user can navigate the product, how easy it is to use, how relevant the content displayed is etc.

☐ UX testing has been conducted	1 point
☑ UX testing has not been conducted yet	0 point

First UX experimentation has been however conducted. The business-logic part is also used as pilot to specific pilot users to get usability feedback. This is used to further develop the user experience of the user-interaction part of the system.

A5: Language: In European projects, user Interface (UI) are usually designed using the English language. In the case of replicability, it is obvious that the UI has to be adapted to the targeted country (even outside Europe).

☑ The solution is already supported other languages	2 points

A few languages are also supported for the marketing

☐ The solution could use other languages	1 point	*phase of pilot user interaction on international level. Also a native German version is naturally included.*
☐ The solution can't use other languages easily	0 point	

A6: Societal readiness: The Societal Readiness Level https://innovationsfonden.dk/sites/default/files/2019-03/societal_readiness_levels_-_srl.pdf is a way of assessing the level of societal adaptation of, for instance, a particular social project, a technology, a product, a process, an intervention, or an innovation (whether social or technical) to be integrated into society. There are 9 levels (SRL) which help to qualify the solution, which one fits the best with your case:

○ SRL 1 – identifying problem and identifying societal readiness	1 point
○ SRL 2 – formulation of problem, proposed solution(s) and potential impact, expected societal readiness; identifying relevant stakeholders for the project.	2 points
○ SRL 3 – initial testing of proposed solution(s) together with relevant stakeholders.	3 points
● SRL 4 – problem validated through pilot testing in relevant environment to substantiate proposed impact and societal readiness	4 points
○ SRL 5 – proposed solution(s) validated, now by relevant stakeholders in the area	5 points
○ SRL 6 – solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact	6 points
○ SRL 7 – refinement of project and/or solution and, if needed, retesting in relevant environment with relevant stakeholders	7 points
○ SRL 8 – proposed solution(s) as well as a plan for societal adaptation complete and qualified	8 points
○ SRL 9 – actual project solution(s) proven in relevant environment	9 points

Regulation/Policy dimension - 3 Questions (R1-R3)

The European Commission and Member states are elaborating a policy strategy that give a long term vision of the evolution of Europe that are translated into laws. It addresses Environment, economy, health, democracy, ...).

The European Union is based on the rule of law. This means that every action taken by the EU is founded on treaties that have been approved democratically by its members. EU laws help to achieve the objectives of the EU treaties and put EU policies into practice. There are several EU acts that are applying to European citizens and industries. There are a number of regulations addressing the digital sectors that all products need to respect

R1: EU regulation compliance: Looking to the EUR-Lex tool (https://eur-lex.europa.eu), there are 633 regulations that are application to the digital sector

☑ Checking the compliance with the European Regulation has been conducted	1 point	*Major GDPR regulations have been checked for the treatment of vehicles-related data in collaboration with major European Automotive Manufacturers. Additional work has however to be conducted for a product-level maturity*
☐ No check of the compliance with the European Regulation has been conducted	0 point	

R2: National regulation Compliance: At national level there are also specific laws that are not against European legislation but that could bring additional constraints.

☑ Checking the compliance with the National Regulation has been conducted	1 point	*Pilot 3b is in the automotive area, where most of regulations are on European-level*
☐ No check of the compliance with the National Regulation has been conducted	0 point	

R3: EU Policy support: The political strategy of this Commission is to set Europe on a path to successfully achieving climate neutrality by 2050, shaping our digital future, strengthening our unique social market economy, building a Union of prosperity, and making Europe stronger in the world. 6 priorities have been identified, when one your solutions to contributing to:

☐ A European Green Deal	1 point	☑ A Europe fit for the digital age	1 point
☑ An economy that works for people	1 point	☑ A stronger Europe in the world	1 point
☐ Promoting our European way of life	1 point	☐ A new push for European democracy	1 point

Alliance for IoT
and Edge Computing
Innovation

Replicability & Scalability assessment tool

Project name	*ASSIST-IoT: GWEN*
Contact name	*Neways*
email	info@newayselectronics.com
Pilot/experimentation location (s)	*[City, Region & Country]*

Technical dimension - 11 Questions (T1-T11)

This assessment dimension would determine if a project result/solution is replicable or scalable from a technical point of view.

Use case / Solution description: ? Please explain in a concise manner what you will deliver (max 200 words)

As part and to support the different use cases, we have developed a modular open IoT hardware platform that can seamlessly handle different communication standards, including 5G. Point-to-point very low latency (to experience real-time feeling) and embedded AI processing at the edge were the key criteria met, using open source tools and application software ported and embedded into this IoT HW platform.

T1: Openess of components: Component provides interfaces that could allow easy integration in other environments

☑ Easy to integrate in another evironment — **2 points**

☐ Difficult to integrate in another environment without expert support — **1 point**

☐ Impossible to integrate in another environment — **0 point**

The development of this open IoT-HW platform with its embedded AI processing is designed in such a way that future required processing expansion is possible via the physical HW/SW interface in accordance with the used industrial standards. The goal achieved was the use of open source software, methods and tools. In addition to the pilots, these options have also been used for

T2: Interoperability of components - Standardized device communication API: Provides application developers with uniform and transparent access to physical devices and wearables. (e.g. SCRAL, LinkSmart)

☑ Standardized API available — **1 point**

☐ No API available — **0 point**

[Elaboration text]

T3: Standardized Data Modeling: Allows IoT syntactic and semantic interoperability (e.g. OGC SensorThings API), Standardized Data model available

☑ Standardized Data Model — **1 point**

☐ Proprietary Data Model — **0 point**

[Elaboration text]

T4: IoT Platform interoperability : Allows the integration with other IoT platforms (e.g. oneM2M, FIWARE, Azzure, ..., see SCoDIHNet platform catalogue)

☑ Component is running on one of the IoT platforms — **1 point**

[Elaboration text]

☐ Component is running on a proprietary platform	**0 point**

T5: Modularity: Referred to modular IoT architecture that can be customized for a diverse range of applications or, in general, to a design principle that subdivides a system into smaller parts called modules, which can be independently created, modified, replaced, or exchanged with other modules or between different systems

☑ Components have been designed with several modules	**1 point**
☐ Components have been designed in one single module	**0 point**

The strongest point of this modular IoT architecture is its HW independence and the use of a container architecture of reusable and recallable small routines.

T6: Compatibility with legacy infrastructure and equipment: The solution is using legacy network infrastructure (5G, Sigfox, Lora, NB-IoT, …) and devices

☑ The solution is using legacy infrastructure	**1 point**
☐ The solution is using proprietary infrastructure	**0 point**
☑ The solution is using legacy devices	**1 point**
☐ The solution is using proprietary devices	**0 point**

The developed solution is compatible with current physical and SW interfaces used by connected and wireless devices make using such as USBc, BLE, IEEE 802.11ax, 5G, UWB, CANopen, etc.

T7: Updates & Maintenance: Components should evolve to add new functionalities or to correct bugs, this could be made could be easily remotely or need intervention of experts

☑ Components updated and maintained by the integrator	**1 point**
☐ Maintenance and updates need expert intervention	**0 point**

[Elaboration text]

T8: Standards Compliance: Many standards have been developed for IoT and communication, interoperability could only become a reality if components are compliant to one or the other standards

☑ Components are compliant to a standard	**1 point**
☐ Components are cot compliant to any standard	**0 point**

The developed solution is compatible with current physical and SW interfaces used by connected and wireless devices make using such as USBc, BLE, IEEE 802.11ax, 5G, UWB, CANopen, etc.

T9: Communication/Cloud infrastructure: : Data generated by IoT need to be stored and manipulated before feeding the end user application. This topic targets the communication protocol used to send out data to the cloud data centre. There are several types of protocol available (Sigfox, LoRa, 4G, 5G, RF, NFC, …) which need to offer interoperability

☑ Components compliant with a communication protocol standard	**1 point**
☐ Components use a proprietary communication	**0 point**

Within the pilots, but also part of the open call, specific attention was paid to the use of communication protocols. For example, IOTLORAMESH has demonstrated that using LoRaWAN strengthens the ASSIST-IoT architecture at the very edge.

T10: Exploitation potential/applicability to industrial relevant environment: In order to contribute to the Digitalisation of the European Industry (Digital Europe Program) through the Digital Innovation Hubs, a component should be used for use cases addressing industry whatever it is

☑ Components able to be used in an industrial environment	1 point
☐ Components not usable in an industrial environment	0 point

If there is one thing that has been demonstrated and proven by facts, it is that the completely different industrial pilots and applications, i.e. port automation, smart safety at work, and cohesion car monitoring, could make excellent use of this open-source modular ASSIT- IoT architecture and the platform used.

T11: Technology Readiness Level: A method to estimate the technology maturity of the solution

○ TRL 1 – Basic principles observed	1 point
○ TRL 2 – Technology concept formulated	2 points
○ TRL 3 – Experimental proof of concept	3 points
○ TRL 4 –Technology validated in lab	4 points
○ TRL 5 – Technology validated in relevant environement	5 points
○ TRL 6 – Technology demonstrated in relevant environement	6 points
● TRL 7 – System prototype demonstration in operational environment	7 points
○ TRL 8 – System complete and qualified	8 points
○ TRL 9 – Actual system proven in operational environment	9 points

The systems have been demonstrated in operational conditions and environments. The next step would be industrial readiness and robustness.

Data dimension - 6 Questions (D1-D6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a “Data” point of view

D1: Compatibility with data privacy rules: Data provided by IoT and used by applications should be under the European regulation. IoT are providing basic information but also videos, pictures or human sensors data that fall under GDPR

☐ Components are not collecting personal data	1 point
☑ Components are collecting personal data but respect the GDPR	0 point

Don't apply to this KER (HW)

D2: Data Modelling: Data modelling is the process of creating a visual representation of either a whole information system or parts of it to communicate connections between data points and structures. Data modelling employs standardized schemas and formal techniques. This provides a common, consistent, and predictable way of defining and managing data resources across an organization, or even beyond. A number of tools are available to support the methodology (Erwin Data Modeller, Enterprise Architect, ER/Studio, Open ModelSphere, …)

☑ A data modelling tool has been used	1 point
☐ No data modelling tool has been used	0 point

The architecture, enablers and code have been set up, made visible and developed within the ASSIST-IoT project using standardized methods, tools and formal techniques and made accessible to the project participants.

D3: Data Security: Data security is the practice of protecting digital information from unauthorized access, corruption, or theft throughout its entire lifecycle. It encompasses Encryption, Data erasure, Data masking and data resiliency

☐ Component is implementing Data encryption	1 point
☐ Component is implementing Data erasure	1 point
☐ Component is implementing Data masking	1 point
☐ Component is implementing Data resilience	1 point
☑ No security implemented	0 point

Don't apply to this KER (HW)

D4: Data Quality: Data quality measures the condition of data, relying on factors such as how useful it is to the specific purpose, completeness, accuracy, timeliness (e.g., is it up to date?), consistency, validity, and uniqueness.

☐ Component is implementing Data completeness control	**1 point**
☐ Component is implementing Data accuracy control	**1 point**
☐ Component is implementing Data timeliness ontrol	**1 point**
☐ Component is implementing Data consistency control	**1 point**
☐ Component is implementing Data validity control	**1 point**
☐ Component is implementing Data uniqueness control	**1 point**
☑ No Data Quality implemented	**0 point**

Don't apply to this KER (HW)

D5: Data Assets Management: Data assets management (DAM) has the objective to Acquiring, monitoring, using, optimizing, and exploiting data assets to generate value. DAM encompasses Accessibility, compliance and Risk management.

☐ Component is providing Data asset catalogue	**1 point**
☐ Component is compliant with all relevant regulation	**1 point**
☐ Component is implementing the relevant security strategy	**1 point**
☑ No DAM implemented	**0 point**

Don't apply to this KER (HW)

D6: Data Relevance: Data relevance is a measure of the impact of specific data on decisions or actions by the user. Collecting irrelevant data contributes to information "overload" and complicates decision-making

☐ Component is able to select relevant data	**1 point**
☐ Component is only using specific collected data	**0 point**

Don't apply to this KER (HW)

Market dimension - 8 Questions (M1-M8)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

M1: Market analysis: A market analysis provides information about industries, customers, competitors, and other market variables. You can also determine the relationship between supply and demand for a specific product or service. Based on these insights, you can make more informed decisions about possible marketing strategies.

☐ A market analysis has been conducted	**1 point**
☑ No market analysis conducted yet	**0 point**

ASSIST-IoT has developed a platform and solutions in an AI market that is emerging. Concrete market data is vaguely available to build a reliable strategy on.

M2: Demand analysis: Demand analysis is a research done to estimate or find out the customer demand for a product or service in a particular market. Demand analysis process needs to be done in a structured manner for a particular market and affects the business strategy and decisions. Some of the steps which are to be followed for the analysing the demand are: Market selection, Product/service category analysis, understanding business parameters, understanding the competitors and partner trends

☐ A Demand analysis has been conducted	**1 point**
☑ No Demand analysis conducted yet	**0 point**

Neways as an ODM/EMS and technology owner, does not own end products/applications and is therefore dependent on emerging partners who want to bring SMART AI-driven solutions and products to the market.

M3: Business model: The term business model refers to a company's plan for making a profit. It identifies the products or services the business plans to sell, its identified target market, and any anticipated expenses. There are a number of Business models but for a manufacturer which is responsible for sourcing raw materials and producing finished products by leveraging internal labor, machinery, and equipment. A manufacturer may make custom goods or highly replicated, mass produced products. A manufacturer can also sell goods to distributors, retailers, or directly to customers

☑ A Business model has been developed	**1 point**
☐ No Business model available yet	**0 point**

The developed GWEN solution and associated roadmap will be explored and positioned by our new business team as a new business opportunities.

M4: Stakeholder needs analysis: A stakeholder analysis is a project management tool used to identify the project's stakeholders, issues they care about and how they will be impacted by the project

☐ A Stakeholder needs analysis has been conducted	**1 point**
☑ No Stakeholder needs analysis conducted yet	**0 point**

[Elaboration text]

M5: IPR analysis: Intellectual property (IP) rights aim to stimulate innovation by enabling inventors to appropriate the returns on their investments

☐ A IPR analysis has been conducted	**1 point**
☑ No IPR analysis conducted yet	**0 point**

[Elaboration text]

M6: IP strategy for your solution: An IP strategy is a plan for you to develop, grow, leverage and monetize your portfolio of IP assets

☐ An IP strategy is in place	**2 points**
☐ An IP strategy has been defined	**1 point**
☑ There is no specific IP strategy defined yet	**0 point**

[Elaboration text]

M7: Solution validated in the market: Market validation includes reviewing your solution with your market (customers and prospects)

☐ Your solution is generating revenues	**2 points**
☑ Your solution is deployed at (prospect) customer site	**1 point**
☐ Your solution has not been deployed at customer site	**0 point**

The developed GWEN solution and associated roadmap will be explored and positioned by our new business team as a new business opportunities.

M8: Business Readiness Level: A method to estimate the business maturity of the solution

○ BRL 1 – Concept	**1 point**
○ BRL 2 – Problem-solution fit	**2 points**
○ BRL 3 – Build team and plan	**3 points**
● BRL 4 – Customer definition	**4 points**
○ BRL 5 – Hypothesis testing	**5 points**
○ BRL 6 – Minimum viable product	**6 points**

As an ODM/EMS and technology owner, Neways does not own end products/applications and is therefore dependent on emerging partners who want to bring SMART AI-driven solutions and products to the market. With our new buisness team we will explore new customer oppertunities.

○ BRL 7 – Feedback	7 points	
○ BRL 8 – Scale	8 points	
○ BRL 9 – Fully embedded business	9 points	

Acceptation dimension - 6 Questions (A1-A6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

A1: End-user interface design/usability: User interface design is responsible for a product's appearance, interactivity, usability, behaviour, and overall feel. UI design can determine whether a user has a positive experience with a product

☐ A focus group has been conducted	1 point	*The pilots test and established KPI's provided a first impression of the usability and experience.*
☐ A user test has been conducted	1 point	
☑ A pilot/experiment has been conducted	1 point	

A2: Implementation instructions and documentation: Product documentation is a type of technical documentation that explains almost everything there is to know about a product or piece of software.

☑ Product specifications and system requirements available	1 point	*The requirements are as ASSIST-IoT deliverables documenten in WP3 .*
☐ Instructions for product setup, installation, and configuration available	1 point	
☐ Specific use case instructions available	1 point	
☐ Troubleshooting info available	1 point	
☐ User documentation and answers to frequently asked questions available	1 point	

A3: Adoption by DIHs: The use case/solution will be well accepted by the DIHs if the component answers to the end user needs, is easy to use, to modify, to maintain and cost effective

☑ The use case / Solution is well-known from DIHs	1 point	*The chosen concept is capable to boost the adoption of AI-at-the-Edge by the digital innovation hub. Enables as distributed learnig and federal learning are part of the concept.*
☐ The use case / Solution is unknown from DIHs	0 point	

A4: User experience: User Experience refers to the feeling users experience when using a product, application, system, or service. It is a broad term that can cover anything from how well the user can navigate the product, how easy it is to use, how relevant the content displayed is etc.

☐ UX testing has been conducted	1 point	*Don't apply to this KER (HW)*
☐ UX testing has not been conducted yet	0 point	

A5: Language: In European projects, user Interface (UI) are usually designed using the English language. In the case of replicability, it is obvious that the UI has to be adapted to the targeted country (even outside Europe).

☐ The solution is already supported other languages	2 points	*Don't apply to this KER (HW)*
☐ The solution could use other languages	1 point	
☐ The solution can't use other languages easily	0 point	

A6: Societal readiness: The Societal Readiness Level https://innovationsfonden.dk/sites/default/files/2019-03/societal_readiness_levels_-_srl.pdf is a way of assessing the level of societal adaptation of, for instance, a particular social project, a technology, a product, a process, an intervention, or an innovation (whether social or technical) to be integrated into society. There are 9 levels (SRL) which help to qualify the solution, which one fits the best with your case:

○ SRL 1 – identifying problem and identifying societal readiness	**1 point**
○ SRL 2 – formulation of problem, proposed solution(s) and potential impact, expected societal readiness; identifying relevant stakeholders for the project.	**2 points**
○ SRL 3 – initial testing of proposed solution(s) together with relevant stakeholders.	**3 points**
● SRL 4 – problem validated through pilot testing in relevant environment to substantiate proposed impact and societal readiness	**4 points**
○ SRL 5 – proposed solution(s) validated, now by relevant stakeholders in the area	**5 points**
○ SRL 6 – solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact	**6 points**
○ SRL 7 – refinement of project and/or solution and, if needed, retesting in relevant environment with relevant stakeholders	**7 points**
○ SRL 8 – proposed solution(s) as well as a plan for societal adaptation complete and qualified	**8 points**
○ SRL 9 – actual project solution(s) proven in relevant environment	**9 points**

Regulation/Policy dimension - 3 Questions (R1-R3)

The European Commission and Member states are elaborating a policy strategy that give a long term vision of the evolution of Europe that are translated into laws. It addresses Environment, economy, health, democracy, ...).

The European Union is based on the rule of law. This means that every action taken by the EU is founded on treaties that have been approved democratically by its members. EU laws help to achieve the objectives of the EU treaties and put EU policies into practice. There are several EU acts that are applying to European citizens and industries. There are a number of regulations addressing the digital sectors that all products need to respect.

R1: EU regulation compliance: Looking to the EUR-Lex tool (https://eur-lex.europa.eu), there are 633 regulations that are application to the digital sector

☐ Checking the compliance with the European Regulation has been conducted	**1 point**
☑ No check of the compliance with the European Regulation has been conducted	**0 point**

[Elaboration text]

R2: National regulation Compliance: At national level there are also specific laws that are not against European legislation but that could bring additional constraints.

☑ Checking the compliance with the National Regulation has been conducted	**1 point**
☐ No check of the compliance with the National Regulation has been conducted	**0 point**

Netherlands

R3: EU Policy support: The political strategy of this Commission is to set Europe on a path to successfully achieving climate neutrality by 2050, shaping our digital future, strengthening our unique social market economy, building a Union of prosperity, and making Europe stronger in the world. 6 priorities have been identified, when one your solutions to contributing to:

☑ A European Green Deal	**1 point**	☑ A Europe fit for the digital age	**1 point**
☐ An economy that works for people	**1 point**	☐ A stronger Europe in the world	**1 point**
☐ Promoting our European way of life	**1 point**	☐ A new push for European democracy	**1 point**

Alliance for IoT and Edge Computing Innovation

Replicability & Scalability assessment tool

Project name	*ASSIST-IoT: Enhanced security center*
Contact name	*Oscar López*
email	olopez@s21sec.com
Pilot/experimentation location (s)	

Technical dimension - 11 Questions (T1-T11)

This assessment dimension would determine if a project result/solution is replicable or scalable from a technical point of view.

Use case / Solution description: ? Please explain in a concise manner what you will deliver (max 200 words)

The Cybersecurity companies are growing up and every week are having new challenges to afford from the costumers, the markets, end-users, goverments,.. At the same time it must be deliver a security solution to each company offering the best way of implementing it and response properly to each event.
In this way we will deliver two different types of use cases. In one hand we will deliver an authentication and authorization solution that enables the acces to the data only to authorized user and dependig the type of user will have access to different data. In other hand we will deliver a detect and response solution, based on an incident dectection and response solution, where the events of the monitored endpoints will be logged and scalated for a proper response.

T1: Openess of components: Component provides interfaces that could allow easy integration in other environments

☑ Easy to integrate in another evironment — **2 points**
☐ Difficult to integrate in another environment without expert support — **1 point**
☐ Impossible to integrate in another environment — **0 point**

The developed solutions are ready for the integration with other tools, and it is done so in the project, for example with the tactile dashboard or GWEN.

T2: Interoperability of components - Standardized device communication API: Provides application developers with uniform and transparent access to physical devices and wearables. (e.g. SCRAL, LinkSmart)

☑ Standardized API available — **1 point**
☐ No API available — **0 point**

Due to the nature of the solution developed, this does not depends from us, just because we develop software solutions.

T3: Standardized Data Modeling: Allows IoT syntactic and semantic interoperability (e.g. OGC SensorThings API), Standardized Data model available

☑ Standardized Data Model — **1 point**
☐ Proprietary Data Model — **0 point**

The main goal of the developments that we have made is to offer the better way of iintegration an we have done it we standardized data.

T4: IoT Platform interoperability : Allows the integration with other IoT platforms (e.g. oneM2M, FIWARE, Azzure, ..., see SCoDIHNet platform catalogue)

☑ Component is running on one of the IoT platforms — **1 point**

☐ Component is running on a proprietary platform — **0 point**

The solutions developed are ready for integration with other tools in other IoT paltforms.

T5: Modularity: Referred to modular IoT architecture that can be customized for a diverse range of applications or, in general, to a design principle that subdivides a system into smaller parts called modules, which can be independently created, modified, replaced, or exchanged with other modules or between different systems

☑ Components have been designed with several modules — **1 point**

☐ Components have been designed in one single module — **0 point**

One of the main goals of the IoT project with the enablers we have developed was to be transeversal to the project. In this way any of the solutiones developed can be configured and deploy in any market, IoT architecture,.... the customization is one of the basics goals of the tools.

T6: Compatibility with legacy infrastructure and equipment: The solution is using legacy network infrastructure (5G, Sigfox, Lora, NB-IoT, …) and devices

☑ The solution is using legacy infrastructure — **1 point**

☐ The solution is using proprietary infrastructure — **0 point**

☑ The solution is using legacy devices — **1 point**

☐ The solution is using proprietary devices — **0 point**

The solutions can be deployed in any network infraestructure so, as far as the transport layer or backbone of the network can be deployed in any technology, this does not affect to the solutions.

T7: Updates & Maintenance: Components should evolve to add new functionalities or to correct bugs, this could be made could be easily remotely or need intervention of experts

☐ Components updated and maintained by the integrator — **1 point**

☑ Maintenance and updates need expert intervention — **0 point**

Depending on the bug or new functionalities that are requested, may be it is need an expert to develop it, but in almost all cases no expert should be needed.

T8: Standards Compliance: Many standards have been developed for IoT and communication, interoperability could only become a reality if components are compliant to one or the other standards

☑ Components are compliant to a standard — **1 point**

☐ Components are cot ompliant to any standard — **0 point**

The components have been developed in other to get better interoperability with other tools and regarding to communication standards

T9: Communication/Cloud infrastructure: : Data generated by IoT need to be stored and manipulated before feeding the end user application. This topic targets the communication protocol used to send out data to the cloud data centre. There are several types of protocol available (Sigfox, LoRa, 4G, 5G, RF, NFC, …) which need to offer interoperability

☑ Components compliant with a communication protocol standard — **1 point**

☐ Components use a proprietary communication — **0 point**

The developed tools are compatible with the IoT communication protocols.

T10: Exploitation potential/applicability to industrial relevant environment: In order to contribute to the Digitalisation of the European Industry (Digital Europe Program) through the Digital Innovation Hubs, a component should be used for use cases addressing industry whatever it is

☑ Components able to be used in an industrial environment	**1 point**	*The Pilots of the projects are industrial pilots and we have been able to integrate in them and use case. As far as the tools area trnasevrsal they can be applied to almost any industrial market.*
☐ Components not usable in an industrial environment	**0 point**	

T11: Technology Readiness Level: A method to estimate the technology maturity of the solution

○ TRL 1 – Basic principles observed	**1 point**	*The solutions developed are ready to be used in the market.*
○ TRL 2 – Technology concept formulated	**2 points**	
○ TRL 3 – Experimental proof of concept	**3 points**	
○ TRL 4 –Technology validated in lab	**4 points**	
○ TRL 5 – Technology validated in relevant environement	**5 points**	
○ TRL 6 – Technology demonstrated in relevant environement	**6 points**	
● TRL 7 – System prototype demonstration in operational environment	**7 points**	
○ TRL 8 – System complete and qualified	**8 points**	
○ TRL 9 – Actual system proven in operational environment	**9 points**	

Data dimension - 6 Questions (D1-D6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a “Data” point of view

D1: Compatibility with data privacy rules: Data provided by IoT and used by applications should be under the European regulation. IoT are providing basic information but also videos, pictures or human sensors data that fall under GDPR

☑ Components are not collecting personal data	**1 point**	*Focus on collecting a minimum of personal data. Personal data which is necessary for functionality (e.g. vehicle location) will be handled to respect GDPR in every aspect.*
☐ Components are collecting personal data but respect the GDPR	**0 point**	

D2: Data Modelling: Data modelling is the process of creating a visual representation of either a whole information system or parts of it to communicate connections between data points and structures. Data modelling employs standardized schemas and formal techniques. This provides a common, consistent, and predictable way of defining and managing data resources across an organization, or even beyond. A number of tools are available to support the methodology (Erwin Data Modeller, Enterprise Architect, ER/Studio, Open ModelSphere, …)

☐ A data modelling tool has been used	**1 point**	*Our tools are comaptible and can be integrated with other tools throuh APIs using standards*
☑ No data modelling tool has been used	**0 point**	

D3: Data Security: Data security is the practice of protecting digital information from unauthorized access, corruption, or theft throughout its entire lifecycle. It encompasses Encryption, Data erasure, Data masking and data resiliency

☐ Component is implementing Data encryption	**1 point**	*Our tools are focused on data security and protect data from unauthorized access*	
☐ Component is implementing Data erasure	**1 point**		
☐ Component is implementing Data masking	**1 point**		
☑ Component is implementing Data resilience	**1 point**	☐ No security implemented	**0 point**

D4: Data Quality: Data quality measures the condition of data, relying on factors such as how useful it is to the specific purpose, completeness, accuracy, timeliness (e.g., is it up to date?), consistency, validity, and uniqueness.

☐ Component is implementing Data completeness control	**1 point**
☐ Component is implementing Data accuracy control	**1 point**
☐ Component is implementing Data timeliness ontrol	**1 point**
☐ Component is implementing Data consistency control	**1 point**
☐ Component is implementing Data validity control	**1 point**
☐ Component is implementing Data uniqueness control	**1 point**
☑ No Data Quality implemented	**0 point**

Tools developed does not participate in Data quality processes

D5: Data Assets Management: Data assets management (DAM) has the objective to Acquiring, monitoring, using, optimizing, and exploiting data assets to generate value. DAM encompasses Accessibility, compliance and Risk management.

☐ Component is providing Data asset catalogue	**1 point**
☑ Component is compliant with all relevant regulation	**1 point**
☑ Component is implementing the relevant security strategy	**1 point**
☐ No DAM implemented	**0 point**

Tools developed does not participate in Data assets management processes

D6: Data Relevance: Data relevance is a measure of the impact of specific data on decisions or actions by the user. Collecting irrelevant data contributes to information “overload” and complicates decision-making

☐ Component is able to select relevant data	**1 point**
☑ Component is only using specific collected data	**0 point**

The main goal of the tools are to collect only the needed data to ensure the proper functionality of the tools

Market dimension - 8 Questions (M1-M8)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

M1: Market analysis: A market analysis provides information about industries, customers, competitors, and other market variables. You can also determine the relationship between supply and demand for a specific product or service. Based on these insights, you can make more informed decisions about possible marketing strategies.

☑ A market analysis has been conducted	**1 point**
☐ No market analysis conducted yet	**0 point**

It is been a market analysis in the project

M2: Demand analysis: Demand analysis is a research done to estimate or find out the customer demand for a product or service in a particular market. Demand analysis process needs to be done in a structured manner for a particular market and affects the business strategy and decisions. Some of the steps which are to be followed for the analysing the demand are: Market selection, Product/service category analysis, understanding business parameters, understanding the competitors and partner trends

☑ A Demand analysis has been conducted	**1 point**
☐	**0 point**

It is been a demand analysis in the project

☐ No Demand analysis conducted yet	0 point

M3: Business model: The term business model refers to a company's plan for making a profit. It identifies the products or services the business plans to sell, its identified target market, and any anticipated expenses. There are a number of Business models but for a manufacturer which is responsible for sourcing raw materials and producing finished products by leveraging internal labor, machinery, and equipment. A manufacturer may make custom goods or highly replicated, mass produced products. A manufacturer can also sell goods to distributors, retailers, or directly to customers

☑ A Business model has been developed	1 point
☐ No Business model available yet	0 point

The Business model is being presented in the projects deliverables

M4: Stakeholder needs analysis: A stakeholder analysis is a project management tool used to identify the project's stakeholders, issues they care about and how they will be impacted by the project

☑ A Stakeholder needs analysis has been conducted	1 point
☐ No Stakeholder needs analysis conducted yet	0 point

This analysis is been done in the project and some surveys have been done

M5: IPR analysis: Intellectual property (IP) rights aim to stimulate innovation by enabling inventors to appropriate the returns on their investments

☑ A IPR analysis has been conducted	1 point
☐ No IPR analysis conducted yet	0 point

In projects deliverables is been presented and IP rights for the tools that have been developed

M6: IP strategy for your solution: An IP strategy is a plan for you to develop, grow, leverage and monetize your portfolio of IP assets

☐ An IP strategy is in place	2 points
☑ An IP strategy has been defined	1 point
☐ There is no specific IP strategy defined yet	0 point

THe IP strategy is being defined

M7: Solution validated in the market: Market validation includes reviewing your solution with your market (customers and prospects)

☐ Your solution is generating revenues	2 points
☑ Your solution is deployed at (prospect) customer site	1 point
☐ Your solution has not been deployed at customer site	0 point

The solutions developed has been analysed before and during the project to ensure the usability of them

M8: Business Readiness Level: A method to estimate the business maturity of the solution

○ BRL 1 – Concept	1 point
○ BRL 2 – Problem-solution fit	2 points

The solutions developed are ready to use them in market

	2 points
○ BRL 3 – Build team and plan	3 points
○ BRL 4 – Customer definition	4 points
○ BRL 5 – Hypothesis testing	5 points
○ BRL 6 – Minimum viable product	6 points
● BRL 7 – Feedback	7 points
○ BRL 8 – Scale	8 points
○ BRL 9 – Fully embedded business	9 points

Acceptation dimension - 6 Questions (A1-A6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

A1: End-user interface design/usability: User interface design is responsible for a product's appearance, interactivity, usability, behaviour, and overall feel. UI design can determine whether a user has a positive experience with a product

☐ A focus group has been conducted	1 point
☐ A user test has been conducted	1 point
☑ A pilot/experiment has been conducted	1 point

The UI of the developed tools are friendly-use

A2: Implementation instructions and documentation: Product documentation is a type of technical documentation that explains almost everything there is to know about a product or piece of software.

☑ Product specifications and system requirements available	1 point
☑ Instructions for product setup, installation, and configuration available	1 point
☐ Specific use case instructions available	1 point
☐ Troubleshooting info available	1 point
☐ User documentation and answers to frequently asked questions available	1 point

It has been developed doumentation for technical aspects and step by step guides for other tools developers and pilots to allow them to integrate with our tools, configure and extract data for KPIs

A3: Adoption by DIHs: The use case/solution will be well accepted by the DIHs if the component answers to the end user needs, is easy to use, to modify, to maintain and cost effective

☑ The use case / Solution is well-known from DIHs	1 point
☐ The use case / Solution is unknown from DIHs	0 point

The tools have been evaluated in the project

A4: User experience: User Experience refers to the feeling users experience when using a product, application, system, or service. It is a broad term that can cover anything from how well the user can navigate the product, how easy it is to use, how relevant the content displayed is etc.

☐ UX testing has been conducted	1 point
☑ UX testing has not been conducted yet	0 point

The user experience has not been evaluated

A5: Language: In European projects, user Interface (UI) are usually designed using the English language. In the case of replicability, it is obvious that the UI has to be adapted to the targeted country (even outside Europe).

☐ The solution is already supported other languages	2 points

The tools that has been developed are in English

☑ The solution could use other languages	1 point	
☐ The solution can't use other languages easily	0 point	

A6: Societal readiness: The Societal Readiness Level https://innovationsfonden.dk/sites/default/files/2019-03/societal_readiness_levels_-_srl.pdf is a way of assessing the level of societal adaptation of, for instance, a particular social project, a technology, a product, a process, an intervention, or an innovation (whether social or technical) to be integrated into society. There are 9 levels (SRL) which help to qualify the solution, which one fits the best with your case:

○ SRL 1 – identifying problem and identifying societal readiness	1 point
○ SRL 2 – formulation of problem, proposed solution(s) and potential impact, expected societal readiness; identifying relevant stakeholders for the project.	2 points
○ SRL 3 – initial testing of proposed solution(s) together with relevant stakeholders.	3 points
○ SRL 4 – problem validated through pilot testing in relevant environment to substantiate proposed impact and societal readiness	4 points
○ SRL 5 – proposed solution(s) validated, now by relevant stakeholders in the area	5 points
○ SRL 6 – solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact	6 points
○ SRL 7 – refinement of project and/or solution and, if needed, retesting in relevant environment with relevant stakeholders	7 points
● SRL 8 – proposed solution(s) as well as a plan for societal adaptation complete and qualified	8 points
○ SRL 9 – actual project solution(s) proven in relevant environment	9 points

Regulation/Policy dimension - 3 Questions (R1-R3)

The European Commission and Member states are elaborating a policy strategy that give a long term vision of the evolution of Europe that are translated into laws. It addresses Environment, economy, health, democracy, …).

The European Union is based on the rule of law. This means that every action taken by the EU is founded on treaties that have been approved democratically by its members. EU laws help to achieve the objectives of the EU treaties and put EU policies into practice. There are several EU acts that are applying to European citizens and industries. There are a number of regulations addressing the digital sectors that all products need to respect.

R1: EU regulation compliance: Looking to the EUR-Lex tool (https://eur-lex.europa.eu), there are 633 regulations that are application to the digital sector

☐ Checking the compliance with the European Regulation has been conducted	1 point	*Part of ASSIST-IoT project.*
☑ No check of the compliance with the European Regulation has been conducted	0 point	

R2: National regulation Compliance: At national level there are also specific laws that are not against European legislation but that could bring additional constraints.

☐ Checking the compliance with the National Regulation has been conducted	1 point	*Part of ASSIST-IoT project.*
☑ No check of the compliance with the National Regulation has been conducted	0 point	

R3: EU Policy support: The political strategy of this Commission is to set Europe on a path to successfully achieving climate neutrality by 2050, shaping our digital future, strengthening our unique social market economy, building a Union of prosperity, and making Europe stronger in the world. 6 priorities have been identified, when one your solutions to contributing to:

☐ A European Green Deal	1 point	☑ A Europe fit for the digital age	1 point
☐ An economy that works for people	1 point	☐ A stronger Europe in the world	1 point
☐ Promoting our European way of life	1 point	☐ A new push for European democracy	1 point

Replicability & Scalability assessment tool

Project name	*ASSIST-IoT: Smart orchestrator*
Contact name	*Alejandro Fornés Leal*
email	alforlea@upv.es
Pilot/experimentation location (s)	*Valencia, Comunitat Valenciana, Spain*

Technical dimension - 11 Questions (T1-T11)

This assessment dimension would determine if a project result/solution is replicable or scalable from a technical point of view.

Use case / Solution description: ? Please explain in a concise manner what you will deliver (max 200 words)

The ASSIST-IoT platform is a software module in charge of deploying Next-Generation IoT solutions within a set of managed edge-cloud computing continuum resources, following the ASSIST-IoT vision. More concretely, it allows IoT architects and users to deploy solutions from different enabling technologies (e.g., VNFs, AI, data governance, big data, etc.) in the form of Helm charts in their Kubernetes-based (k0s, K3s, kubeadm) infrastructure, with additional features including: (i) policies to allow automatic workload placement; (ii) network policies to increase communication security, preventing unintended connections; (iii) management of dynamic use cases, i.e., considering sites without public IP addresses; (iv) observability and mobility tools; (v) access control technologies, (vi) and Open API for 3rd-party solutions integration, and (vii) a dedicated graphical user interfaces to control the

T1: Openess of components: Component provides interfaces that could allow easy integration in other environments

☑ Easy to integrate in another evironment — **2 points**

☐ Difficult to integrate in another environment without expert support — **1 point**

☐ Impossible to integrate in another environment — **0 point**

The orchestrator exposes an API, with different API groups composed by several endpoints, to be consumed by users or third party systems (e.g., to manage K8s clusters of the computing continuum, artifacts repositories, and artifacts' lifecycle). In any case, the preferred way to interact with it is via the dedicated GUIs.

T2: Interoperability of components - Standardized device communication API: Provides application developers with uniform and transparent access to physical devices and wearables. (e.g. SCRAL, LinkSmart)

☐ Standardized API available — **1 point**

☑ No API available — **0 point**

No communication with devices is expected - only with K8s masters of computing nodes in deployment sites, considering direct K8s API consumption.

T3: Standardized Data Modeling: Allows IoT syntactic and semantic interoperability (e.g. OGC SensorThings API), Standardized Data model available

☐ Standardized Data Model — **1 point**

☑ Proprietary Data Model — **0 point**

The API follows a custom data model, available but not standard, as any of the published ones fits (or is close to) the needs of the solution.

T4: IoT Platform interoperability : Allows the integration with other IoT platforms (e.g. oneM2M, FIWARE, Azzure, ..., see SCoDIHNet platform catalogue)

☑ Component is running on one of the IoT platforms	**1 point**	*Orion, FIWARE's conext broker, is in fact part of the solution for managing the context of dynamic scenarios.*
☐ Component is running on a proprietary platform	**0 point**	

T5: Modularity: Referred to modular IoT architecture that can be customized for a diverse range of applications or, in general, to a design principle that subdivides a system into smaller parts called modules, which can be independently created, modified, replaced, or exchanged with other modules or between different systems

☑ Components have been designed with several modules	**1 point**	*The smart orchestrator follows the ASSIST-IoT architecture, in which solutions consist of different components, realized as independent containers. They can be modified/mantained separately, being some essential for having the basic features in place. Components interact among them via internal APIs.*
☐ Components have been designed in one single module	**0 point**	

T6: Compatibility with legacy infrastructure and equipment: The solution is using legacy network infrastructure (5G, Sigfox, Lora, NB-IoT, …) and devices

☑ The solution is using legacy infrastructure	**1 point**	*Any proprietary infrastructure/device is needed, just a standard Ubuntu OS with a set of minimum requirements.*
☐ The solution is using proprietary infrastructure	**0 point**	
☑ The solution is using legacy devices	**1 point**	
☐ The solution is using proprietary devices	**0 point**	

T7: Updates & Maintenance: Components should evolve to add new functionalities or to correct bugs, this could be made could be easily remotely or need intervention of experts

☑ Components updated and maintained by the integrator	**1 point**	*Most of the components of the solution can be upgraded via single command from the CLI, without requiring the intervention or aid of an expert. v4.0.0 will replace the only service directly installed over the host to achive it as a whole.*
☐ Maintenance and updates need expert intervention	**0 point**	

T8: Standards Compliance: Many standards have been developed for IoT and communication, interoperability could only become a reality if components are compliant to one or the other standards

☑ Components are compliant to a standard	**1 point**	*The solution is compatible with the standards from ETSI MANO NFV and MQTT. It also follows the NGSI, OpenAPI and Prometheus specifications within its components.*
☐ Components are cot ompliant to any standard	**0 point**	

T9: Communication/Cloud infrastructure: : Data generated by IoT need to be stored and manipulated before feeding the end user application. This topic targets the communication protocol used to send out data to the cloud data centre. There are several types of protocol available (Sigfox, LoRa, 4G, 5G, RF, NFC, …) which need to offer interoperability

☑ Components compliant with a communication protocol standard	**1 point**	*Communication relies on MQTT specifications (over 5G, 4G, wired networks) when data are moved from edge sites to cloud.*
☐ Components use a proprietary communication	**0 point**	

T10: Exploitation potential/applicability to industrial relevant environment: In order to contribute to the Digitalisation of the European Industry (Digital Europe Program) through the Digital Innovation Hubs, a component should be used for use cases addressing industry whatever it is

☐ Components able to be used in an industrial environment	**1 point**
☑ Components not usable in an industrial environment	**0 point**

This module is software and thought for cloud, thus not specifically prepared for industry. In the framework of ASSIST-IoT project, it is used in automovilistic, maritime (ports) and construction verticals. Still, it has not being tested to ensure a robust performance in industrial ecosystems (hence marked as not usable, at least yet).

T11: Technology Readiness Level: A method to estimate the technology maturity of the solution

○ TRL 1 – Basic principles observed	**1 point**
○ TRL 2 – Technology concept formulated	**2 points**
○ TRL 3 – Experimental proof of concept	**3 points**
○ TRL 4 –Technology validated in lab	**4 points**
● TRL 5 – Technology validated in relevant environement	**5 points**
○ TRL 6 – Technology demonstrated in relevant environement	**6 points**
○ TRL 7 – System prototype demonstration in operational environment	**7 points**
○ TRL 8 – System complete and qualified	**8 points**
○ TRL 9 – Actual system proven in operational environment	**9 points**

As aforementioned in T10, the technology has been validated and demonstrated not just in lab but also considering use cases from real (automobile, construction, port) environments. Some refinements related primarily to robustness are still needed before moving to upper TRLs.

Data dimension - 6 Questions (D1-D6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a “Data” point of view

D1: Compatibility with data privacy rules: Data provided by IoT and used by applications should be under the European regulation. IoT are providing basic information but also videos, pictures or human sensors data that fall under GDPR

☑ Components are not collecting personal data	**1 point**
☐ Components are collecting personal data but respect the GDPR	**0 point**

This tool does not manage any kind of personal data.

D2: Data Modelling: Data modelling is the process of creating a visual representation of either a whole information system or parts of it to communicate connections between data points and structures. Data modelling employs standardized schemas and formal techniques. This provides a common, consistent, and predictable way of defining and managing data resources across an organization, or even beyond. A number of tools are available to support the methodology (Erwin Data Modeller, Enterprise Architect, ER/Studio, Open ModelSphere, …)

☐ A data modelling tool has been used	**1 point**
☑ No data modelling tool has been used	**0 point**

A dedicated data model is in place, however, any ontology nor dedicated tool for creating it have been used.

D3: Data Security: Data security is the practice of protecting digital information from unauthorized access, corruption, or theft throughout its entire lifecycle. It encompasses Encryption, Data erasure, Data masking and data resiliency

☑ Component is implementing Data encryption	**1 point**
☐ Component is implementing Data erasure	**1 point**
☑ Component is implementing Data masking	**1 point**
☐ Component is implementing Data resilience	**1 point**
☐ No security implemented	**0 point**

HTTPS & MQTTS are used for transmissions, and K8s pods from different sites are communicated with uTLS encryption. Data erasure is not applied. Data masking is considered for protecting secrets, with K8s standard processes. Resiliency mechanisms are in place due to the deployment ecosystem, but not just by itself.

D4: Data Quality: Data quality measures the condition of data, relying on factors such as how useful it is to the specific purpose, completeness, accuracy, timeliness (e.g., is it up to date?), consistency, validity, and uniqueness.

☑ Component is implementing Data completeness control	1 point
☑ Component is implementing Data accuracy control	1 point
☑ Component is implementing Data timeliness ontrol	1 point
☐ Component is implementing Data consistency control	1 point
☐ Component is implementing Data validity control	1 point
☑ Component is implementing Data uniqueness control	1 point
☐ No Data Quality implemented	0 point

The solution has followed MANO standard to be implemented, following a very similar model as OSM, but extended for supporting its additional features. Not exhaustive analysis has been made yet, still, it has been validated with real cases and potential users so the information displayed is enough and not ambiguous for stakeholders (completeness), correct and according to the reality (accuracy), and updates with sufficient frequency, including when errors happen (timeliness). Some validation checks and ACK mechanisms are in place, but not exhaustive. Some minor redundancy issues are to be solved.

D5: Data Assets Management: Data assets management (DAM) has the objective to Acquiring, monitoring, using, optimizing, and exploiting data assets to generate value. DAM encompasses Accessibility, compliance and Risk management.

☐ Component is providing Data asset catalogue	1 point
☑ Component is compliant with all relevant regulation	1 point
☑ Component is implementing the relevant security strategy	1 point
☐ No DAM implemented	0 point

The solution does not provides a data asset catalogue, still, it incorporates mechanisms to expose and store relevant data + metadata of the system in Prometheus and graphs for consulting them. Data regulation is followed (not critical in this case), and SotA data security strategy (RBAC, encryption, etc.) are applied.

D6: Data Relevance: Data relevance is a measure of the impact of specific data on decisions or actions by the user. Collecting irrelevant data contributes to information “overload” and complicates decision-making

☑ Component is able to select relevant data	1 point
☐ Component is only using specific collected data	0 point

The solution exposes a "/metrics" endpoint to be automatically scrapped by Prometheus server. These data is complemented with additional data from the infrastructure, so the user can see how their decisions are affecting the system. In any case, no advanced analytics or ML to assess it is applied at this moment.

Market dimension - 8 Questions (M1-M8)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

M1: Market analysis: A market analysis provides information about industries, customers, competitors, and other market variables. You can also determine the relationship between supply and demand for a specific product or service. Based on these insights, you can make more informed decisions about possible marketing strategies.

☑ A market analysis has been conducted	1 point
☐ No market analysis conducted yet	0 point

A market analysis was carried out to understand what are the solutions available, the lacks and challenges to design a solution with potential.

M2: Demand analysis: Demand analysis is a research done to estimate or find out the customer demand for a product or service in a particular market. Demand analysis process needs to be done in a structured manner for a particular market and affects the business strategy and decisions. Some of the steps which are to be followed for the analysing the demand are: Market selection, Product/service category analysis, understanding business parameters, understanding the competitors and partner trends

☐ A Demand analysis has been conducted	1 point
☐	0 point

No demand analysis conducted yet.

☑ No Demand analysis conducted yet	0 point

M3: Business model: The term business model refers to a company's plan for making a profit. It identifies the products or services the business plans to sell, its identified target market, and any anticipated expenses. There are a number of Business models but for a manufacturer which is responsible for sourcing raw materials and producing finished products by leveraging internal labor, machinery, and equipment. A manufacturer may make custom goods or highly replicated, mass produced products. A manufacturer can also sell goods to distributors, retailers, or directly to customers

☑ A Business model has been developed	**1 point**
☐ No Business model available yet	**0 point**

Business models of project Key Innovation Results (KERs) have been developed during the last months of the ASSIST-IoT project.

M4: Stakeholder needs analysis: A stakeholder analysis is a project management tool used to identify the project's stakeholders, issues they care about and how they will be impacted by the project

☐ A Stakeholder needs analysis has been conducted	**1 point**
☑ No Stakeholder needs analysis conducted yet	**0 point**

Any formal stakeholder analysis has been carried out. In any case, different documents - related to the challenges and future of this kind of solutions - written by this kind of users has been consulted to come up with its design.

M5: IPR analysis: Intellectual property (IP) rights aim to stimulate innovation by enabling inventors to appropriate the returns on their investments

☐ A IPR analysis has been conducted	**1 point**
☑ No IPR analysis conducted yet	**0 point**

IPR analysis of project Key Innovation Results (KERs) will be developed in the last months of the ASSIST-IoT project.

M6: IP strategy for your solution: An IP strategy is a plan for you to develop, grow, leverage and monetize your portfolio of IP assets

☐ An IP strategy is in place	**2 points**
☑ An IP strategy has been defined	**1 point**
☐ There is no specific IP strategy defined yet	**0 point**

An IP strategy has been depicted, considering a roadmap to evolve the solution to further TRLs and gather funds for a potential monetization. The idea is to start this process in April 2024.

M7: Solution validated in the market: Market validation includes reviewing your solution with your market (customers and prospects)

☐ Your solution is generating revenues	**2 points**
☑ Your solution is deployed at (prospect) customer site	**1 point**
☐ Your solution has not been deployed at customer site	**0 point**

In the framework of ASSIST-IoT project, the solution is being tested in premises of 4 potential pilots.

M8: Business Readiness Level: A method to estimate the business maturity of the solution

○ BRL 1 – Concept	**1 point**
○ BRL 2 – Problem-solution fit	**2 points**

An MVP was released some months ago, being now in a testing and validation phase from the project stakeholders and technical partners. In

○ BRL 3 – Build team and plan	3 points
○ BRL 4 – Customer definition	4 points
○ BRL 5 – Hypothesis testing	5 points
○ BRL 6 – Minimum viable product	6 points
● BRL 7 – Feedback	7 points
○ BRL 8 – Scale	8 points
○ BRL 9 – Fully embedded business	9 points

parallel, development effort is being put to enhance the solution with the gathered feedback.

Acceptation dimension - 6 Questions (A1-A6)

This assessment dimension would determine if a project result/solution is replicable or scalable from a business point of view

A1: End-user interface design/usability: User interface design is responsible for a product's appearance, interactivity, usability, behaviour, and overall feel. UI design can determine whether a user has a positive experience with a product

☑ A focus group has been conducted	1 point
☑ A user test has been conducted	1 point
☑ A pilot/experiment has been conducted	1 point

As aforementioned, the soultion - and thus its GUI - has been tested in pilots, with good feedback. Three senior developers discussed its design and representative potential users have tested it (considering agile methodologies during development process)

A2: Implementation instructions and documentation: Product documentation is a type of technical documentation that explains almost everything there is to know about a product or piece of software.

☐ Product specifications and system requirements available	1 point
☑ Instructions for product setup, installation, and configuration available	1 point
☐ Specific use case instructions available	1 point
☑ Troubleshooting info available	1 point
☑ User documentation and answers to frequently asked questions available	1 point

Specifications are available in ASSIST-IoT D4.2 - however, they were intermediate so we do not mark it here (in some months, the full set will be ready). Instructions for setup, installation and configuration are available in the project's ReadTheDocs and the solution's WiKi, along with troubleshooting.

A3: Adoption by DIHs: The use case/solution will be well accepted by the DIHs if the component answers to the end user needs, is easy to use, to modify, to maintain and cost effective

☐ The use case / Solution is well-known from DIHs	1 point
☑ The use case / Solution is unknown from DIHs	0 point

Some presentations of the project and particulars of the solution have been made, still, DIHs have not been targeted yet.

A4: User experience: User Experience refers to the feeling users experience when using a product, application, system, or service. It is a broad term that can cover anything from how well the user can navigate the product, how easy it is to use, how relevant the content displayed is etc.

☑ UX testing has been conducted	1 point
☐ UX testing has not been conducted yet	0 point

The solution is being tested in pilots. A questionnaire has been prepared for them and results will be aggregated and published in D8.3

A5: Language: In European projects, user Interface (UI) are usually designed using the English language. In the case of replicability, it is obvious that the UI has to be adapted to the targeted country (even outside Europe).

☑ The solution is already supported other languages	2 points

The interface currently supports Spanish besides

☑ The solution could use other languages	1 point
☐ The solution can't use other languages easily	0 point

English, and thanks to the development framework used for the GUI (Prodevelop's PUI9) it could be easily adapted to other lenguages.

A6: Societal readiness: The Societal Readiness Level https://innovationsfonden.dk/sites/default/files/2019-03/societal_readiness_levels_-_srl.pdf is a way of assessing the level of societal adaptation of, for instance, a particular social project, a technology, a product, a process, an intervention, or an innovation (whether social or technical) to be integrated into society. There are 9 levels (SRL) which help to qualify the solution, which one fits the best with your case:

○ SRL 1 – identifying problem and identifying societal readiness	1 point
○ SRL 2 – formulation of problem, proposed solution(s) and potential impact, expected societal readiness; identifying relevant stakeholders for the project.	2 points
○ SRL 3 – initial testing of proposed solution(s) together with relevant stakeholders.	3 points
○ SRL 4 – problem validated through pilot testing in relevant environment to substantiate proposed impact and societal readiness	4 points
○ SRL 5 – proposed solution(s) validated, now by relevant stakeholders in the area	5 points
● SRL 6 – solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact	6 points
○ SRL 7 – refinement of project and/or solution and, if needed, retesting in relevant environment with relevant stakeholders	7 points
○ SRL 8 – proposed solution(s) as well as a plan for societal adaptation complete and qualified	8 points
○ SRL 9 – actual project solution(s) proven in relevant environment	9 points

Regulation/Policy dimension - 3 Questions (R1-R3)

The European Commission and Member states are elaborating a policy strategy that give a long term vision of the evolution of Europe that are translated into laws. It addresses Environment, economy, health, democracy, ...).

The European Union is based on the rule of law. This means that every action taken by the EU is founded on treaties that have been approved democratically by its members. EU laws help to achieve the objectives of the EU treaties and put EU policies into practice. There are several EU acts that are applying to European citizens and industries. There are a number of regulations addressing the digital sectors that all products need to respect.

R1: EU regulation compliance: Looking to the EUR-Lex tool (https://eur-lex.europa.eu), there are 633 regulations that are application to the digital sector

☐ Checking the compliance with the European Regulation has been conducted	1 point
☑ No check of the compliance with the European Regulation has been conducted	0 point

Check with GDPR and some key regulations performed, but not at a full extent.

R2: National regulation Compliance: At national level there are also specific laws that are not against European legislation but that could bring additional constraints.

☐ Checking the compliance with the National Regulation has been conducted	1 point
☑ No check of the compliance with the National Regulation has been conducted	0 point

An analysis of spanish, german, polish, german and malt regulations were made, but for pilot execution (use cases), not this particular solution. This activity is pending.

R3: EU Policy support: The political strategy of this Commission is to set Europe on a path to successfully achieving climate neutrality by 2050, shaping our digital future, strengthening our unique social market economy, building a Union of prosperity, and making Europe stronger in the world. 6 priorities have been identified, when one your solutions to contributing to:

☑ A European Green Deal	1 point	☑ A Europe fit for the digital age	1 point
☐ An economy that works for people	1 point	☐ A stronger Europe in the world	1 point
☐ Promoting our European way of life	1 point	☐ A new push for European democracy	1 point