AMAZING-6G
Amazing Large-Scale Trials and Pilots for Verticals in 6G

Deliverable 7.1

Trials and evaluation intermediate developments

Co-funded by the European Union

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Executive Summary

This deliverable provides insights into the intermediate progress of Work Package 7 (WP7) of the AMAZING-6G project, covering the activities performed between months M7 and M18. WP7 acts as the convergence point for the project's 6G technological enablers (WP3) and vertical use cases work packages (WP4-WP6), by coordinating trial planning, monitoring experimentation activities, and establishing a common evaluation methodology across all vertical use cases.

Therefore, the deliverable starts with a comprehensive overview of the trialing ecosystem, including sixteen trial and pre-trial sites distributed across ten European countries and spanning four vertical sectors: health, public safety, energy, and transport verticals. It analyzes the capabilities of each site from the perspectives of radio access, core and transport networks, edge computing, user equipment, and deployment architecture, demonstrating the diversity of infrastructures available for validating Beyond 5G and 6G technologies under realistic operational conditions for the aforementioned vertical sectors.

The core contribution of this deliverable is the establishment of a harmonized framework for Key Performance Indicators (KPIs) and Key Value Indicators (KVIs), covering all 15 use cases within four vertical sectors. The document defines both vertical-agnostic and vertical-specific KPIs together with their target values and measurement methodologies, enabling consistent performance evaluation across all trial sites. Furthermore, it introduces a common KVI framework addressing societal, environmental, and economic sustainability pillars, ensuring that the impact of 6G technologies is assessed beyond purely technical performance.

The deliverable also reports the current status of pre-trial activities conducted across four vertical domains, presented in WP4, WP5, and WP6. The initial measurements demonstrate the feasibility of the preliminary integrations between use cases and technological enablers, and provide early evidence that the deployed infrastructures are capable of supporting the targeted communication, compute, AI, and IoT functionalities. These preliminary activities validate the readiness of the trial sites and provide valuable feedback for the optimization of the upcoming large-scale trials.

Finally, the deliverable closes with the planning and timeline for trial activities that will be the fore focus for the second half of the AMAZING-6G project. By harmonizing trial methodologies, defining common evaluation metrics, documenting the capabilities of the trial infrastructure, and reporting the progress of pre-trial activities, this deliverable prepares the consortium for the execution of full-scale cross-vertical trials and the comprehensive evaluation of 6G technologies during the final project phase.

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List of Acronyms and Abbreviations

TERM	DESCRIPTION
3GPP	3rd Generation Partnership Project
5GC	5G Core
5G SA	5G Standalone
5G NSA	5G Non-Standalone
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AI/ML	Artificial Intelligence / Machine Learning
AMF	Access and Mobility Management Function
APN	Access Point Name
AUSF	Authentication Server Function
B5G	Beyond 5G
BBU	Baseband Unit
BSF	Binding Support Function
CAAS	Compute-as-a-Service
CAMARA	CAMARA Open API Framework
CMM	Cloud Management Module
CN	Core Network
COTS	Commercial-off-the-shelf
CPE	Customer Premises Equipment
DNN	Data Network Name
DOT	Digital Outdoor/Distributed Radio Unit
EC	European Commission
EMBB	Enhanced Mobile Broadband
EU	European Union

GA	Grant Agreement
GNB	Next Generation NodeB
GNSS	Global Navigation Satellite System
HPE	Hewlett Packard Enterprise
IOT	Internet of Things
IRU	Integrated Radio Unit
ISAC	Integrated Sensing and Communication
KPI	Key Performance Indicator
KVI	Key Value Indicator
LTE	Long-Term Evolution
MEC	Multi-access Edge Computing
MMWAVE	Millimeter Wave
NPN	Non-Public Network
NR	New Radio
NRF	Network Repository Function
NSA	Non-Standalone
NSSF	Network Slice Selection Function
OAI	OpenAirInterface
OBU	Onboard Unit
ORAN	Open Radio Access Network
PCF	Policy Control Function
PPDR	Public Protection and Disaster Relief
QOD	Quality on Demand
RAN	Radio Access Network
REC	Renewable Energy Community
RSU	Roadside Unit

RTK	Real-Time Kinematic
SA	Standalone
SDR	Software Defined Radio
SMF	Session Management Function
SNS JU	Smart Networks and Services Joint Undertaking
TN	Transport Network
UC	Use Case
UDM	Unified Data Management
UDR	Unified Data Repository
UE	User Equipment
UPF	User Plane Function
URLLC	Ultra-Reliable Low-Latency Communications
VM	Virtual Machine
VPN	Virtual Private Network
VRAN	Virtualized Radio Access Network
WP	Work Package
ZSM	Zero-touch Service Management

1 Introduction

This deliverable is the first report on WP7 activities, covering the period from M7 until M18. This WP is a converging point for other technical WPs, i.e., WP3-WP6, which focus on 6G technological enablers and their impact on vertical services (WP3), and specific vertical clusters: health and public safety (WP4), energy (WP5), and transport (WP6). As such, WP7 is overseeing all trial planning and execution activities, which are in detail reported in deliverables D4.1, D5.1, and D6.1, and providing guidance on those activities, while capturing the cross-use case trial analysis. In particular, WP7 is organized in three tasks; the work on T7.1 Trials planning is the one that this deliverable covers the most, as it started from the beginning of WP7, while T7.2 started as of 2026 and is reporting some preliminary pre-trial activities that will be captured in this deliverable. Finally, T7.3 has just been officially kicked-off, and it is focused on trials result analysis. The majority of work performed in T7.2 and T7.3 will be reported in the final deliverable, i.e., the D7.2.

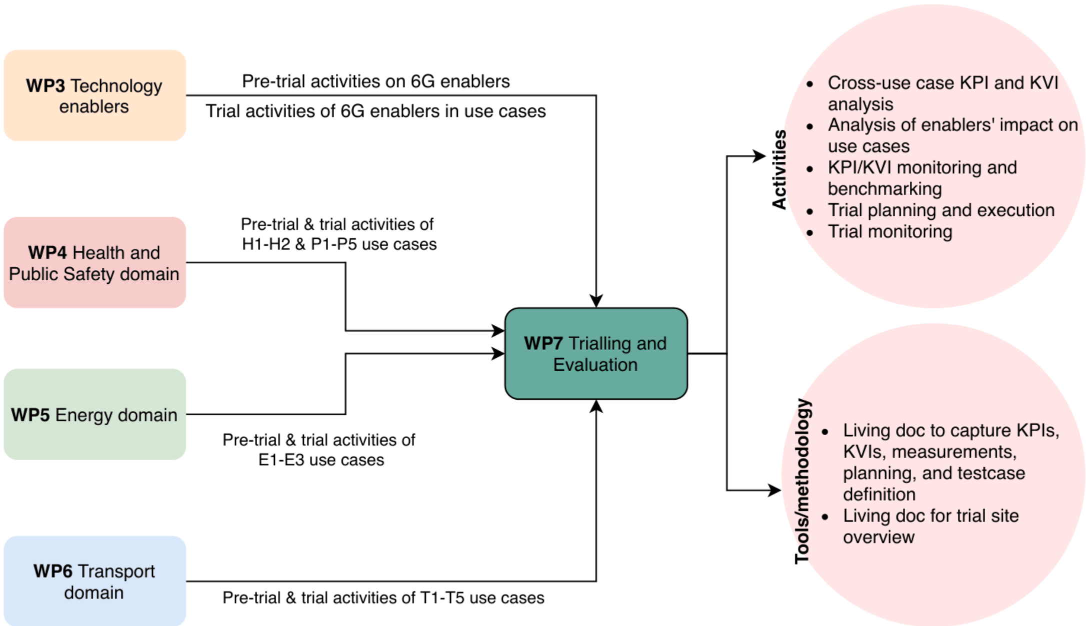

Figure 1-1 WP7 positioning and scope with reference to other AMAZING-6G WPs.

As the main objective of WP7 is to manage trials, which spans trial planning and monitoring, as well as post-trial analysis of collected data, this deliverable provides: i) overview of trial sites and their capabilities, ii) cross-analysis of Key Performance Indicators (KPIs) and Key Value Indicators (KVIs) for different use cases and vertical clusters, and iii) overview of trial planning, including snapshots of preliminary results obtained during the pre-trial phase. The trialing activities are executed in two phases: i) **pre-trial phase** that takes place at various trial and pre-trial sites (partners' testbeds used as complementary setup to project trial sites), performing preliminary trial activities and testing either 6G enablers' capabilities, or a subset of use case functionalities, and ii) **full trial phase** that is conducting full-scale testing of use cases and their integration with the technological enablers. Therefore, this deliverable delves into the trial methodology framework, overviewing progress with pre-trial activities and planning of full trial activities.

Section 2 delves into the trial site capabilities, looking into the 5G/6G architecture, spectrum bands, Radio Access Network (RAN) specifications (number of base stations, vendors, and coverage area), Core Network (CN) specifications (type of CN deployment, vendors, User Plane

Function (UPF) location, and Network exposure capabilities), presence of edge computing, Transport Network (TN) type, and devices and user equipment (number of users in trialing activities, types of users, type of their hardware). This overview of trial sites will provide better context for KPI and KVI analysis, and measurements, especially in a subsequent deliverable, when we present all obtained results.

Further, Section 3 and Section 4 dive into the KPI and KVI presentations, providing harmonized lists of AMAZING-6G KPIs and KVIs, respectively. These Sections present a cross-analysis of KPIs and KVIs for all use cases/vertical clusters in AMAZING-6G, while more detailed use-case-oriented KPIs/KVIs are reported in D4.1, D5.1, and D6.1. Section 5 provides insights into pre-trial and full trial activities across all trial sites and use cases, capturing also preliminary measurements of some KPIs and their analysis, associated with the pre-trial activities. This section closes with the planning of the remaining pre-trial activities, and full trials that will take place during the last year of the project. Finally, Section 6 concludes the deliverable and summarizes the status of pre-trial activities and trial planning for the second half of the AMAZING-6G project.

2 Overview of trial sites

This section delves into the overview of the AMAZING-6G trial sites, stemming from the seven main trial sites such as Italian, Romanian, Dutch, Dutch/Norwegian, Finnish, Greek, and German, to the five additional (pre)trial sites used for pre-trialing activities. These trial sites consist of network infrastructure based on 5G with additional advanced 5G and 6G technologies, as well as vertical infrastructure combining edge computing nodes, User Equipment (UE), Internet of Things (IoT) devices, and other vertical-specific infrastructure and equipment.

In Table 2-1, we list the general information about the trial sites, alongside the IDs that will be used throughout the document. For the sake of completeness and better understanding of acronyms and terminology in D7.1, we list the Use Cases (UCs) and their classification to vertical clusters in Table 2-2.

Table 2-1 Overview of trial sites and mapping with UCs and technology enablers.

Trial site ID	Trial site name	Pre-trial/Trial	Use cases	Technology enablers
IT_1	Italian	Pre-trial and Trial	T1, T2	QoD, Edge Cloud, network slicing, compute-as-a-service, IoT sensors, IoT localization
RO_1	Romanian	Pre-trial and Trial	E1, E3, P5	Communication: ZSM, network performance monitoring, network slicing (eMBB + URLLC) Compute-as-a-Service: intelligent orchestration, intent-based management, cloud-native design IoT: data ingestion/telemetry, monitoring platform, IoT sensor orchestration
NL_1	Dutch	Pre-trial and Trial	E2	Communication: Network slicing (dedicated slice for drone traffic, separate slice for background); Public-private network integration (DNN-based UPF separation) Compute-as-a-Service: Distributed user-edge-cloud compute continuum; Multi-party cloud AI/Application: CAMARA APIs for Quality on Demand; CAMARA APIs for Edge/Cloud IoT & Localization: Hybrid localization (5G + GNSS); GNSS/RTK positioning (u-box EVK-X20P, cm-level accuracy) Note: NTN integration identified as future enabler but not implemented in current pilot
NLNO_1	Dutch/Norwegian	Pre-trial and Trial	H1, H2	Communication: Network slicing (dedicated slice for H1/H2 client, separate slice for background), Wi-Fi (as an alternative access to 5G) Compute-as-a-Service: Distributed user-edge-cloud compute continuum; Multi-party cloud

				AI/Application: CAMARA APIs for Quality on Demand; CAMARA APIs for Edge/Cloud
FI_1	Finnish	Pre-trial and Trial	P4	Communication resource management
FI_2	Finnish	Pre-trial and Trial	P2, P3	Network performance monitoring and control CAMARA APIs Quality on Demand and Energy management Network slicing
GR_1	Greece Patras 5G	Pre-trial and Trial	P1	Automated gNB Configuration. Network Performance Monitoring and Control. Identification and Selection of Backhauling. Intelligent service and resource orchestration in extreme edge/edge/cloud compute continuum Creation of Kubernetes clusters on demand AI-as-a-Service framework OpenAPIs for Network Exposure TM Forum APIs- P1
GR_2	Greece Patras 5G (pre-trial)	Pre-trial	P1	Same as GR_1
GR_3	Greece WINGS Private 5G testbed	Pre-trial	P1, T5	AI-as-a-Service enabler IoT connectivity enablers, APIs and infrastructure IoT sensors and devices IoT platforms and management enablers
GR_4	Greek (Port of Thessaloniki)	Pre-trial and Trial	T5	Communication: ZSM, Identification and selection of backhauling, Automated gNB configuration
DE_1	German	Pre-trial and Trial	T3	Integrated Sensing and Communication (ISAC), AI/ML-based object detection Data Ingestion and Telemetry - Data Collection from sensors and devices
DE_2	German	Pre-trial and Trial	T3	Communication: Network programmability, Network performance monitoring and control, Network slicing. CaaS: Cloud-native service design, Energy efficient compute management
DE_3	German	Pre-trial and Trial	T4	IoT Contextual Awareness Systems
BE_1	Imec NextG-Lab testbed	Pre-trial	T4	Network Programmability Network slicing

BE_2	Imec Smart Highway testbed	Pre-trial	T4	Communication resource management - Zero-touch network and service management Communication resource management - Network performance monitoring and control
PL_1	Polish	Pre-trial	T3	Communication: Network programmability, Network performance monitoring and control, Network slicing. CaaS: Cloud-native service design, Energy efficient compute management

Table 2-2 AMAZING-6G use cases and vertical clusters.

UC acronym	Use case name	Vertical cluster	WP
H1	Wearable ultrasound patch for cardiac function monitoring	Health	WP4
H2	Event-aware real-time reprogramming of pacemaker through wearable patch	Health	WP4
P1	Ubiquitous B5G/6G communication and slice deployment across operators for PPDR AR/VR assisted Control Centres	Public safety	WP4
P2	Mission critical services interoperability with other systems	Public safety	WP4
P3	Emergency private 5G/6G communication on-the-Move	Public safety	WP4
P4	Arctic Area Search and Rescue Operation	Public safety	WP4
P5	Emergency private 5G/6G communication on-the-move	Public safety	WP4
E1	Renewable Energy Communities	Energy	WP5
E2	Robotized offshore wind turbine blade inspection and maintenance	Energy	WP5
E3	Solar energy monitoring, control and predictions using B5G/6G communications and edge-cloud	Energy	WP5

T1	Protection of Vulnerable Road Users	Transport	W P6
T2	Enhancing Urban Security with UGV Monitoring	Transport	W P6
T3	Wireless Signaling on Rail Tracks	Transport	W P6
T4	Tele-operation as a back-up to autonomous driving	Transport	W P6
T5	Port logistics and transport operations optimization and safety	Transport	W P6

To showcase the geographical distribution of the AMAZING-6G trial and pre-trial sites, Figure 2-1 provides both the geographical view and the classification of sites into trial and pre-trial ones. All sites participating in the experimentation activities are highlighted with distinct colors and mapped to the origin countries, while the corresponding trial site IDs (listed in Table 2-1) are displayed directly on the map to facilitate identification of the different deployment locations.

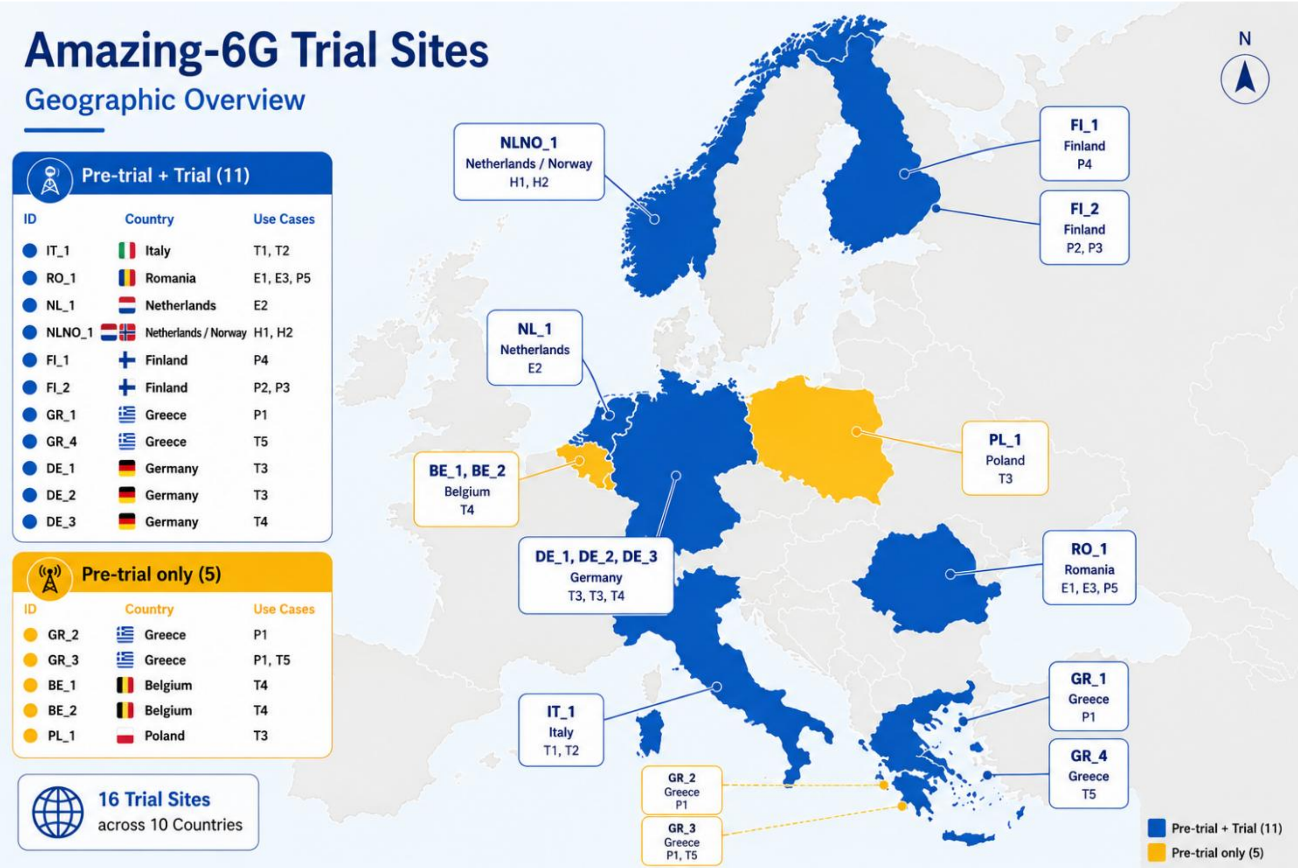

Figure 2-1 Map of pre-trial and trial sites in AMAZING-6G.

This figure highlights the broad European coverage of the project, spanning Northern, Central, Southern, and Eastern Europe. In particular, the map highlights the presence of multiple experimental environments in countries such as Germany, Finland, Greece, the Netherlands, and Belgium, reflecting the diversity of infrastructures, deployment conditions, and vertical use cases targeted within AMAZING-6G. The involvement of the NLNO_1 in both the Netherlands and Norway emphasizes the cross-country trial cooperation and distributed nature of certain experimentation facilities.

Now that the general information about the trial sites is provided, we can dive deeper into the specific implementations of radio, core, transport and edge networks within different trial sites, focusing on diverse Beyond 5G/6G capabilities, stemming across network, compute, Artificial Intelligence (AI), and Internet of Things (IoT).

2.1 Network infrastructure overview

This section provides more details about the general network infrastructure at different trial sites in AMAZING-6G. In particular, Table 2-3 shows a comprehensive overview of the network infrastructure configurations across the AMAZING-6G trial sites, highlighting the diversity in network deployment types, architectural maturity, and spectrum usage.

Table 2-3 Network infrastructure overview of trial sites.

Site ID	Network deployment type	Architecture	Spectrum bands and bandwidth
IT_1	Hybrid public-private deployment	5G SA, Rel. 16	Private network - n258, 200 MHz; Public network - n78, 80 MHz;
RO_1	Private 5G / Hybrid (Private + public APN)	5G SA, Rel. 15/16/17	n78 (3.5 GHz), 100 MHz
NL_1	Private 5G (lab setup replicating offshore private/public network scenario)	5G SA, Rel. 17/18	n77 (3.7 GHz), 50 MHz
NLNO_1	Public network	5G SA, Rel. 16/17	n78 (3.5 GHz), NA
FI_1	Private 5G	5G SA (NSA possible)	n78 (LTE band 3, B3 possible), 100 MHz
FI_2	Private 5G	5G SA, NSA also present	n77 (3.8 GHz), 100 MHz; n78 (3.5 GHz), 60 MHz
GR_1	Portable Private 5G	5G SA, Rel. 15/16	n77 (3.8 GHz), 100 MHz; n78 (3.5 GHz), 100 MHz

GR_2	Private 5G	5G SA, Rel. 15/16	n77 (3.8 GHz), 100 MHz; n78 (3.5 GHz), 100 MHz
GR_3	Private 5G, Non-public network (NPN)	5G SA, Rel. 16/17	n78 (3.75GHz), 100 MHz
GR_4	Private 5G, Non-public network (NPN)	5G NSA, Rel. 16	n78 (3.5 GHz), 100 MHz
DE_1	Private 5G, Non-public network (NPN)	5G SA	n78, n257, n259, n261: 40 MHz, 100 MHz
DE_2	Private 5G, Non-public network (NPN)	5G SA	n78: 40 MHz, 100 MHz
DE_3	Private 5G, Non-public network (NPN)	5G SA	n78, 100 MHz
BE_1	Private 5G	5G SA, Rel. 19	n77 (3.7 GHz), 50 MHz
BE_2	Private 5G	N/A	n77, 50 MHz
PL_1	Private 5G	5G SA	n78, 40 MHz, 100 MHz

Concerning the network deployment type, the majority of sites (13 out of 16, Figure 2-2) rely on private or non-public 5G networks. This shows a strong presence of more controlled experimentation environments that enable flexible configuration, network slicing, and tight integration with edge and core resources. This is particularly important for large-scale trials as it brings more flexibility to test and validate advanced B5G/6G technologies and their impact on vertical service performance. Apart from the private network deployments, we also have two hybrid deployments, i.e., Italian and Romanian sites, which combine private and public networks. These hybrid setups are also valuable in support of the evaluation of interoperability and real-world integration scenarios. Finally, only one site, i.e., the Dutch/Norwegian one (NLNO_1), operates on public infrastructures, but it is a specific site that enables addressing cross-operator/cross-country integration activities in the context of health use cases (H1 and H2). The distribution shown in Figure 2-2 confirms that AMAZING-6G trial sites are predominantly based on private 5G networks, offering higher flexibility for performing large-scale trials.

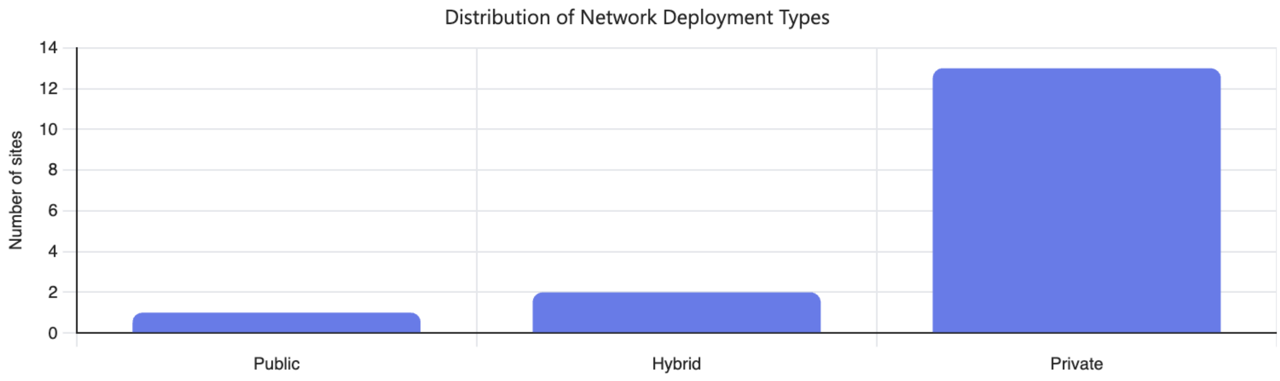

Figure 2-2 Distribution of Network Deployment Types.

From the architectural point of view, large majority of trial sites adopt a 5G Standalone (SA) configuration, which is essential for advanced network features such as low-latency communication enabled by network slicing, and end-to-end service orchestration. Only one trial site, i.e., the Greek site in the Port of Thessaloniki is based on 5G Non-Standalone (NSA), but deployed in Release 16, which brings latency improvements by advancing the 5G New Radio (NR) compared to previous releases. It is important to note that this particular trial site, although used in full trial activities, is extended with pre-trial sites (such as GR_3), for the purpose of testing and validating more advanced network features associated with SA deployments (e.g., network slicing, network orchestration). Another site with no SA deployment is the BE_1 site, which is only used for pre-trial activities with technological enablers such as Zero-touch Network and Service Management, and advanced service orchestration solutions, solely focusing on the distributed edge compute infrastructure. Those pre-trialed enablers will be fully tested in SA environments, such as DE_3 in the case of BE_1 site (trialing of T4 use case).

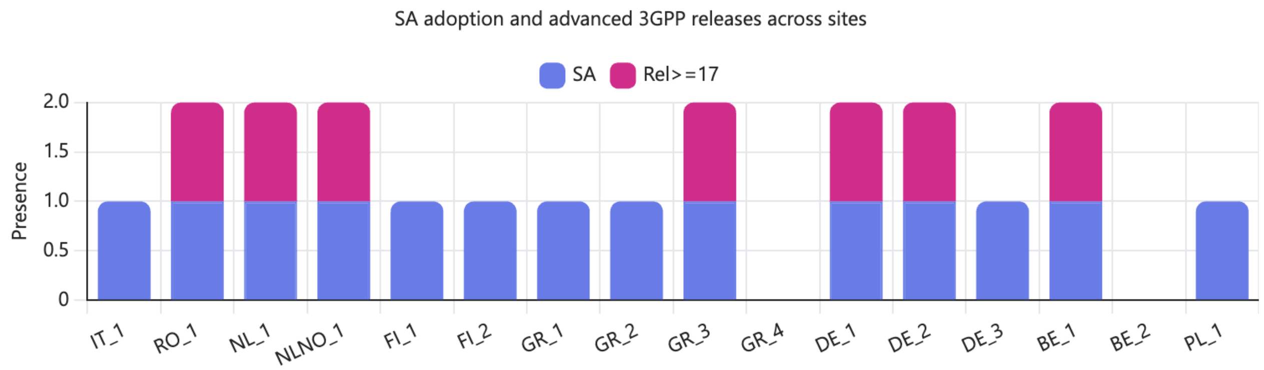

Figure 2-3 Presence of 5G SA and advanced 3GPP releases across trial sites.

Nevertheless, although consistent in terms of 5G SA presence, there is a larger variation in supported 3GPP releases, ranging from Release 15 to more advanced versions such as Release 18 and beyond, as shown in Figure 2-3. Although this usually indicates different levels of technological maturity, it is worth highlighting that, despite the absence of more advanced releases, all trial sites are heavily involved in B5G/6G enablers' development and integration (as reported in D3.1 [1]), which enables use of more advanced network and compute capabilities in all trials. These technological enablers are transforming current 5G-based trial sites into the true 6G network ecosystems.

In terms of spectrum, the deployments are largely focalized around mid-band frequencies (notably bands n77 and n78), ensuring a balance between coverage and capacity across sites.

Also, a large majority of trial sites offers higher bandwidth allocations, often around 100 MHz or more, which is essential for performance-intensive use cases. Some of the sites, such as Italian (IT_1 and German (DE_1), additionally incorporate higher-frequency bands (mmWave) or multi-band configurations (6 out of 16 sites) to support enhanced throughput and specialized trials. In summary, Table 2-3 and Figure 2-4 provide the foundational technological landscape of the project, showing a convergence toward private 5G SA mid-band deployments complemented by heterogeneous spectrum capacities and deployment strategies, which collectively shape the experimental capabilities and performance potential of the different trial environments.

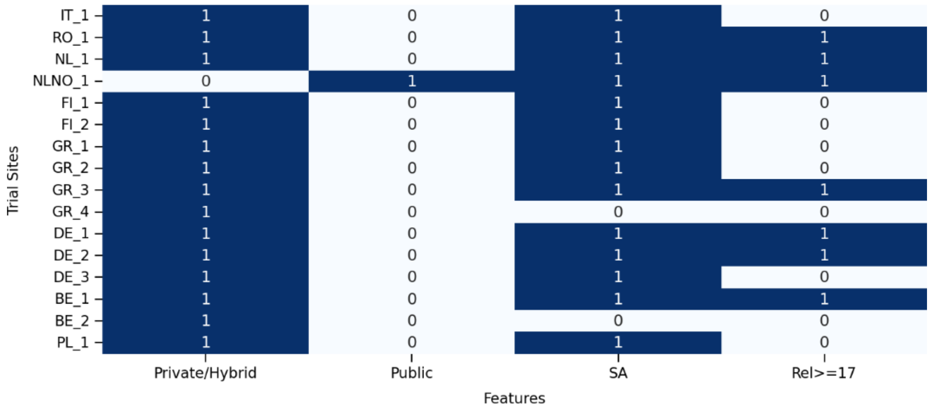

Figure 2-4 Heatmap of network deployment types across trial sites.

2.2 Radio Access Network (RAN) capabilities

This section provides a detailed overview of the Radio Access Network (RAN) configurations across the AMAZING-6G trial sites, focusing on vendor information, deployment scale, architectural approaches, and coverage characteristics.

Table 2-4 RAN capabilities in the trial sites.

Site ID	RAN vendor	Number of gNBs	RAN architecture	Coverage area
IT_1	Private network: Bellantenna; Public network: TIM	Private network: 1 gNB Public network: 1 gNB	Private network: vRAN Public network: Traditional	200m2 outside PoliTO
RO_1	Ericsson	Multiple (indoor BBU+IRU+DOTs, outdoor BBU+AAU)	Traditional RAN (Ericsson-based); indoor + outdoor units	Bucharest 5G Lab – indoor and outdoor campus coverage; 99.7% commercial coverage in Romania
NL_1	Amarisoft (AMARI Callbox Classic)	1 gNB (Amarisoft Callbox at Zephyros lab, Vlissingen)	Traditional RAN (Amarisoft Callbox – all-in-one gNB + core unit)	Zephyros Fieldlab outdoor area, Vlissingen – covers wind turbine blade test area

NLNO_1	USRP B210 (Open Air Interface)	1 gNB	Traditional RAN (OpenAir Interface)	indoors
FI_1	Nokia	2 gNBs	Traditional RAN (Nokia-based)	Sod5g-test track
FI_2	Nokia Accelleran ORAN	1 outdoor 2 indoor	Traditional and ORAN	Oulu 5G test network – indoor and outdoor campus coverage
GR_1	Ericsson, Amarisoft	6 indoors (pre-trial), 2 outdoor (trial)	Both Traditional and ORAN /Traditional for Trials	400m radius around University of Patras cell
GR_2	Ericsson, Amarisoft	6 indoors (pre-trial) and Amarisoft	Both Traditional and ORAN /Traditional for Trials	Indoors
GR_3	ASKEY	2 outdoor (pre-trial)	Traditional RAN (Ericsson-based); indoor + outdoor units	400m radius
GR_4	Ericsson	3 small cells (DOT)	Traditional RAN (Ericsson-based); indoor units	3 different floors in WINGS premises (~900 m2)
DE_1	Benetel	1	RAN server (gNB) , Traditional RAN (OpenAir Interface)	Indoors, Outdoors
DE_2	Benetel, IS-Wireless Liquid RAN	1	ORAN, cloud RAN	Outdoors
DE_3	Benetel	1	Traditional RAN	Outdoors
BE_1	SDR N310 + imec gNB	3	ORAN	Indoors, Outdoors
BE_2	Open Air Interface	1 at Campus 3 at E313 Range at most 100m	ORAN	80-100m range for each gNodeB
PL_1	Benetel, IS-Wireless Liquid RAN	2	ORAN, cloud RAN	indoors

We start with the information about RAN vendors and architectural types in Table 2-4. The table shows that the majority of trial sites adopt traditional RAN deployments based on established vendors such as Ericsson, Nokia, and Amarisoft. This ensures alignment with typical commercial deployments, and applicability and scaling of trial practices and results to those environments. At the same time, a subset of sites incorporates Open Radio Access Network (ORAN) or hybrid architectures mainly for pre-trial activities, reflecting an ongoing transition toward more flexible and programmable RAN solutions. The trial phase is intended to use mainly traditional centralized RAN solutions. This coexistence of ORAN and traditional RAN indicates that ORAN is being introduced selectively in environments where experimentation demands more flexibility in the RAN deployment, including disaggregation, virtualization, and cloud integration (e.g., pre-trial activities with dynamic end-to-end network slicing), while traditional

RAN continues to support robustness, mimicking realistic commercial setups in the EU landscape.

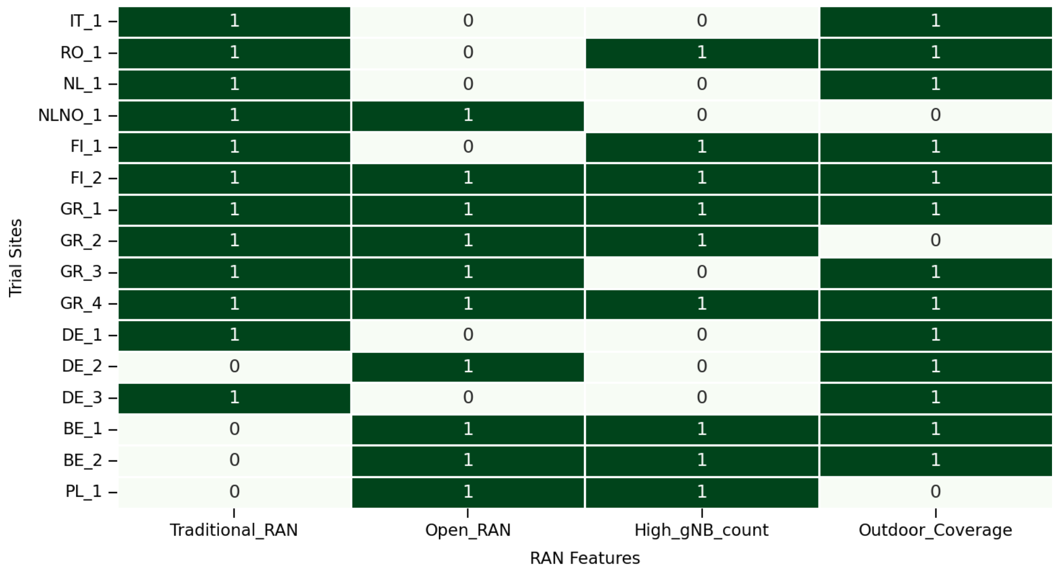

Figure 2-5 Heatmap with RAN capabilities.

The number of deployed gNBs varies across sites, which is in line with the nature of use cases that are being trialed. The single base station setups are typical for sites that are used for trialing use cases with lower mobility (e.g., health use cases) or those that will be deployed in more confined areas due to restrictions in regulations (e.g., transport use cases involving teleoperation). Those sites are used for more focused feature testing. On the other hand, the multi-cell deployments enable indoor-outdoor coverage and support more realistic operational conditions, which is essential for high-mobility use cases such as transport and public safety ones. Those sites are generally designed for broader experimentation scenarios, including mobility, handover, and large-scale service validation. Finally, the coverage characteristics further differentiate the trial sites, with some of them operating exclusively in indoor settings for controlled experimentation, while others providing outdoor or campus-level coverage to support more mobility, particularly in transport and public safety domains, and more cooperation between units within the Renewable Energy Communities (RECs) from the energy domain.

In a nutshell, Table 2-4 highlights a heterogeneous but structured RAN landscape, where traditional architectures serve as the backbone of most deployments, complemented by selective adoption of ORAN and varying deployment scales. This reflects a layered approach to experimentation, balancing stability with flexibility and enabling both controlled validation and large-scale trial scenarios. In Figure 2-5, we visualize the RAN capabilities among sites, to streamline the correlation between the number of gNBs and coverage, for instance, or identification of hybrid setups with both traditional and ORAN deployments. We can see that some sites support both Traditional and ORAN deployments, whereas Traditional is mainly used for full trial and ORAN for pre-trial activities and focused testing and validation of 6G technological enablers where architectural flexibility and openness are essential. Also, it is interesting to note that all trial sites have outdoor coverage, except for NLNO_1 site, which is used for the indoor-focused health use cases. The other two sites with only indoor coverage (GR_2 and PL_1) are primarily used for pre-trial activities with 6G technological enablers.

While Table 2-3 showcases consistent adoption of private 5G SA networks, Table 2-4 reveals a more diverse pool of RAN deployments, where traditional architectures are complemented by selective adoption of ORAN and varying deployment scales. This combination reflects a diverse and vertical-centric trialing approach, balancing stability with flexibility for advanced 6G trials across four distinct vertical sectors (health, public safety, energy, and transport).

2.3 Core Network (CN) and Transport Network (TN) capabilities

To cover the end-to-end perspective of 5G/B5G systems in AMAZING-6G trial sites, we now continue with the 5G Core and Transport network capabilities. In particular, Table 2-5 presents a quick overview of the Core Network (CN) and Transport Network (TN) specifications, highlighting differences in CN deployment types, architectural styles, User Plane Function (UPF) placement location, and underlying transport technologies.

Table 2-5 CN and TN capabilities in the trial sites.

Site ID	Core deployment	Core vendor	UPF location	Transport type
IT_1	On-premises	HPE	Edge	Fiber
RO_1	On-premises (virtualized cloud in Bucharest 5G Lab datacenter)	ORO & Nokia (5GC stack – AMF, SMF, UPF, AUSF, UDM, PCF, APC, CMM)	Local breakout / edge (UPF in Bucharest Lab + distributed edge nodes)	Fiber (backbone Bucharest–Orange DC); Private APN for campus connectivity
NL_1	Central cloud / on-premises split: control plane at TNO lab (The Hague); UPF also deployed locally at Vlissingen	Open5GS (open-source 5GC: AMF, SMF, AUSF, NRF, UPF)	Dual UPF: (1) local breakout at Zephyros lab (Vlissingen) for drone URLLC slice; (2) centralized UPF at TNO (The Hague) for background traffic	VPN over internet (site-to-site between Vlissingen and The Hague); standard IP backhaul
NLNO_1	Central cloud + Edge cloud (both deployed at the TNO lab (The Hague)	Open5GS (commercial version for AMF, SMF, UPF, PCF, UDM, UDR, NRF, NSSF, BSF, AUSF) + TNO Open5GS modifications (e.g., NEF, PCF, AMF, SMF) + TNO AF (that	UPF is deployed at a separate VM in the cloud. That second VM is representing the edge. 5GC control plane is deployed in a different VM, representing the central cloud.	Fiber/CAT cables

		exposes NEF via CAMARA APIs)		
FI_1	On-premises or in Oulu	Open5GS on premises	Local breakout, or Oulu.	Fiber
FI_2	On-premises	Open5GS	Centralized	Fiber
GR_1	On-premises, edge, and cloud	ERICSSON/Open5GS	Kubernetes deployment	Various
GR_2	On-premises, edge, and cloud	ERICSSON /Open5GS/Amarisoft	Kubernetes deployment	Various
GR_3	On-premises	Druid	Edge	Various
GR_4	Core provided via mobile operator (OTE)	Core provided via mobile operator (OTE)	UPF provided by operator	Fiber
DE_1	On-premises	Open5Gs , OpenAirInterface (OAI) 5G Core Network	Centralized	Various
DE_2	On-premises	Open5GS	Edge	Various
DE_3	On-premises	Open5GS	Centralized	Various
BE_1	Edge cloud	Open5GS, OAI	Edge and centralized	Fiber
BE_2	On-premises	N/A	Edge and centralized	Local switch inside each gNodeB 100MBps - 1GBps wired uplink
PL_1	On-premises	Open5GS	Edge	Various

The Table 2-5 shows that CN is primarily deployed on-premises in majority of trial sites, where the core is placed locally using virtualized or cloud-native environments. This reflects the need for full control, flexibility, and tight integration with edge computing resources, which are essential for experimentation with advanced 6G functionalities. In parallel, a number of sites adopt distributed or hybrid core architectures, where control and user plane functions are split between centralized cloud environments and local edge nodes, enabling a balance between scalability and low-latency.

Although pursuing decentralized 5G CN models, not all sites have consistent UPF deployment at edge network locations, which is one of the key differentiators across the sites. Many of the trial sites deploy UPF at edge, which enables traffic to be processed closer to the end user, thereby directly reducing end-to-end latency. Nevertheless, some trial sites, such as FI_2, GR_4, DE_1, and DE_3, maintain centralized UPF deployments or combine both approaches through distributed setups, enabling flexible traffic steering and differentiated service management. This diversity highlights the support for a wide range of use cases, from real-time mission-critical services (e.g., public safety, transport) to data-intensive analytics (e.g., healthcare, energy). Regarding transport infrastructure, Table 2-5 indicates the dominance of fiber, which is essential for providing high bandwidth and low latency between RAN, core, and edge network segments. In some distributed setups, additional transport mechanisms such as IP-based connections or VPNs are used to interconnect geographically separated sites and extend the scope of specific sites to enable more flexibility in experimentation.

As we can see from Table 2-5, the AMAZING-6G trial portfolio demonstrates a quite structured 5G CN and TN outlook. The on-premises and edge-enabled deployments form the baseline, and are complemented by distributed architectures and flexible UPF placement. This combination enables the trial sites to support both more and less latency-critical services.

2.4 Edge Network availability and features

This sections provides a brief overview of edge compute infrastructure, which is available in different trial sites. Table 2-6 shows the presence of edge resources, the type of compute capabilities (CPU/GPU), and the deployment location.

Table 2-6 Edge capabilities in the trial sites.

Site ID	Edge computing availability	Compute resources	Edge location
IT_1	Yes	64 core CPU, NVIDIA L4 24GB, 960 GB	On-site
RO_1	Yes – edge computing at Bucharest 5G Lab; Orange national datacenter for cloud fallback	CPU + GPU; Prometheus/Grafana monitoring; containerized microservices (Docker/K8s)	On-site (Bucharest 5G Lab); telco edge (Orange DC)
NL_1	Yes – local edge node at Zephyros lab (Vlissingen) hosting local UPF and Digital Twin system	CPU-based edge server; Digital Twin (surrogate FEM model); containerized services	On-site (Zephyros Fieldlab, Vlissingen)
NLNO_1	Yes, edge node is located in The Hague.	CPU, GPU, Prometheus/Grafana monitoring; containerized microservices (Docker/K8s)	on-site (The Hague)
FI_1	"Yes" on the same switch as the radio.		on-site
FI_2	Yes	CPU + GPU	On-site (Oulu)
GR_1	Yes	CPU and 2xGPUs	On site

GR_ 2	Yes	CPU and 2xGPUs	On site
GR_ 3	Yes	WINGS compute resources currently comprises two powerful GPUs having two Intel Xeon Platinum 8462Y+ Processors each (60MB Cache 32 cores, 64 threads, 2.8 GHz to 4.1 GHz Turbo, 300W), a Memory of 256GB (8x32GB, DDR5, 4800MHz, RDIMM ECC), storage controllers of 2x Integrated Intel 4 port SATA controllers, storage configuration of Internal PCIe SSD (Dell Ultra-Speed Drive) and C11 Dell Ultra-Speed Drive Boot (M.2 PCIe NVMe SSD). Moreover, WINGS analyses the tests results through four (4) powerful workstations, having an Intel Core i9-13900H, vPro Enterprise (24MB Cache, 14 Cores, 20 Threads, 2.6 - 5.4 GHz Turbo, 45W) processor, NVIDIA RTX 2000 Ada/8GB GDDR6 Video Card, Memory of 32 GB (2x16GB, LPDDR5, 6000MT/s).	On site
GR_ 4	No	N/A	N/A
DE_ 1	Yes	CPU + GPU	
DE_ 2	No	N/A	N/A
DE_ 3	Yes		
BE_ 1	Yes	128 GB RAM, 1 TB NVME, Nvidia RTX 400 20 GB VRAM, 10GigaE network card, Intel Xeon CPU 14C/28T @ 3.3 – 4.8GHz	on-site and Nearby
BE_ 2	Yes	Single VM/Container server at each gNodeB. In total: 1x Xeon 4309Y 16C/32@2.8GHz CPU, 64GB RAM, 1TB SSD, NVidia RTX A4000 16 GB VRAM GPU 3x Xeon E5-2620v4 16C/32C@2.1GHz CPU, 32 GB RAM, 1 TB SSD, no GPU	On-site
PL_ 1	N/A	N/A	N/A

The Table 2-6 shows that edge computing is adopted as a compute design choice in the majority of trial sites, which highlights the importance of enabling low-latency and data-intensive services across diverse vertical sectors. As the edge location indicates, most of the trial sites deploy edge nodes on-site or in close proximity to the radio and core infrastructure, which enables efficient processing of user data and tight coupling with network functions. A key difference among sites is associated with the type of edge compute resources, particularly GPU availability. Several trial sites, such as IT_1, RO_1, GR_1, GR_4, and BE_2, incorporate GPU-enabled edge platforms, enabling support for computationally demanding applications such as AI inference, digital twins, and real-time analytics. In contrast, some sites rely primarily on CPU-based edge resources, which is sufficient for vertical services exhibiting low-latency criticality but with lower computation workloads. This variation highlights the difference in levels of computational intensity across AMAZING-6G use cases. Finally, Table 2-6 also indicates a strong adoption of cloud-native and containerized compute environments, mainly based on Docker and Kubernetes (K8s), which is essential for dynamic service deployments, orchestration, and scalability for all vertical services consuming AMAZING-6G enablers.

As it can be seen from the table and analysis, edge computing can be considered as a core architectural pillar in AMAZING-6G, as all use cases will be, to some extent, trialed in environments with edge computing capabilities. This is true due to the fact that the lack of edge resources in trial sites (e.g., GR_4 or DE_2) is compensated with edge capabilities in pre-trial sites where specific focused experimentation (subset of use case components, focus on technological enablers, etc.) is being performed (in particular, GR_3 and DE_1).

2.5 Devices and User Equipment

Finally, we close this section with the analysis of devices and User Equipment (UE) in AMAZING -6G trials. In particular, Table 2-7 provides an interesting overview of diverse devices and UEs, capturing the device types, number of devices/UEs, and the presence of specialized hardware required to support different use cases.

Table 2-7 Devices and UE types in the trial sites.

Site ID	Type of UEs	Number of UEs	Specialized hardware
IT_1	Smartphones, Autonomous Mobile Robot (OBU), vehicles (OBU), Road Side Unit	4-6	OBU, RSU
RO_1	Industrial IoT devices, sensors, 5G modules (RedCap and NR), solar inverters, gateways	~10–20 devices/sensors per use case (lab phase); scalable for field trials	Quectel RM500Q-GL (5G NR module, 2x); Industrial power meters (2x); Industrial temp sensors (4x); Air quality sensors (4x); Fimer PVS-50 solar inverter (1x); Meteocontrol Si-I-420-T irradiance sensor (1x); OrangePi 4A edge gateway (1x)
NL_1	UAV/drone (5G-connected); GNSS/RTK positioning modules	2 UEs (2x Quectel RM500Q-GL modems on drone + DJI Matrice 4T); 2 GNSS/RTK modules	Drone DJI Matrice 4T UAV (1x) and DJI Matrice M600 UAV (1x); Quectel RM500Q-GL 5G modem (2x); u-blox EVK-X20P GNSS/RTK module (2x); Sonatest rolling ultrasound sensor (scan speed 40–60 mm/s, width 85 mm, up to 110 mm depth)
NLNO_1	Quectel RedCap modem	1 UE (Quectel RG255C Redcap modem)	NI USRP B210 as RU; Intel NUC (i7) to run OAI; Quectel RG255C as Redcap modem
FI_1	Computers with telewell 5G modem	4	N/A

FI_2	Smartphones, Vehicle	2	N/A
GR_1	All	4 UEs (smart phones) several body cameras, and a variety of other sensing (cameras, etc.) UMV	N/A
GR_2	All	4 UEs (smart phones) several body cameras, and a variety of other sensing (cameras, etc.) UMV	N/A
GR_3	Smartphones, Industrial devices	N/A	modems
GR_4	Smartphones, Industrial devices, Sensors, Cameras, Robots, AGV, UAV	2+	Gateways
DE_1	Smartphones	2	LCX cables, Microamp CPE, FR2 radio units, 5G CN, RAN server, R&S®TSMA, Signal and spectrum analyzer
DE_2	Smartphones	2	Benetel650 RU, RAN servers, GNSS antenna, GPS antenna for Benetel;
DE_3	Automated vehicle	1	Automated vehicle (Smart camera, 360 camera view, Automotive Radar, LiDAR, CAN Gateway, IMU, GNSS, Real-time prototyping system, car PC, Sensors on steering wheel and pedals)
BE_1	Commercial-off-the-shelf (COTS)	5	SDR N310, Quectel RM500Q-GL
BE_2	Quectel RM5(2/0)0 Modems, Smartphones	N/A	USRP N310 SDRs used as RU
PL_1	Smartphones	2	Benetel650 RU, RAN servers, GNSS antenna, GPS antenna for Benetel;

As Table 2-7 shows, there is a wide spectrum of UE types, which is expected given the high number of use cases stretching over four vertical domains. The UE types are ranging from conventional smartphones to highly specialized devices such as industrial sensors, drones, vehicles, and robots. As said, this diversity is in line with the multi-vertical nature of the project and the need to support heterogeneous communication and computation requirements across health, public safety, energy, and transport domains. In particular, this diversity is even more pronounced in some trial sites, such as IT_1, GR_1, GR_2, and GR_4, including smartphones, sensing devices, cameras, vehicles, and autonomous platforms, thereby enabling complex, multi-device interaction scenarios. This is typical for transport use cases, involving mobility and thus need for increasing situational awareness around users, and creating digital twins. On the other hand, other sites deploy a more limited set of UEs, often focusing on specific device categories (e.g., smartphones or IoT sensors), which supports targeted experimentation and controlled validation of individual functionalities.

Concerning the specialized hardware, the trial sites offer industrial sensors, gateways, Global Navigation Satellite System (GNSS) positioning modules, modems, and Unmanned Aerial Vehicle (UAV) platforms, which are critical for enabling high-precision localization, environmental monitoring, and autonomous operation. Finally, the number of UEs is relatively low across sites, given the nature of AMAZING-6G use cases, but some sites such as RO_1 offer higher number of devices in total, which is important for data processing and sensing in energy and public safety scenarios.

2.6 Summary

The AMAZING-6G trial sites, both in pre-trial and full trial phases, are designed and deployed to enable tight integration between advanced B5G/6G technological enablers (WP3) and vertical services (WP4-WP6). Following the AMAZING-6G functional architecture defined in WP2 (D2.1 [2]), where different Functional Components (FCs) are defined to abstract the technological enablers and generalize their characteristics, it is important to note that different trial sites adopt different implementations of these FCs (compute, communication, AI, and IoT), depending on the site capabilities and use case scope. Thus, this section will be particularly helpful for understanding other deliverables where technological enablers (D3.1) and vertical clusters with use cases (D4.1, D5.1, and D6.1) are presented.

What we have learned from this section is that the AMAZING-6G trial site infrastructure follows a layered and complementary design, where a stable network and RAN baseline is combined with distributed core, edge-enabled processing, and heterogeneous device ecosystems, enabling both controlled experimentation and realistic large-scale 6G trial scenarios. In Table 2-8, we extract the main characteristics of trial and pre-trial sites per network segment, and network as a whole, where we see that Private 5G Standalone is a dominant network deployment, with traditional radio and some ORAN deployments that enable more flexibility and programmability in network design. The core networks are primarily deployed on the edge network side, with fiber-based transport, focusing on reducing end-to-end latency and improving throughput. The edge networks are de-facto standard for all trial sites, while UEs remain the most heterogenous segment of trial site ecosystem, with strong dependency on the type of vertical cluster and use case.

Table 2-8 Takeaways from the trial site analysis.

Network segment	Implementation trends in AMAZING-6G pre-trial and trial sites
End-to-end network	Private 5G Standalone
RAN	Traditional RAN with selective ORAN deployments
Core	Mainly deployed on edge, with a distributed UPF
Transport	Fiber
Edge	Omnipresent with some GPU-enabled sites
UE	Strong diversity

Finally, Figure 2-6 provides a snapshot of trial infrastructure available in AMAZING-6G, highlighting the vertical clusters that are present in different trial sites, where we can see that:

- ORAN mainly relevant for public safety and transport use cases, given their more stringent requirements for network slicing and network resource flexibility in general;
- Outdoor coverage present almost everywhere, except in health use cases which are focused on indoor patient support, and some transport pre-trial site that act as support to trial sites with outdoor coverage;
- Edge available everywhere: for transport and public safety relevant for mission-critical low-latency requirements, while for health and energy it is mainly used for localized processing of vast amount of sensitive data;
- Fiber de facto transport type in all trial sites, except DE_3;
- Low number of UEs planned in general, but will be compensated with long trial duration, diversity in network configurations, and high TRL for majority of use cases.

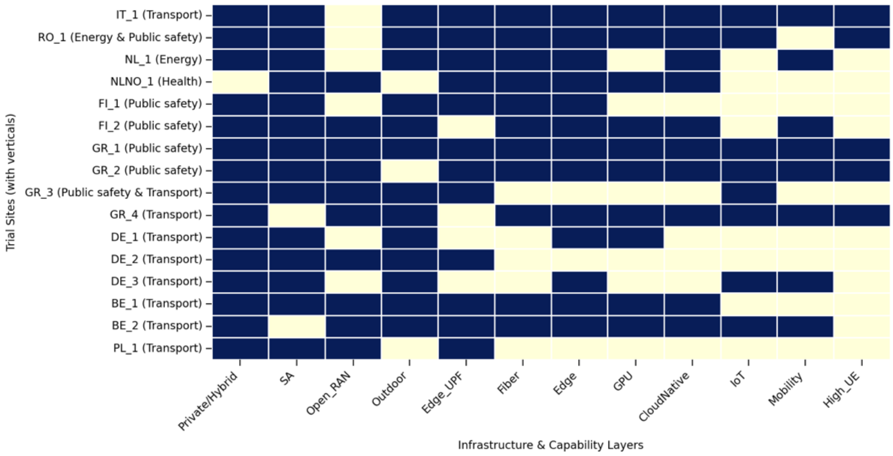

Figure 2-6 Summary of AMAZING-6G trials per vertical cluster.

3 Key Performance Indicators (KPIs)

In this section, we discuss a comprehensive list of 30 AMAZING-6G KPIs, stretching over 15 use cases, and including both vertical-specific (use-case specific) and vertical-agnostic KPIs (applicable to multiple use cases/verticals). We will first present a general view on the AMAZING-6G KPIs, and then dive deeper into the above-mentioned categories of KPIs, focusing on their target values and meta-analysis that includes KPI coverage score and KPI variability, as well as KPI stringency compared to other SNS JU projects.

3.1 Overview of AMAZING-6G KPIs

In Table 3-1, we present a cross-analysis of all KPIs defined within the project, spanning multiple vertical domains, i.e., health (H1-H2), public safety (P1-P5), energy (E1-E3), and transport (T1-T5), which are listed in Table 2-2.

Table 3-1 Full list of AMAZING-6G KPIs.

KPI Name	KPI Code	KPI Family	KPI Category
Service availability	KPI_VA_1	Reliability and Availability	Vertical-agnostic
Service reliability	KPI_VA_2	Reliability and Availability	Vertical-agnostic
End-to-end Network service latency	KPI_VA_3	Latency	Vertical-agnostic
One-way application latency	KPI_VA_4	Latency	Vertical-agnostic
Slice provisioning time	KPI_VA_5	Latency	Vertical-agnostic
Satellite Backhaul Latency (one-way latency)	KPI_VA_6	Latency	Vertical-agnostic
Multi-RAT handover latency	KPI_VA_7	Latency	Vertical-agnostic
Orchestration latency	KPI_VA_8	Latency	Vertical-agnostic
Application migration latency	KPI_VA_9	Latency	Vertical-agnostic
QoS restoration time	KPI_VA_10	Latency	Vertical-agnostic
User experienced data rate/Throughput – downlink	KPI_VA_11	Data rate and capacity	Vertical-agnostic
User experienced data rate/Throughput – uplink	KPI_VA_12	Data rate and capacity	Vertical-agnostic
Uplink data rate	KPI_VA_13	Data rate and capacity	Vertical-agnostic

Connection density	KPI_VA_14	Data rate and capacity	Vertical-agnostic
Internet throughput	KPI_VA_15	Data rate and capacity	Vertical-agnostic
Scalability	KPI_VA_16	Data rate and capacity	Vertical-agnostic
(Device) energy efficiency	KPI_VA_17	Energy efficiency	Vertical-agnostic
Average RSU power consumption	KPI_VS_1	Energy efficiency	Vertical-specific
Power consumption reduction vs Sub-6 GHz baseline	KPI_VA_18	Energy efficiency	Vertical-agnostic
Watt per Throughput	KPI_VA_19	Energy efficiency	Vertical-agnostic
Increase in battery life of RSU	KPI_VS_2	Energy efficiency	Vertical-specific
Increase in operational time of RSU	KPI_VS_3	Energy efficiency	Vertical-specific
Run time	KPI_VA_20	Compute	Vertical-agnostic
Coverage	KPI_VA_21	Coverage	Vertical-agnostic
Mobility	KPI_VA_22	Mobility	Vertical-agnostic
Positioning accuracy	KPI_VA_23	Positioning and Localization	Vertical-agnostic
Service area	KPI_VA_24	Other KPIs	Vertical-agnostic
Deployment time	KPI_VS_4	Other KPIs	Vertical-specific
PM10 Emissions	KPI_VS_5	Other KPIs	Vertical-specific
Dust emissions	KPI_VS_6	Other KPIs	Vertical-specific
Safety levels	KPI_VS_7	Other KPIs	Vertical-specific
Response time to emergencies and incidents	KPI_VS_8	Other KPIs	Vertical-specific

Average truck turnaround time	KPI_VS_9	Other KPIs	Vertical-specific
Average straddle carrier productivity	KPI_VS_10	Other KPIs	Vertical-specific
Average NCR (net crane rate)	KPI_VS_11	Other KPIs	Vertical-specific
Average container loading/unloading time	KPI_VS_12	Other KPIs	Vertical-specific
Average truck loading time	KPI_VS_13	Other KPIs	Vertical-specific
Average vessel waiting time at anchor	KPI_VS_14	Other KPIs	Vertical-specific
Average time of crane maintenance	KPI_VS_15	Other KPIs	Vertical-specific
Inference speed	KPI_VA_25	AI-related Capabilities	Vertical-agnostic
ML accuracy	KPI_VA_26	AI-related Capabilities	Vertical-agnostic
Time for detection of incident	KPI_VA_27	AI-related Capabilities	Vertical-agnostic
False positives rate	KPI_VA_28	AI-related Capabilities	Vertical-agnostic
Operational Continuity Index (OCI)	KPI_VA_29	Other KPIs	Vertical-agnostic
Boundary Logic Compliance Rate (BLCR)	KPI_VA_30	Other KPIs	Vertical-agnostic

The KPI methodology established in WP7 associates each KPI with a set of attributes, such as the KPI name, KPI code (so that each KPI can be uniformly referenced in all WPs), family (as per SNS JU guidance and definition), KPI definition(s), associated use cases, and target values. In this section, we only focus on the general information (KPI names, codes, family, and categorization to vertical-specific and vertical-agnostic), while specific definitions and target values are provided in Sections 3.2 and 3.3.

Concerning the definitions of KPIs, almost all KPIs have multiple definitions, reflecting the heterogeneity of metrics across use cases and different measurement methodologies they pursue. These definitions are differentiated into:

- Common (baseline) definitions, intended to reflect the project-level view on specific metrics, and
- Use-case-specific definitions, capturing the particularities of individual pre-trial and trial scenarios.

This approach enables the KPI framework to balance standardization and flexibility, allowing both consistent cross-vertical assessment (focus of WP7) and detailed use-case-specific evaluation (focus of WP4-6). Nevertheless, for the sake of readability, Table 3-2 only presents the common/baseline definition for each KPI, while the full list of all definitions is provided in Annex A.

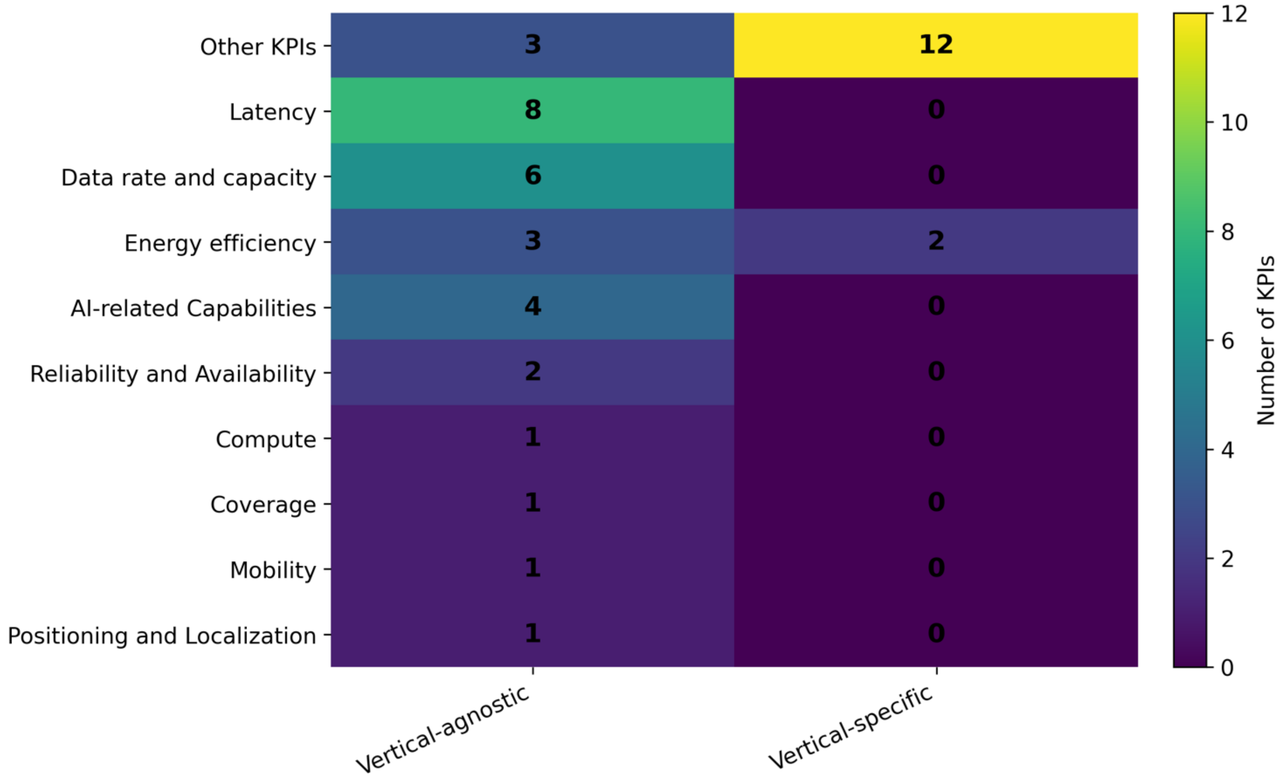

Figure 3-1 Overview of KPI families.

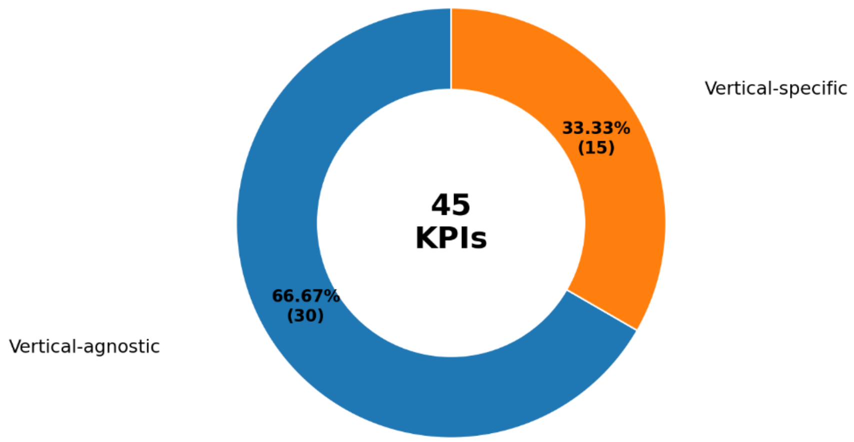

Figure 3-2 KPI distribution to vertical-agnostic and vertical-specific.

From an analytical perspective, the KPI list adopts a broad set of performance metrics, including latency, reliability, data rate, energy efficiency, compute, coverage, and AI-related capabilities. However, as it can be seen from the Table 3-1 and Figure 3-1, the KPI distribution sets a strong emphasis on latency and capacity-related metrics, highlighting their essential role in enabling advanced 6G services. This observation is quite common for majority of B5G/6G projects, such as SNS JU, given the presence of mission-critical/latency-sensitive and throughput-greedy applications across different vertical domains. Similarly, it can be observed that the majority of KPIs are categorized as vertical-agnostic (Figure 3-2), as they apply to multiple vertical domains and use cases at the same time, being uniformly relevant for evaluating the impact of network and compute services on diverse vertical operations and their large-scale adoption in 6G ecosystem. This classification/categorization will be further discussed in the following subsections.

3.2 Vertical-agnostic KPIs

As it can be seen from Table 3-1, vertical-agnostic KPIs represent the majority of the AMAZING-6G KPIs, creating a common foundation for performance evaluation across all four vertical domains. These KPIs are primarily addressing core network and service-level characteristics, including latency, throughput, service availability, reliability, coverage, and connectivity. Table 3-2 provides the full list of vertical-agnostic KPIs, along with their baseline definitions, as well as use case association.

From a structural perspective, vertical-agnostic KPIs span multiple layers of the system, including:

- **Network-level KPIs**: such as end-to-end latency, data rate, and connection density,
- **Service-level KPIs**: such as service availability, reliability, and slice provisioning time,
- **Application-related KPIs**: such as inference speed and AI/ML model accuracy.

Table 3-2 Definitions of vertical-agnostic KPIs and associated use cases[1].

KPI Name	Definition	UCs
Service availability	Percentage of time the service can be delivered (H1, H2, P2, P3, P4)	P1, P2, P3, P4, H1, H2, E1, E2, E3, T5
Service reliability	Period of time for which the service satisfies the required performance constraints (DL/UL throughput, end-to-end service latency, etc.) (H1, H2, T4)	H1, H2, T4, E1, E3, T5, T1, T2
End-to-end Network service latency	Time between the source node sends a data packet to when the destination node receives it (H1, H2, E2, T4: UE-edge, P2, P3)	H1, H2, E2, T4, P2, P3, P4, E3, E1, P5, T1, T2, T5, P1, T3
One-way application latency	Time it takes for a message or command to travel from the source application to the destination application (e.g., SB-EMS app to actuator), including any processing at edge or cloud (Layers: Application, Edge, Cloud; Segments: App → Edge → App) (E1)	E1, T1, T2, P5
Slice provisioning time	The time elapsed between a vertical request and an active slice ready to carry traffic (T4)	P1, T4
Satellite Backhaul Latency (one-way latency)	One-way latency introduced by the satellite backhaul segment, measured as the time for a packet to traverse the satellite link between the local edge/core and the remote macro network (Local Core/Edge ↔ Satellite Backhaul ↔ Remote Core) (P5)	P5
Multi-RAT handover latency	Time elapsed during handover between 5G NR and Wi-Fi connectivity within the port operational area, ensuring service continuity for teleoperation and IoT data	T5

1 It is important to note that the definitions contain the reference to some specific use cases (second column), which means that these specific use cases have adopted the exact definition. The third column lists all use cases that are measuring this specific KPI, but some of them have adopted the use-case-specific definitions, which are listed in Annex of this deliverable.

	flows. Measured as the interruption time perceived at the application layer during RAT switching (T5)	
Orchestration latency	Service deployment time/Service scaling time for network service orchestrator (T4)	E3, T4
Application migration latency	Time needed to migrate/relocate an edge application from one edge node to another (T4)	T1, T2, T4
QoS restoration time	The elapsed time between the detection of an SLA violation and the restoration of compliant service conditions (T4)	T4
User experienced data rate/Throughput – downlink	Number of bits, originating from the source node, correctly received by the destination node over a certain period of time (H1, H2, P3, P4)	H1, H2, P3, P4, E3, E1, T3, P5, T5
User experienced data rate/Throughput – uplink	Number of bits, originating from the source node, correctly received by the destination node over a certain period of time (P2, P3)	P2, P3, E2, E3, E1, T3, T4, T1, T2, T5, P5
Uplink data rate	Maximum achievable data rate successfully transmitted from the UE to the network in uplink direction toward edge-hosted MCx and non MCx' services and for VR-enabled services (Scenario 1: UE ↔ RAN ↔ Local Core ↔ Edge, Scenario 2: UE ↔ RAN ↔ Core) (P1)	P1
Connection density	Number of connected devices per area (H1)	E3, E1, H1, H2, P1
Internet throughput	- Achievable downlink data rate between the local tactical network and external IP networks via satellite backhaul - downlink: Local Core ↔ Satellite Backhaul ↔ Internet (P5) - Achievable uplink data rate from the local tactical network to external IP networks via satellite backhaul - uplink: Local Core ↔ Satellite Backhaul ↔ Internet (P5)	P5
Scalability	- Availability of RLDT service in stressed scenarios (e.g., when number of devices and/or data volume increases) (T1) - Availability of object warning service in stressed scenarios (e.g., when number of devices and/or data volume increases) (T2)	T1, T2
(Device) energy efficiency	Power/energy consumption reduction in the source/destination nodes (W/J) per bit or bit per W/J)) (P2)	H1, H2, T4, P2, T3
Power consumption reduction vs Sub-6 GHz baseline	Average electrical power drawn by the mmWave RU during data transfer (T1, T2)	T1, T2
Watt per Throughput	Power-to-performance efficiency metric (T1, T2)	T1, T2
Run time	The execution time of the algorithm, including overhead of the container (e.g., TLS session termination) (H2)	H1, H2
Coverage	Geographic area where a network signal can be received and used by a device (H1, H2, P2)	H1, H2, P2, E3, E1

Mobility	Max. speed, at which a defined QoS and seamless transfer between radio nodes which may belong to different layers and/or radio access technologies (multi-layer/multi-RAT) can be achieved (H1)	H1
Positioning accuracy	Difference between the calculated position and the actual position of the device (E2)	E2, T1, T2
Service area	Description of the area within which the UE could find itself while satisfying the other KPIs with and without enabler (P1)	P1
Inference speed	Latency incurred in the computation of an AI model in inference model (E1, E3)	E1, E3, T4
ML accuracy	Accuracy of ML model (RMSE, F1-score,..) (E1, E3)	E1,E3, P1, T5
Time for detection of incident	Time for detection of PPDR incident (e.g. fire etc) (P1)	P1
False positives rate	False positives for detection of PPDR incident (e.g. fire etc) (P1)	P1
Operational Continuity Index (OCI)	Measures the level of gradual and linear response of the DT model to input changes with only minor deviations from linearity, under normal circumstances.	T5
Boundary Logic Compliance Rate (BLCR)	Evaluates the fraction of degenerate or extreme scenarios for which the model produces outputs that match analytically expected results.	T5

To enrich the cross-analysis of the KPIs from Table 3-2, we defined the **KPI meta-analysis** layer (Table 3-3), combining metrics such as KPI Coverage Score, KPI Variability, and KPI Stringency compared to other SNS JU projects.

In particular, the KPI Coverage Score defines how many use cases are measuring a specific KPI, highlighting the overall coverage of this KPI in the project, across different vertical domains. It can be noticed that vertical-agnostic KPIs are shared across a large number of use cases, making them suitable for defining a project-wide evaluation baseline. However, despite the broad coverage, some KPIs may have different target values depending on the use case. This is why we introduced the KPI variability metric with the following indications: High, Moderate, and Low, because of the target values spanning multiple orders of magnitude depending on the use case. Finally, the KPI Stringency is a relative metric that reflects how stringent a specific AMAZING-6G KPI is compared to the same KPIs defined by other SNS JU projects reported in the SNS JU Whitepaper on 6G KPIs - Definitions and Target Values [3].

As we can see from Table 3-3, the End-to-end Network service latency can be considered as a key KPI in the project, as it is measured in all use cases. However, it also exhibits very high variability in terms of target values, which is expected given that AMAZING-6G use cases vary significantly in terms of mission-criticality and real-time operations, especially depending on the vertical sector they belong to. For instance, we have a quite strict requirement of below 5ms in case of public safety (P5) to below 300ms in case of energy (E3) or even 100s in case of health (H1). Comparing to other SNS JU projects, the most strict requirement from the public safety domain is also more stringent than majority of use cases in the SNS JU portfolio, while other use cases follow the same trends as other reported projects [3].

Another high-variability KPI is throughput, as its target values also strongly depend on the use case. The most stringent requirement comes from the transport domain, where above 150 Mbps is needed for smooth uplink video and sensor data transmission. This requirement is also more stringent than majority of use cases reported in [3]. Nevertheless, we noticed that throughput and other high-variability KPIs in AMAZING-6G also exhibit high-variability across SNS JU projects.

The low-variability KPIs, such as application migration latency, are more stable and better suited for standardization. However, it is important to note that in some cases, the same KPI captures different aspects of system performance (e.g., network-level vs. application-level latency), which reflects the complexity of the evaluated system but may limit direct comparability. This is why we refrain from detailed comparisons and only identify trends and alignments between KPIs in the project, but also among the projects.

This analysis indicates that all identified KPIs are generally aligned with the state-of-the-art B5G/6G trial activities, with particularly stringent targets in areas such as ultra-low latency, throughput, and high reliability. The broad coverage of certain KPIs indicates the presence of a core set of KPIs that play a central role in cross-vertical evaluation, with the potential of yielding interesting learnings about latency, throughput, and reliability trends and achievements across a broad set of use cases. Finally, there are also many vertical-agnostic KPIs that AMAZING-6G identifies, which are previously not reported or analyzed in the SNS JU whitepaper, such as satellite backhaul latency, multi-RAT handover latency, among others, highlighting the potential for valuable contributions from AMAZING-6G to the SNS JU community.

Table 3-3 Meta-analysis of vertical-agnostic KPIs.

KPI Name	Target values	KPI Coverage Score	KPI Variability	KPI Stringency compared to SNS JU KPI White paper
Service availability	>99,999% (P1, P2, P3, P4, E1, E3) >99% (E2) >99,99% (H1 scenarios 1 and 2) **>99,9999% (H1 scenarios 3, 4 and 5, H2)** >99,99% (T5)	10	Moderate	Similar (PREDICT-6G 99,9999% and TrialsNet 100%)
Service reliability	**>1 month (H1 scenarios 1 and 2)** **>1 year (H1 scenarios 3, 4 and 5, H2)** >99,999% (T4) >99,999% (E1) >99,999% (E3) >99,99% (T5) >99,999% (T1, T2)	8	Moderate	Similar (100% in TrialsNet and 99.9999% in PREDICT-6G, and 99.99999% in HEXA-X-II)
End-to-end Network service latency	<100 s (H1 scenarios 1, 2, 3, 4, and 5) <10 ms (H2, E3) <20 ms (E1) <30 ms (T4, P2, P3, P4)	15	High	More stringent in case of P5 (only not in case of HEXA-X-II and collaborative robots use case <0.8ms), similar with

	<5 ms (P5) <20 ms (T1, T2) <15 ms (T5) <100ms (P1, E2, T3) <200ms (T1, T2) <300ms (E3)			other projects for other use cases
One-way application latency	<300ms (E1, E3) **<20ms (T1, T2)** **<20ms (P5)**	5	High	More stringent in case of T1/T2 than most of the projects TrialsNet: UC1 (Madrid, Iasi) < 100ms, UC2 800ms, UC3 80ms, UC4 < 100ms, UC9 10-15ms (03/2023)) Envelope: <= 150ms, <=100ms, <=75ms.
Slice provisioning time	<1min (P1) **<30s (T4)**	2	Moderate	More stringent. Service deployment time present in ImagineB5G, <30s, but that is not entirely equal to slice provisioning time which usually takes longer. 6G-SANDBOX doesn't provide any target value.
Satellite Backhaul Latency (one-way latency)	<20ms (P5)	1	NA	NA
Multi-RAT handover latency	<50 ms (T5)	1	NA	NA
Orchestration latency	**<10ms (E3)** <500ms-2s (T4)	2	NA	More stringent. Service deployment time present in ImagineB5G, <30s, but that is just one type of orchestration latency
Application migration latency	<100 ms (T1, T2, T4)	3	Low	NA
QoS restoration time	<500ms (T4)	1	NA	NA
User experienced data rate/Throughput – downlink	<86Mbps (H1 all scenarios) >4 kbps (H2, one packet per heart beat or per second), downlink minimal >50 Mbps (E3) >100 Mbps (T5, P3/P4/T3) **>1 Gbps (P5)** >10 Mbps (E1)	9	High	Less stringent. High variability among use cases in SNS JU, and the most strict downlink throughput requirement is 4.1Gbps in case of 6GXR

User experienced data rate/Throughput – uplink	>50 Mbps (E2) >20 Mbps (P2, and P3/T3) >100 Mbps (P5) >10 Mbps (E3/E1) >5 Mbps (P1) >5 Mbps per sensor (T4) **> 150 Mbps (T1, T2, and T5)**	12	High	Less stringent than 6GXR but more stringent than most of the use cases. High variability among use cases in SNS JU, and the most strict uplink throughput requirement is 570Mbps in case of 6GXR
Uplink data rate	>100 Mbps (P1)	1	NA	Less stringent than most use cases in SNS JU.
Connection density	1 device/m2 (E3) **50 devices/m2 (E1)** 10/km2 to 100/km2 (H1, scenarios 1 and 2) 20-30 per hospital NPN (H1, scenario 3) <10 /km2 (H1, scenario 4) <1 /km2 (H1, scenario 5) <5 /km2 (H2) UEs from more than one private network connected on the fly --> 2 UEs from distinct private networks connect on the fly to one of the cores (P1)	5	High	More stringent than most of the use cases in case of E1.
Internet throughput	>100 Mbps (P5 - downlink) >20 Mbps (P5 - uplink)	2	NA	NA
Scalability	Stable behavior with load increase ≥100% (T1, T2)	2	NA	NA
(Device) energy efficiency	Energy-efficient transmissions using a device powered with a 3.3V battery of capacity < 1000 mAh that can last at least several hours without recharging (H1) >20% (T4, T3, P2)	4	NA	Less stringent than 6G-SANDBOX 10x compared to 5G requirement
Power consumption reduction vs Sub-6 GHz baseline	<100W (T1, T2)	2	NA	NA
Watt per Throughput	20 mW/Mbps (T1, T2)	2	NA	NA
Run time	<1s (H1) **<10 ms (H2)**	2	High	NA
Coverage	**Urban and rural areas and indoor (H1 scenarios 1 and 2)**	5	Moderate	Different scales used, i.e., NA

	100m2 (H1 scenario 3) **Country wide including rural areas (H1 scenarios 4 and 5, and H2)** 200m radius (P2) >99% (E3, E1)			
Mobility	stationary (H1 scenarios 1, 3) <250 km/h (H1 scenarios 2, 5) <140 km/h (H1 scenario 4) **<300 km/h (H2)**	2	High	More stringent than almost all use cases, and equal to HEXA-X-II Network Assisted Mobility (up to 83m/s)
Positioning accuracy	**<10 cm (E2)** <60 cm (T1, T2)	3	Moderate	More stringent than majority of use cases, especially in E2 case, but less stringent than Remote surgery and Digital twin use cases in 6GTandem (<5cm and 1cm, respectively)
Service area	100% increase of the initial coverage area (5G In A BOX) through AMAZING 6G enablers (P1)	1	NA	NA
Inference speed	<5s (E1, E3) <1s (T4)	3	Moderate	NA: Two use cases measure inference speed. CENTRIC one does not have a target value, and ImagineB5G is 'improve by 20%'
ML accuracy	>0.9 (E1) <5 % (E3) **>=99% (P1)** >80% (T5)	4	Moderate	More stringent in case of P1 (ImagineB5G improve by 20%, 6G-SANDBOX >95%, ACROSS >90%)
Time for detection of incident	<1 min	1	NA	NA
False positives rate	Up to 1 per day per camera	1	NA	NA
Operational Continuity Index (OCI)	≥ 0.85	1	NA	NA
Boundary Logic Compliance Rate (BLCR)	100%	1	NA	NA

3.3 Vertical-specific KPIs

The vertical-specific KPIs complement the core KPI set by capturing domain-dependent performance aspects that are not directly comparable across verticals. These KPIs are tailored to the specific objectives and impact metrics of individual use cases.

The overview in Table 3-4 shows that vertical-specific KPIs are predominantly linked with the transport domain, particularly the T5 use case, where they address operational and environmental performance indicators, such as emissions: PM10 and dust levels, operational efficiency: truck turnaround time, crane productivity, and safety and incident response metrics.

Compared to the vertical-agnostic KPIs, these KPIs show low cross-use-case coverage, as they are designed for specific operational contexts. Some of the KPIs are common for two use cases, such as T1 and T2, which are complementary use cases, while the rest of the KPIs are associated with T5 solely.

It is important to note that vertical-specific KPIs play a crucial role in complementing the technical evaluation framework by providing insights into how technological improvements translate into operational gains, such as increased efficiency, improved safety, or reduced environmental impact, which will also be studied in the context of Key Value Indicators (KVIs).

Table 3-4 Definitions of vertical-specific KPIs, associated use cases, and target values.

KPI Name	Definition	Associated use cases	Target values
Average RSU power consumption	Average electrical power drawn by the mmWave RU during data transfer (T1, T2)	T1, T2	<100 W (T1, T2)
Increase in battery life of RSU	RSU lifetime gain enabled by energy-aware offloading and orchestration (T1, T2)	T1, T2	30% (T1, T2)
Increase in operational time of RSU	RSU lifetime gain enabled by energy-aware offloading and orchestration	T1	30% (T1)
Deployment time	Minimum amount of time for non-experts to deploy the system (T5)	T5	<15 min (T5)
PM10 Emissions	Measured concentration of PM10 or equivalent operational indicator associated with port transport and cargo-handling operations (T5)	T5	- 50% (T5)
Dust emissions	Measured level of dust emissions generated by cargo-handling and transport movements in the port (T5)	T5	- 50% (T5)
Safety levels	Number of safety-related incidents or accidents occurring in the operational environment. It captures the effect of automation, teleoperation support, improved situational awareness and faster event detection/response (T5)	T5	- 50% (T5)
Response time to emergencies and incidents	Elapsed time between incident detection/alarm generation and operational response initiation by relevant personnel or automated support function (T5)	T5	- 70% (T5)
Average truck turnaround time	Average time required for a truck to complete its targeted operational cycle in the port area, from arrival/process initiation to departure/process completion. It measures the effect of routing optimization, real-time visibility, Digital Twin-assisted coordination and better synchronization between unloading, yard and loading operations (T5)	T5	- 50% (T5)
Average straddle carrier productivity	Average number of effective moves per hour performed by straddle carriers (T5)	T5	- 30% (T5)

Average NCR (net crane rate)	Average number of effective crane moves per hour achieved during cargo-handling operations (T5)	T5	10% (T5)
Average container loading/unloading time	Average time required to load or unload a container during the port processes (T5)	T5	15% (T5)
Average truck loading time	Average time required to load or unload a container during the port processes (T5)	T5	- 10% (T5)
Average vessel waiting time at anchor	Average time a vessel remains at anchor before berth-side process execution can begin (T5)	T5	- 25% (T5)
Average time of crane maintenance	Average duration required to complete a maintenance intervention on the crane (T5)	T5	- 10% (T5)

3.4 Measuring impact of 6G technological enablers

In the AMAZING-6G, we define four categories of 6G technological enablers: communication, compute-as-a-service, AI/ML, and IoT. While the design of these 6G technological enablers is being performed in WP3, their integration with use cases is the focus of WP4, WP5, and WP6. At the same time, one of the main objectives of WP7 is to assess the impact of technological enablers on the use cases. To achieve that, we identified relevant KPIs that will be measured before and after the technological enablers are leveraged to support vertical services within use cases. The final deliverable of WP7, i.e., D7.2 will report the findings based on the analysis of the difference between service performance with and without enablers, assessing the enablers' impact.

Table 3-5 KPIs for Communication Enablers.

Enabler	Key KPIs (grouped)	Use cases
5G RedCap IoT	Service availability, Service reliability, End-to-end network service latency, User experienced data rate, Mobility, Connection density, Coverage, (Device) energy efficiency	H1, H2
Network slicing	Service availability, Service reliability, End-to-end network service latency, User experienced data rate, (Device) energy efficiency, Coverage, One-way application latency, Connection density	H1, H2, P3, E1, E2, E3, T1, T2, T4
Multi-RAT connectivity	Service availability, Service reliability, End-to-end network service latency, User experienced data rate, Coverage, Multi-RAT handover latency	P2, P3, P4, E2, T1, T2
Advanced localization and positioning systems	Positioning accuracy, Safety levels, Response time to emergencies and incidents, Average straddle carrier	E2, T1, T2, T5

	productivity, Average truck loading time	
Network Performance Monitoring and Control	Service availability, Service reliability, End-to-end network service latency, Safety levels, Response time to emergencies and incidents, Coverage	P1, E1, E3, T5
Automated gNB Configuration	Service reliability, End-to-end network service latency, Slice provisioning time	P1, T5
Identification and Selection of Backhauling	Service availability, User experienced data rate, Connection density, Service area	P1, T5
Zero-touch network and service management	Service reliability, End-to-end network service latency, User experienced data rate, Orchestration latency, (Device) energy efficiency	E3, T4, T5
Public-private network integration	Service availability, User experienced data rate	E2, T5
Communication resource management	End-to-end network service latency, Satellite Backhaul Latency, Internet throughput, User experienced data rate, Orchestration latency, (Device) energy efficiency, Average vessel waiting time at anchor, Average time of crane maintenance,	P5, T5
mmWave gNodeB	Average RSU power consumption, Power consumption reduction vs Sub-6 GHz baseline, Watt per Throughput	T1, T2

Table 3-6 KPIs for Compute-as-a-Service Enablers.

Enabler	Key KPIs (grouped)	Use cases
Distributed user-edge-cloud compute	End-to-end network service latency, Runtime	H1, H2, E2
Intelligent service and resource orchestration in extreme edge/edge/cloud compute continuum	Slice provisioning time, Average vessel waiting time at anchor, Application migration latency	P1, T1, T2, T5
Creation of Kubernetes clusters on demand	Slice provisioning time	P1

Table 3-7 KPIs for AI/ML Enablers.

Enabler	Key KPIs (grouped)	Use cases
Application enablers and AI – MLOps / AI-as-a-S	One-way application latency	E1

Network exposure	End-to-end network service latency, (Device) energy efficiency, Slice provisioning time	P1, P2
Digital twin framework	PM10 Emissions, Safety levels, Response time to emergencies and incidents, Average truck turnaround time, Average straddle carrier productivity, Average container loading/unloading time, Average truck loading time, Average vessel waiting time at anchor, Average time of crane maintenance	T5
AI-as-a-Service framework	PM10 Emissions, Dust emissions, Average truck turnaround time, Average straddle carrier productivity, Average container loading/unloading time, Average truck loading time, Average vessel waiting time at anchor, Average time of crane maintenance, Inference speed	E1, E3, T5
ML models catalogue	PM10 Emissions, Dust emissions, Average straddle carrier productivity, Average container loading/unloading time, Average truck loading time, ML accuracy	E1, E3, T5
MLOps	PM10 Emissions, Dust emissions, Average truck turnaround time	T5

Table 3-8 KPIs for IoT Enablers.

Enabler	Key KPIs (grouped)	Use cases
IoT Exposure Function	Safety levels, Average straddle carrier productivity, Average truck loading time	T5
IoT Gateways, IoT Sensors and Devices	One-way application latency, Connection density	E3
Real-time actuation	One-way application latency, Safety levels, Response time to emergencies and incidents, Average truck loading time, Average NCR (net crate rate)	E3, T5
IoT Connectivity & Infrastructure	User experienced data rate, Coverage	E3

In Table 3-5, Table 3-6, Table 3-7, and Table 3-8, we show the mapping between different groups of enablers (respectively), key KPIs, and use cases. The mapping shows that:

- Communication enablers primarily influence core network performance KPIs such as latency, throughput, reliability, and coverage,
- Compute and orchestration enablers mainly impact latency, execution efficiency, and service deployment capabilities,
- AI/ML enablers contribute to application-level KPIs, including inference performance, accuracy, and operational efficiency indicators, and
- IoT enablers support connectivity-related KPIs as well as real-time responsiveness and interaction with the physical environment.

As some of the enablers are being embedded into a large group of use cases, such as network slicing, multi-RAT connectivity, and intelligent resource orchestration, it will be essential to explore the impact they create across use cases and vertical sectors. Therefore, WP7 will further focus on studying this impact from a cross-enabler/cross-use case perspective and report the findings in D7.2.

4 Key Value Indicators (KVIs)

The Key Values (KVs) have been identified as key drivers of Information and Communication Technology (ICT) research [4], and according to SUSTAIN-6G, they refer to principles or qualities that individuals or groups deem important, desirable, or intrinsically good that may be addressed or impacted by ICT [5].

Therefore, this section focuses on the Key Value Indicators (KVIs), which are qualitative or quantitative metrics used to measure the degree to which AMAZING-6G contributes to sustainability outcomes within Economic, Social, or Environmental pillars. In particular, KVIs are seen as a method for analyzing the values-related outcomes stemming from ICT developments. Same as for the KPIs analyzed in Section 3, WP7 also defines the list of KVIs as a common observing point for the value identification, KVI definition, and KVI assessment activities.

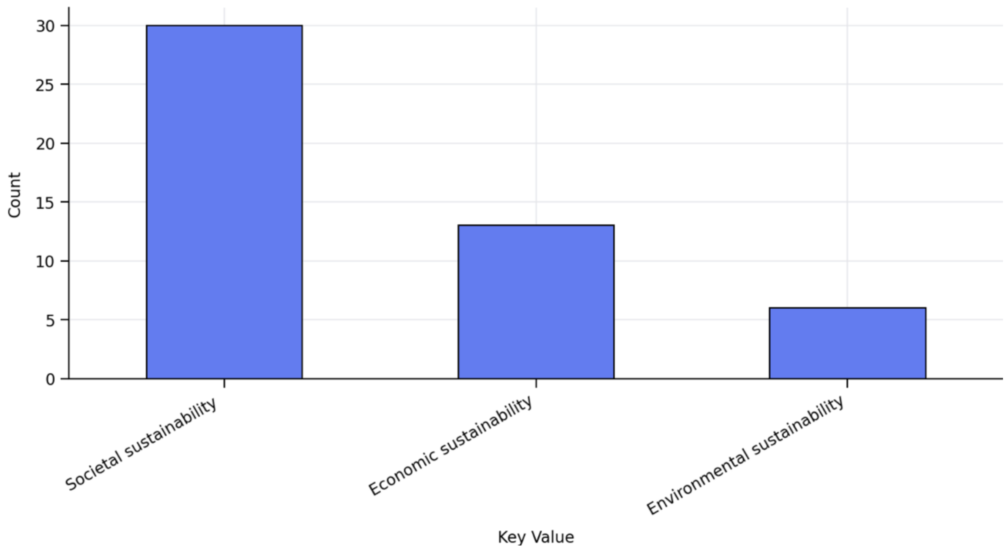

Figure 4-1 Key Value trends in AMAZING-6G.

From the analysis obtained in WP7, we identify the following three key values that cross all use cases and vertical domains in AMAZING-6G: Societal sustainability, Environmental sustainability, and Economic sustainability. These KVs are also considered as sustainability pillars, as they are tightly coupled and interdependent [6]. The resilience and adaptability in each of these pillars is required to protect and enhance natural, human, societal, financial and manufactured capitals that together support the modern digital world [6].

In AMAZING-6G, each of them is accompanied by a list of use case-specific KVIs, but not all of them are equally represented in the project. For instance, as it can be seen from Figure 4-1, societal sustainability is the most present one in all use cases, with 30 KVIs in total. The trend shows almost the double reduction in the amount of KVIs supporting other two KVs. However, it is important to note that societal KVIs are more unique and use case-specific than the other two, as majority of KVIs are specific only to one use case, assessing the impact of specific use case context on the end users, while for economic and environmental sustainability, many KVIs are common for multiple use cases.

In this section, we will deep dive into some specific findings from each of the KVI category, but before that is also interesting to observe the KVI assessment trends shown in Figure 4-2. Unlike the typical performance measurement expressed via KPIs in 5G and 6G context, KVIs are more subjective indicators and measurement/assessment techniques significantly differ from those for KPIs. Therefore, no single assessment methodology can be applied consistently across all KVIs. The choice of evaluation approach is highly dependent on the specific KVI under consideration, the characteristics of the use case, the stakeholders involved, and the nature of the evidence that can realistically be collected. Consequently, meaningful KVI assessment requires a combination of complementary methodologies rather than relying on a single measurement technique.

The KVI evaluation framework adopted in AMAZING-6G relies on a hybrid methodology, combining:

- Quantitative methods: KPI analysis, simulations, operational metrics,
- Qualitative methods: questionnaires, expert assessment, user surveys, and
- Comparative analysis: before/after enabler deployment.

Overall, Figure 4-2 clearly illustrates significant diversity of assessment approaches. While questionnaires, user surveys, and expert assessments are the most frequently adopted methodologies in AMAZING-6G, this does not mean they are universally preferable. Instead, it reflects the fact that many KVIs cannot be adequately evaluated using objective technical metrics alone. Other KVIs, however, can leverage quantitative evidence or comparative analyses, demonstrating that the selection of assessment methods must always be tailored to the specific KVI and the context of the trial.

In different subsections, we study KVIs that belong to three key values, but something that we noticed is joint for all three KVI categories. The analysis of Table 4-1 to Table 4-6 reveals that KVIs are not designed as standalone metrics but are linked to KPIs, which is highlighting the relationship between technical performance improvements and perceived or measurable value creation. For instance, we notice that KPIs such as latency, reliability and throughput, are linked with responsiveness and safety KVIs. On the other hand, coverage and availability KPIs impact accessibility and service continuity KVIs. Finally, the AI-related KPIs are associated with trust, accuracy and decision-quality KVIs. During the full trial activities, which will mainly take place in the second half of the project, these relationships will be further studied and assessed. For the moment, we have identified the link and will proceed with the study of results during the trial phase.

Finally, before going into more details of KV groups, it is important to highlight that KVIs will be collected and analyzed during the trial phase of the project, when users are involved in the testing process, unlike KPIs that are also being evaluated during the pre-trial phase.

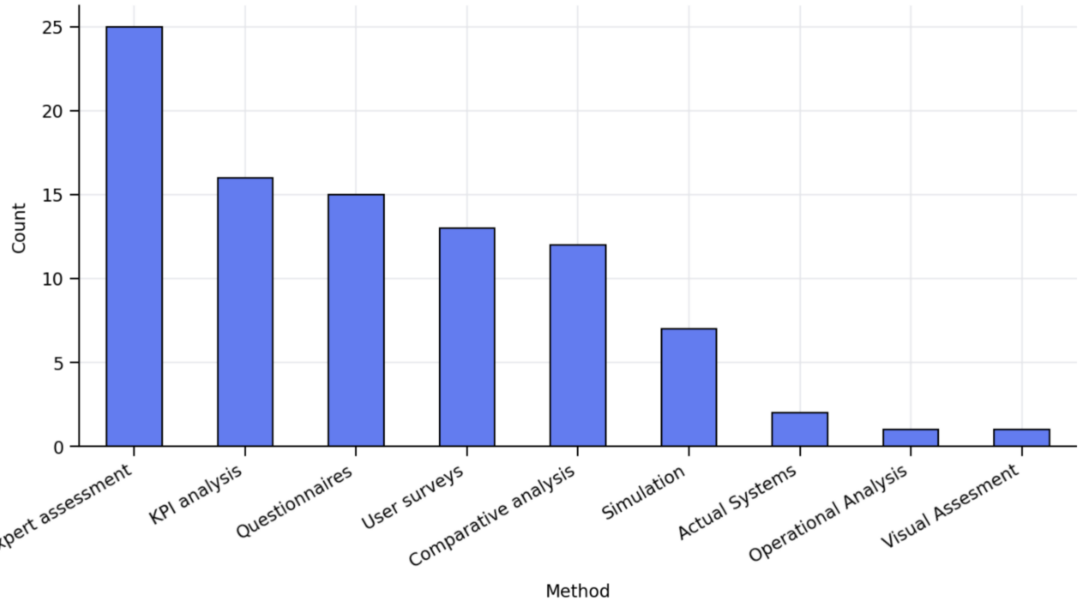

Figure 4-2 KVI assessment techniques.

4.1 Societal sustainability

According to SUSTAIN-6G, the societal pillar of sustainability in 6G refers to the system's capacity to embed and promote societal values such as inclusion, trust and positive impact across diverse populations [6]. In AMAZING-6G, it is as well considered as a core component of network and service sustainability, taking into account the societal relevance and acceptability of technologies.

The tables Table 4-1 and Table 4-2 provide a comprehensive list of the KVIs within the AMAZING-6G KVI framework established in WP7, focusing on societal sustainability and impact assessment. These tables extend the KPI-centric evaluation by capturing human-centric, operational, and societal outcomes of 6G enablers across all AMAZING-6G vertical domains. In Table 4-1, we can see the KVI list along with the KVI definition and associated use cases. Unlike in the case of KPIs, we cannot derive a single definition on a KVI level, as those metrics are more use-case oriented and thus require more domain-specific context in the definition.

The analysis shows that the dominant group of KVIs relates to safety improvements, including: Operational safety improvement (public safety, transport), Reduced accident risk (transport, mobility scenarios), and Improved safety for inspection personnel (energy domain). These KVIs consistently target substantial reductions, such as up to 40-70% reduction in accidents or response times, or qualitative improvements validated through user perception scores. This highlights that safety emerges as a primary value driver of 6G technologies, especially when combined with AI, automation, and real-time connectivity. Another KVI strand we notice is the trust in system operation, which is substantiated by KVIs such as Trust in AI-driven decisions, Operator confidence in remote control, Service continuity and perceived reliability, and Trust in obstacle detection/notifications. This means that 6G is not solely performance-driven network ecosystem, because it also values user acceptance and confidence in innovative technologies, which is extremely important especially because of the AI omni-presence in network and vertical automation domains.

Concerning human well-being, we identify several KVIs such as Quality-of-life improvement (health use cases), User comfort (energy systems), Mobility independence and accessibility (transport), and Reduced cognitive load and improved urban experience (transport). Shifting from purely technical evaluation, where measuring KPIs indicates how successful the technology is, these types of KVIs will highlight the impact on human life, which in the end heavily impacts the long-term and sustainable adoption of such technologies.

The assessment of operational improvements can be performed by measuring KPIs, but it is also important to capture the impact on key values. For instance, KVIs that fall into that domain are Reduced disruption in rail and transport systems, Faster emergency response, Improved coordination and system responsiveness, and Reduced downtime and improved workflow efficiency, which are quantified through time reductions (e.g., 12–20% disruption reduction) and response efficiency gains (≥20% faster response). As it can be seen, these operational KVIs bridge KPIs such as latency and reliability with real-world performance and improvements, which are especially important for mission-critical environments.

Table 4-1 Societal sustainability KVIs and definitions.

Key Value Indicator	Definition	Use cases
Operational Safety Improvement	-Assesses perceived improvement in responder safety and coordination enabled by rapidly deployable private B5G connectivity and deterministic MCx service delivery in isolated PPDR scenarios (P5) -By introducing enhanced first responder team with extensive monitoring instrumentation we expect improved initialization and coordination of rescue operation, resulting more effective dimensioning of the rescue operation itself, and the most important, possibility for less casualties in accidents (P4) -Captures the positive impact of automation and reducing direct human involvement in high-risk operational tasks, minimizing exposure to hazardous environments and decreasing the risk of accidents and human injuries (T5)	P5, P4, T5
Mission-Critical Communication Availability	-Evaluates confidence in continuous MCx service availability during on-the-move operations, including standalone mode without satellite backhaul (P5)	P5
User Comfort and Quality of Life Satisfaction	-Assesses user-perceived indoor comfort (thermal, air quality, lighting) while SB-EMS optimization loops are active (E1) Quality-of-life score increase: The improvement in standardized patient-reported quality-of-life metrics reflecting better physical, psychological, and social well-being (H2), especially due to at home monitoring at waiting list (H1)	E1, H1, H2
Trust in Automated and AI-driven Energy Decisions	-Measures user and operator trust in AI-generated recommendations and automated actuation, including explainability and predictability (E1)	E1
Improved safety for inspection personnel	-Drone-based ultrasound inspection eliminates the need for technicians to climb or access turbine blades, reducing exposure to hazardous offshore working conditions and extreme weather risks (E2)	E2
Improvement in Energy System Responsiveness	-Measures the perceived ability of the solar park to execute grid-related control commands within regulatory time constraints, enabled by URLLC slicing and edge-local breakout for deterministic command delivery (E3)	E3
Operator Confidence in Remote Energy Control	Assesses operator trust in remotely monitoring and controlling PV inverters without on-site intervention, based on observed system stability, control accuracy, and availability during trial operation (E3)	E3

Minimal disruption of rail services	Assesses the reduced disruption time that rail services experience with the use of 5G/6G for signaling	T3
Minimized time of disruption	Minimized time of disruption in case of situations where autonomous driving is deemed unsafe or ineffective	T4
Minimized risk of accidents	Assesses the improvement in the trust and acceptance of autonomous driving as a result of the minimized risk of accidents (T4) Reduction of accident risk thanks to higher awareness and support to VRUs (T1, T2)	T4, T1, T2
Mortality risk reduction	The percentage decrease in the probability of patient death within a specified period due to improved monitoring and treatment optimization	H1, H2
Clinic visits reduction	The percentage decrease in routine hospital or clinic visits required for patient follow-up through remote monitoring and automated decision support.	H1, H2
Improved end-user experience through optimal connectivity selection	Evaluates the perceived improvement in service quality experienced by PPDR users (first responders and control center operators) through dynamic selection of the most suitable connectivity option (terrestrial or satellite backhaul) based on real-time network performance monitoring.	P1
Workforce Skills and Digital Readiness Improvement	Raise workforce skills though competence building in the use of new technologies	T5
Increased Perceived Safety and Confidence	Degree to which visually impaired users feel safer when crossing intersections thanks to timely alerts.	T1
Improved Mobility Independence	Extent to which the system reduces reliance on human assistance for road crossing.	T1
Trust in System Reliability	User trust that alerts are timely, correct, and non-intrusive.	T1
Service continuity and trust	Maintaining satisfying quality of experience for video services in command and control center (CCC). Using multi-RAT connectivity or network slicing to ensure and maintain video service continuity when streaming from avalanche site towards CCC (P2, P3)	P2, P3
Accessibility and Ease of Use	How easy and intuitive the alerting app is for visually impaired people.	T1
Reduced Cognitive Load for Drivers	Lower driver stress or mental load due to improved awareness of VRUs.	T1
Increased Driver Compliance to Safe Behaviors	Observable increase in safe driving patterns when alerts are received.	T1
Enhanced VRU Awareness Coverage	Percentage of events where vehicles became aware of hidden VRUs through digital twin fusion.	T1
Improved Urban Accessibility Index	Contribution to municipal accessibility KPIs for inclusive mobility.	T1
Enhanced Emergency Response Efficiency	Faster detection of risky situations enabling better deployment of safety forces.	T1
Improved Walkability Perception	Users feel sidewalks and pedestrian areas are safer and more navigable thanks to AMR monitoring.	T2

Increased Independence in Daily Mobility	Reduction in reliance on assistance to navigate obstacles or hazardous areas.	T2
Trust in Obstacle Notifications	Confidence that alerts are timely, correct, and relevant.	T2
Improved Accessibility Awareness	Users perceive the system as contributing to a more accessible city.	T2
Improved Urban Obstacle Management	Reduction of persistent obstacles in walkways thanks to AMR detection.	T2
Better Compliance of Shared Mobility Operators	Improved adherence of scooter/bike-sharing operators to proper parking rules.	T2

Table 4-2 Target values, assessment methodology, and related KPIs, for Societal Sustainability KVIs.

Key Value Indicator	Target values	Assessment methodology	Related KPIs
Operational Safety Improvement	≥75% respondents rate safety improvement ≥4/5; avg ≥4.0/5 (P5) Improve rescue operation response time (P4) -70% accidents, -50% response time (T5)	Questionnaires, User surveys, Expert assessment, KPI analysis	End-to-end Network service latency, Service availability, Service reliability, Coverage, Response time to emergencies and incidents
Mission-Critical Communication Availability	Avg score ≥4.0/5; ≥70% confidence in primary usage (P5)	Questionnaires, KPI analysis	End-to-end Network service latency, User experienced data rate/Throughput - UPLINK and DOWNLINK
User Comfort and Quality of Life Satisfaction	Avg comfort score ≥4.0/5; ≥75% users report maintained or improved comfort (E1) Quality-of-life score increase for the patients >20% (This would be due to increased physical activity levels by around 20% and a reduced hospital visits by 40% - H2; due to increased safety before and after surgery/intervention of around 20% and a reduced expenditure of time and effort for hospital visits by 50% - H1)	Questionnaires, User surveys, Comparative Analysis, Analysis of KPIs, Simulation	End-to-end Network service latency, Service reliability, Coverage
Trust in Automated and AI-driven Energy Decisions	Avg trust score ≥4.0/5; ≥70% willingness to rely on automation (E1)	Questionnaires, Expert assessment	Service availability, Service reliability, End-to-end Network service latency

Improved safety for inspection personnel	Risk-prone manual blade access replaced by remote operation with centimeter-level positioning accuracy (<10 cm) (E2)	Expert assessment, Operational analysis	Service availability, Positioning accuracy
Improvement in Energy System Responsiveness	Control commands executed within sub-second latency; operators reported consistent and timely system response during simulated grid-balancing events (E3)	Questionnaires, KPI analysis, Expert assessment	End-to-end Network service latency, One-way application latency, Service availability, Service reliability
Operator Confidence in Remote Energy Control	High perceived reliability of remote operations supported by continuous connectivity and deterministic control paths (E3)	Questionnaires, User surveys	Service availability, Service reliability, User experienced data rate/Throughput - UPLINK and DOWNLINK
Minimal disruption of rail services	12–20% disruption-time reduction (T3)	Expert assessment	NA
Minimized time of disruption	Not yet available.	Expert assessment	NA
Minimized risk of accidents	Reduction of 40-45%	Expert assessment	NA
Mortality risk reduction	Mortality risk reduction >10% (Annual deaths among pacemaker/defibrillator patients are around 2,500 in Norway. This means that a 10% reduction in mortality could save the lives of at least 250 patients per year.)	Comparative Analysis, Analysis of KPIs, Simulation	End-to-end Network service latency
Clinic visits reduction	Clinic visits reduction >20% (H1) and >40% (H2). H1: With around 250.000 cardiac patients in Norway and about 2 visits per year, remote monitoring could lead to approximately 100,000 avoided visits annually. H2: With around 50,000 PM/ICD patients in Norway and about 3 visits per year, remote monitoring could lead to approximately 60,000 avoided visits annually.	Comparative Analysis, Analysis of KPIs, Simulation	End-to-end Network service latency
Improved end-user experience through optimal connectivity selection	≥75% users rate service quality improvement ≥4/5	Questionnaires, User surveys, KPI analysis	End-to-end network service latency, User experienced data rate/Throughput - UPLINK, Service availability
Workforce Skills and Digital Readiness Improvement	≥80% of targeted staff successfully trained, average training satisfaction ≥4.0/5	KPI analysis, Questionnaires, Expert assessment	NA

Increased Perceived Safety and Confidence	≥ 30% improvement in perceived safety	User Surveys	NA
Improved Mobility Independence	≥ 25% reduction in need for assistance	User Surveys	NA
Trust in System Reliability	≥ 80% trust rating	User Surveys	NA
Service continuity and trust	Decrease video stalls or erroneous packets	Actual systems, comparative analysis, visual assessment	User experienced data rate/Throughput - UPLINK
Accessibility and Ease of Use	≥ 85% accessibility rating	User Surveys	
Reduced Cognitive Load for Drivers	≥ 20% reduction in cognitive load	User Surveys	NA
Increased Driver Compliance to Safe Behaviors	≥ 15% improvement	Expert assessment	NA
Enhanced VRU Awareness Coverage	≥ 90% VRU awareness coverage	Expert assessment	NA
Improved Urban Accessibility Index	Qualitative improvement validated by experts	Expert assessment	NA
Enhanced Emergency Response Efficiency	≥ 20% faster response	Expert assessment	NA
Improved Walkability Perception	≥ 30% improvement in perceived walkability	User Surveys	NA
Increased Independence in Daily Mobility	≥ 25% reduction in assistance requests	User Surveys	NA
Trust in Obstacle Notifications	≥ 80% trust level	User Surveys	NA
Improved Accessibility Awareness	≥ 75% positive perception	User Surveys	NA
Improved Urban Obstacle Management	≥ 20% reduction in recurring obstacles	Expert assessment	NA
Better Compliance of Shared Mobility Operators	≥ 25% increase in compliance	Expert assessment	NA

4.2 Environmental sustainability

Environmental sustainability is the ability to maintain an ecological balance in our planet's natural environment and conserve natural resources to support the social and economic wellbeing of current and future generations **[5]**.

In AMAZING-6G, we tackle environmental sustainability pillar through the environmental KVIs, presented in Table 4-3 and Table 4-4, which mainly focus on direct environmental benefits, such as emission reduction and its environmental impact. Some of these KVIs refer to at least 50%

reduced PM10 and dust emissions, and >600 tons/year CO_2 reduction of carbon emissions (CO_2), yielding lower environmental footprint of operations. These reductions highlight the indirect impact of 6G-enabled automation, optimization, and AI-driven control, particularly in domains such as port logistics and energy systems, where operational inefficiencies directly translate into emissions and negative impact on environment.

Another important group of KVIs refer to energy efficiency, focusing on reduction in energy consumption, improved energy efficiency of networks and devices, and optimized data and compute usage. Savings in energy consumption will demonstrate the importance of edge computing as localized processing reduces transport energy, network softwarization and cloud-native architectures that enables efficient resource allocation, as well as AI-based optimization that improves overall network and service usage.

Concerning the KVI assessment for environmental sustainability, the assessment methodology follows similar trends as in the case of societal sustainability. Nevertheless, it is interesting to note that the benefits are partially quantitative (e.g., measurable emissions) and partially systemic (efficiency gains across workflows).

Table 4-3 Environmental sustainability KVIs and definitions.

Key Value Indicator	Definition	Use cases
Energy Efficiency Compared to Legacy PPDR Systems	Captures perceived energy efficiency gains from edge-hosted MCx services and reduced backhaul dependency compared to legacy PPDR systems	P5
Reduction in Energy Consumption	- Evaluates stakeholder perception of reduced building and REC-level energy consumption achieved through AI-driven joint optimization of energy usage and comfort, leveraging edge-based inference and federated learning (E1) - Energy efficiency through minimization of the time the autonomous cars are idling until they are allowed to resume their operation (e.g., in the case of roadblocks) (T4) - Reduced energy consumption through energy-aware service orchestration (Zero-touch service management framework) (T4) - Using energy-efficient video/network parametrization (P4)	E1, T4, P4
Reduced environmental footprint	- Replacement of human offshore inspection with drone-based inspection reduces vessel trips and technician transfers, directly lowering fuel consumption and CO_2 emissions associated with offshore maintenance operations (E2) - Reduced Environmental Footprint of Port Transport Operations - Improve environmental footprint (reduced emissions) of port transport operations through optimal use of resources. To what extent is reduced the environmental footprint of port logistics and transport operations through optimized routing, reduced idle and waiting times, improved synchronization of cargo-handling activities, and data-driven operational decisions enabled by B5G/6G, IoT and Digital Twin capabilities (T5)	E2, T5
Perceived Increase in Renewable Energy Utilization	- Evaluates stakeholder perception of improved utilization of solar generation through AI-based forecasting and optimized inverter control, combining real-time telemetry with weather data (E3) - Using electrical snowmobiles as essential vehicle within Arctic Rescue	E3, P4, P2

	scenario, we will have less fossils emissions (P4) - Using solar-powered B5G small cells/networking (P2)	
Lower Data Overhead	Lower data overhead through leveraging edge computing for data processing and service runtime.	T4
Carbon emission reduction	- The decrease in CO_2 emissions associated with reduced patient travel and healthcare service utilization (H1, H2) - Using energy-efficient video/network parametrization (P4) - Reduction of carbon footprint through optimized deployment of applications and consequent effective resource usage of B5G/6G system elements (T1, T2)	H1, H2, P4, P2, T1, T2

Table 4-4 Target values, assessment methodology, and related KPIs, for Environmental sustainability KVIs.

Key Value Indicator	Target values	Assessment methodology	Related KPIs
Energy Efficiency Compared to Legacy PPDR Systems	≥65% respondents perceive energy efficiency improvement ≥4/5	Questionnaires, Comparative analysis, KPI analysis	(Device) energy efficiency, Watt per Throughput
Reduction in Energy Consumption	≥70% respondents rate energy reduction ≥4/5; measured energy reduction >10% (E1) Lower carbon footprint of video feed from the field (P4)	Questionnaires, Comparative analysis, Analysis of KPIs	End-to-end Network service latency, User experienced data rate/Throughput - UPLINK and DOWNLINK, Service availability, (Device) energy Efficiency
Reduced environmental footprint	Fewer offshore personnel deployments required per inspection campaign, leading to measurable reduction in vessel usage (E2) -50% PM10 emissions, -50% dust emissions (T5)	Comparative analysis, Expert assessment, KPI analysis, simulation	Service availability, Service reliability, (Device) Energy efficiency, PM10 emissions, Dust emissions
Perceived Increase in Renewable Energy Utilization	Forecast-driven recommendations enabled better alignment between production and grid constraints, with reduced curtailment perception (E3) Decrease CO2 emission by the use of electrical snowmobiles (P4) Grid-based energy reduction on daily basis (P2)	Questionnaires, Comparative analysis	User experienced data rate/Throughput - UPLINK, One-way application latency, Coverage
Lower Data Overhead			
Carbon emission reduction	Carbon emission reduction 1000 tons per year (Assuming about 10 kg CO_2 per visit, reducing	Comparative Analysis,	End-to-end Network service

	100,000 visits per year would result in approximately this level of emission reduction in Norway) (H1) Emission reduction >600 tons per year (Assuming about 10 kg CO_2 per visit, reducing 60,000 visits per year would result in approximately this level of emission reduction in Norway.) (H2, P2) Lower carbon footprint of video feed from the field (P4) Reduction of 15-20% (T1, T2)	Analysis of KPIs, Simulation, Expert Assessment	latency, (Device) Energy efficiency

4.3 Economic sustainability

The economic pillar of 6G sustainability focuses on the financial viability, value distribution, and innovation capacity of future 6G ecosystems, considering how 6G infrastructures and services can remain cost-effective, accessible, and economically beneficial to a broad set of stakeholders across their lifecycle [6].

From Table 4-5 and Table 4-6, we can identify that the dominant trend among economic sustainability KVIs is the reduction of costs, stemming from operational and maintenance costs, over lower energy-related costs, to the reduced restoration and repair costs. These reductions are expected to imply from the use of advanced 6G technologies referring to automation and AI-based optimization, predictive maintenance, and reduced downtime and resource waste.

Another trend refers to productivity improvements, focusing mainly on the transport domain (reduced truck turnaround time, increased crane productivity, etc.), which benefits from edge analytics and AI-assisted decision-making.

As scalability of the proposed 6G-enhanced use cases in AMAZING-6G is critical for reaching higher technological maturity, some specific KVIs focus exactly on scaling out, replicability and business impact. For instance, Scalability of solutions across deployments, Business replicability across markets, and Infrastructure cost avoidance and efficiency, are some of the KVIs that emphasize those important aspects. These KVIs emphasize that 6G solutions must be not only effective but also deployable at scale and economically sustainable across different application domains/vertical industries.

Table 4-5 Economic sustainability KVIs and definitions.

Key Value Indicator	Definition	Use cases
Reduction in Operational Downtime	Measures perceived reduction in service downtime due to autonomous local core operation, rapid deployment, and edge-based resilience (P5) Reduced downtime and cost of maintenance through optimal use of resources and predictive maintenance (T5)	P5, T5
Reduction in Operational and Energy-related Costs	Assesses perceived cost savings from reduced reliance on fixed infrastructure, lower energy usage, and minimized service interruptions (P5) Evaluates operator perception of operational cost savings due to reduced	P5, E1, E3, T3, T4,

	energy consumption, efficient slice utilization, and edge-local processing (E1) Captures perceived reduction in operational expenditures due to fewer site visits, automated monitoring, and remote control of PV assets enabled by B5G connectivity and edge intelligence (E3) Lower loss of revenue for railway operator due to the minimal service disruption. Assesses the financial benefit as a result of the reduced disruption time in rail services (T3) Lower cost for drivers through the increased efficiency and safety of autonomous driving (T4) Network operational cost savings through performance optimization. Measures perceived reduction in operational costs enabled by automated network deployment, dynamic orchestration of network and compute resources, and optimized performance management of B5G/6G infrastructure during emergency response operations (P1) Operational Cost Efficiency through Port Process Optimization: Reduced cost through port operations (time) optimization i.e., turnaround times (ship, truck), (un)loading times (ship, container, truck). (T5) Network operational cost savings through multi-connectivity. Using the most optimal available communication network configuration, or combining multiple networks, to ensure the best possible connection. (P2, P3)	P1, T5, P2, P3
Confidence in Scalability to Multi-building and REC Scenarios	Captures perceived capability of the SB-EMS to scale from single buildings to REC scope using federated learning and cloud-native orchestration (E1)	E1
Reduced inspection time	Real-time uplink of ultrasound data from the drone to an edge-hosted Digital Twin enables near-real-time fault assessment and maintenance decision-making within a single inspection flight, reducing inspection-to-decision latency compared to offline processing.	E2
Business Scalability and Replicability	Measures stakeholder confidence that the E3 solution can be replicated across additional solar parks with limited customization, leveraging standardized APIs, RedCap gateways, and orchestrated slicing.	E3
Lower cost of restoration/repairs in case of equipment fault or theft	NA	T3
Perceived Increase in Renewable Energy Utilization	By the use of electrical snowmobiles as essential vehicle within Arctic Rescue scenario, we expect cost savings from reduced fuel consumption (P4)	P4
Network resource efficiency improvement through multi-connectivity	Assesses the improvement in network resource utilization achieved through the combined use of multiple connectivity solutions (private/public B5G networks, alternative backhaul options and cross-operator slices), dynamically orchestrated through standardized APIs and monitoring mechanisms (P1)	P1
Reduced healthcare expenditure	Economic benefit associated with accident prevention involving VRU	T1, T2
Reduced TCO for MNOs	Reduced operator cost through lower energy expenditure and more efficient resource usage	T1, T2
Increased revenues for MNOs	Opportunity to offer value-added energy-aware and safety-related innovative services	T1, T2

Reduced Need for Physical Infrastructure Upgrades	Value gained from digital augmentation instead of physical redesigns.	T1
Enhanced Planning for Urban Accessibility	Use of AMR-generated datasets for long-term urban mobility planning.	T2

Table 4-6 Target values, assessment methodology, and related KPIs, for Economic sustainability KVIs.

Key Value Indicator	Target values	Assessment methodology	Related KPIs
Reduction in Operational Downtime	≥70% operators rate downtime reduction ≥4/5; avg ≥3.8/5 (P5) -25% Average time of maintenance	Questionnaires, Expert assessment, KPI analysis, simulation	Deployment time, Average time of crane maintenance
Reduction in Operational and Energy-related Costs	≥60% operators report perceived cost reductions ≥10% (≥4/5) (P5) ≥60% operators report perceived Opex reduction ≥10% (E1) Operators reported fewer manual interventions and reduced need for on-site diagnostics during trial period (E3) 5–12% revenue-loss reduction (T3) ≥60% operators report perceived cost reduction ≥10% (P1) -30% Average truck turnaround time, +15% Average NCR, +10% Average straddle carrier productivity, -10% Average container loading/unloading time, -25% Average truck loading time, -10% Average Vessel waiting time at anchor (T5) Cost reduction ≥10% (P2, P3)	Questionnaires, Comparative analysis, Expert assessment, simulation, KPI analysis	(Device) Energy efficiency, Service availability, End-to-end Network service latency, User experienced data rate/Throughput - UPLINK and DOWNLINK, Connection density, Slice provisioning time, Average truck turnaround time, Average NCR, Average straddle carrier productivity , Average container loading/unloading time, Average truck loading time, Average Vessel waiting time at anchor
Confidence in Scalability to Multi-building and REC Scenarios	≥75% respondents rate scalability ≥4/5	Questionnaires, Expert assessment	Connection density, Service availability, Service reliability
Reduced inspection time	Inspection cycle shortened by eliminating post-mission data offload and delayed analysis; decisions available within one drone flight window.	Comparative analysis, KPI analysis, Expert assessment	User experienced data rate/Throughput - UPLINK, End-to-end Network service latency, Service availability

Business Scalability and Replicability	Architecture perceived as scalable to multi-site deployments using the same edge–cloud control model.	Questionnaires, Expert assessment	Coverage, Connection density, Service availability
Lower cost of restoration/repairs in case of equipment fault or theft	8–15% restoration-cost reduction		
Perceived Increase in Renewable Energy Utilization	Decrease fuel consumption with use of electrical snowmobiles	Actual systems	(Device) energy efficiency
Network resource efficiency improvement through multi-connectivity	≥15% improvement in network resource utilization	KPI analysis, comparative analysis, expert assessment	User experienced data rate/Throughput - UPLINK, Service availability, Connection density
Reduced healthcare expenditure	Reduction of 40-45%	Expert assessment	NA
Reduced TCO for MNOs	Reduction of 30%	Expert assessment	NA
Increased revenues for MNOs	Increase of 20%	Expert assessment	NA
Reduced Need for Physical Infrastructure Upgrades	15% estimated cost avoidance	Expert assessment	NA
Enhanced Planning for Urban Accessibility	Qualitative improvement confirmed by planners	Expert assessment	NA

4.4 Cross-pillar analysis

The Smart Networks and Services Joint Undertaking (SNS JU) [7] adopts the concepts of "Sustainability for 6G" and "6G for Sustainability", which are considered as complementary and essential for sustainable future communication networks.

In particular, in AMAZING-6G, we adopt the sustainable design and deployment of 5G, B5G, and 6G network components, and especially 6G technological enablers, as critical for achieving Sustainability for 6G. To truly evaluate the impact on footprint reduction of 6G communications, we define KVIs such as Trust in Automated and AI-driven Energy Decisions, Trust in System Reliability, Reduction in Energy Consumption through energy-aware network and service orchestrators, Lower data overhead when deploying services in edge-cloud continuum, and Network resource efficiency improvement through multi-connectivity, among others.

On the other hand, to achieve 6G for Sustainability, all use cases focus on creating the positive impact on society, environment, and economy, through the use of advanced network and service features in 6G. As it can be seen from the previous subsections, a large majority of AMAZING-6G KVIs focuses exactly on this aspect. In particular, KVIs such as User Comfort and Quality of Life Satisfaction, Operational Safety Improvement, Minimized risk of accidents, Reduced environmental footprint, Carbon emission reduction, and Reduction in Operational and Energy-related Costs, among others, will assess the benefits of 6G technological enablers and the entire 6G ecosystem for the three sustainability pillars. The evaluation of both groups of KVIs, i.e., Sustainability for 6G and 6G for Sustainability, stretching over three sustainability pillars, will be one of the key aspects of the second phase of AMAZING-6G trials.

From the analysis we performed in previous subsections, focusing on specific pillar of sustainability KVIs, we will now briefly discuss some of the common trends. For instance, there is a strong alignment between environmental and economic benefits, as better energy efficiency usually implies cost reductions, or higher operational optimization yields lower emissions and higher productivity. This observation confirms that environmental and economic sustainability reinforce each other, and thus, after the full trial phase, it would be important to analyze the obtained KVIs from these two pillars and confirm whether this logical connection also stands in the field.

All three groups of KVIs mainly focus on assessing the role of AI, edge, and automation, in vertical industry domains and their process optimization. The improvements these technologies bring often reflect in higher efficiency, responsiveness, and scalability of vertical systems.

Given the importance of both KPI and KVI assessment in AMAZING-6G trials, we will further focus on the evaluation of both objective performance and subjective perception, and their mutual impact.

5 Current status and planning of pre-trial and trial activities

5.1 Pre-trial activities

This section presents a set of preliminary results that were achieved during the pre-trial phase, throughout 2025 and Q1 and Q2 of 2026. While Table 5-1 provides a snapshot of the obtained results for different KPIs presented in Section 3, the more detailed elaboration on these results in specific use-case context is provided in deliverables D4.1, D5.1, and D6.1. Therefore, D7.1 provides a project-wide view on KPI achievements at this stage, looking at the overall success in meeting use case requirements.

Table 5-1 Preliminary results from pre-trial activities.

KPI Name	Target values	Measurement	Yes/No
Service availability	>99,999% (E1, E3)	100% (E1) 100% (E3)	Yes (E1, E3)
Service reliability	>99,999% (T4)	100% (T4)	Yes (T4)
End-to-end Network service latency	<100 s (H1 scenarios 1, 2, 3, 4, and 5) <10 ms (H2, E3) <20 ms (E1) <30 ms (T4) <100ms (E2) <300ms (E3) <200ms (T1)	<30ms (H1) 7ms (H2) 10 ms (E1) 7.9–10.9 ms (5 runs) (E2) 20 ms (E3) 4ms (T4) 107.8ms (T1, simulation)	Yes (H1, H2, T1, E1, E2, T4) No (E3)
One-way application latency	<300ms (E3) <20ms (P5, T1, T2)	17 ms (P5) 250 ms (E3) 14.6ms (T1, T3)	Yes (P5, E3, T1, T2)
Slice provisioning time	<30s (E1)	15 s (E1)	Yes (E1)
Satellite Backhaul Latency (one-way latency)	<20ms (P5)	30 ms (P5)	No (P5)
User experienced data rate/Throughput – downlink	<86Mbps (H1 all scenarios) >4 kbps (H2, one packet per heart beat or per second), downlink minimal >50 Mbps (E3) >1 Gbps (P5)	12.6 Mbit/s (H1) 15 Mbps (H2) 750 Mbps (P5) 28 Mbps (E3)	No (H1, P5, E3) Yes (H2)
User experienced data rate/Throughput – uplink	>50 Mbps (E2) >100 Mbps (P5) >10 Mbps (E3/E1)	56.5Mb/s (T1, T2) 70 Mbps (P5) 100 Mbps (E1)	No (T1, T2, P5, E2) Yes (E1, E3, T4)

	>5 Mbps per sensor (T4) > 150 Mbps (T1, T2)	12.4–17.6 Mbps (E2) 21 Mbps (E3) 25 Mbps (T4)	
Internet throughput	>100 Mbps (P5 - downlink) >20 Mbps (P5 - uplink)	250 Mbps (P5 - downlink) 40 Mbps (P5 – uplink)	Yes (P5)
(Device) energy efficiency	Energy-efficient transmissions using a device powered with a 3.3V battery of capacity < 1000 mAh that can last at least several hours without recharging (H1)	93 days (H1) 17 hours (H2)	Yes (H1, H2)
Average RSU power consumption	<100 W (T1)	49.03W (T1, simulation)	Yes (T1)
Power consumption reduction vs Sub-6 GHz baseline	20%	24.7% (T1, simulation)	Yes (T1)
Increase in operational time of RSU	30%	32.9% (T1, simulation)	Yes (T1)
Run time	<10 ms (H2)	20ms (H2)	No (H2)
Coverage	>99% (E3)	100% (E3)	Yes (E3)
Positioning accuracy	<10 cm (E2)	1.72 cm (H: 1.4 cm, V: 1.0 cm) (E2)	Yes (E2)
Inference speed	<5s (E1, E3) <1s (T4)	0.02 s (E1) 0.5 s (E3) 55.2-65.19ms (T4)	Yes (E1, E3, T4)
ML accuracy	>0.9 (E1) <5 % (E3)	93.5% (E1) 4.66% (E3)	Yes (E1, E3)

In Table 5-1, we summarize the main results obtained for both vertical-agnostic and vertical-specific KPIs. Along with the results, we also remind the reader about the requirements, to facilitate the understanding of pre-trial achievements so far. As it can be seen from the table, only a subset of use cases have finalized measurements during the pre-trial phase. The remaining activities will be performed later in Q3 and Q4 of 2026, along with the full trials planned for 2027 (as discussed in Section 5.2). Thus, current results only reflect the ongoing work, while D7.2 will provide the full analysis of all trials and project-wide learnings.

Concerning the achievements so far, some KPIs such as Service availability, Service reliability, End-to-end network service latency, Slice provisioning time, and One-way application latency, are met for all use cases that performed pre-trial activities (apart from the deviation in case end-to-end latency for E3). This is, in particular, visualized in Figure 5-1, which highlights the fact that the core KPIs related to network and service performance are mature. This is a critical achievement for the full trial phase.

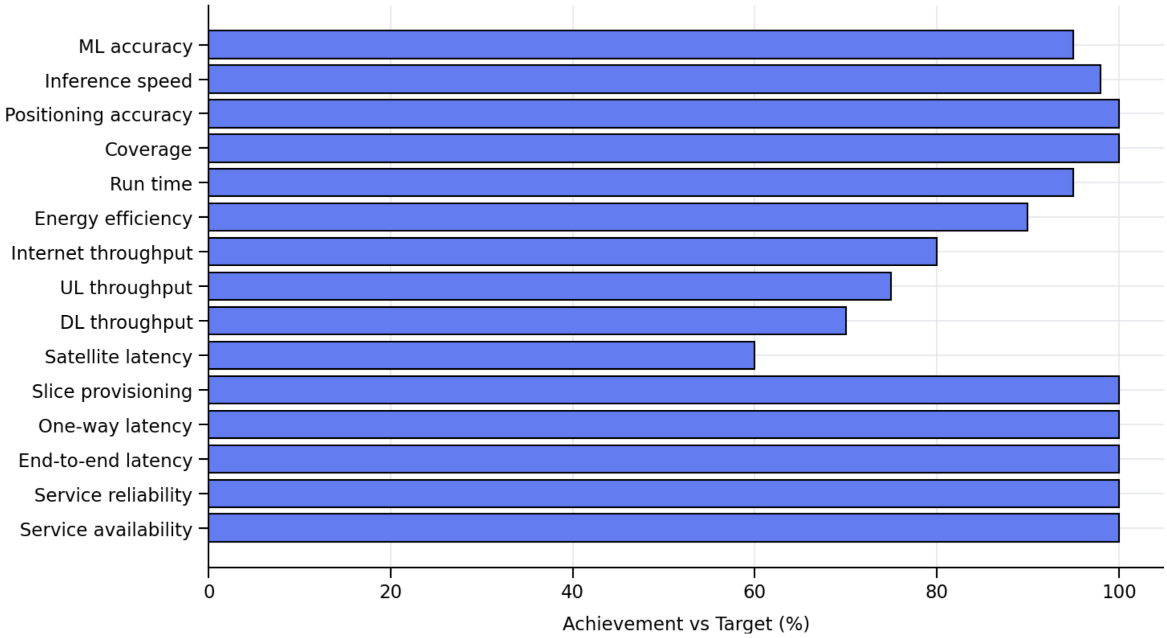

Figure 5-1 Pre-trial KPI achievement.

Now we zoom into some specific KPIs among the aforementioned group, such as latency-related KPIs. In particular, Figure 5-2 shows the three KPIs that belong to the Latency family, with very distinct target values. For the sake of clarity, it is important to note that the End-to-end network service latency also includes the computation time, which could be different for different applications, and as such, its target value is higher than the one for satellite backhaul latency that only refers to the communication part. Among these three latency KPIs, the only one that is not met yet is the satellite backhaul latency, which requires further optimization and testing. In particular, the impact of technological enablers related to Multi-RAT connectivity and NTN optimizations is expected to yield lower values of this type of latency.

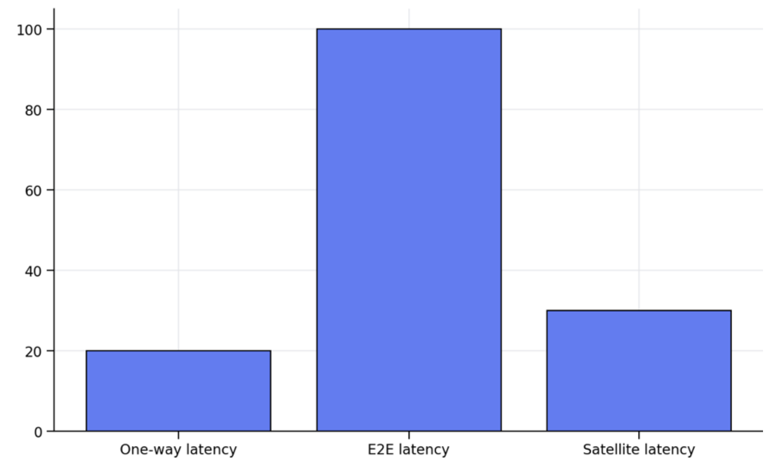

Figure 5-2 Latency family KPIs and preliminary achievements.

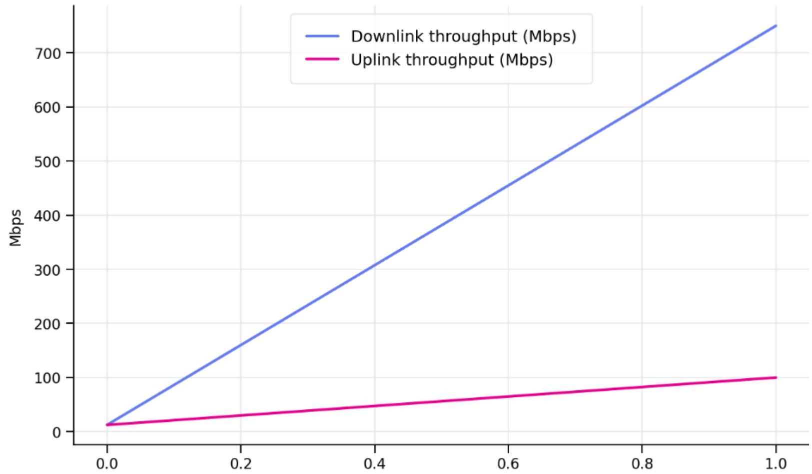

Figure 5-3 Uplink and downlink throughput achievements.

Finally, Figure 5-3 showcases the uplink and downlink throughput trends, i.e., measurements obtained across different pre-trial activities. The variability of obtained downlink throughput measurements is more significant than in the case of uplink throughput, which highlights the importance of further improvements and the use of advanced technological enablers and resource optimization in all network segments to achieve much higher throughput values. This is particularly important for uplink, as AMAZING-6G requirements are generally more strict than in majority of SNS JU projects reported in [3], as highlighted in Section 3.2 (Table 3-3).

Concerning the other KPIs whose target values are not met yet (Table 5-1 and Figure 5-1), it is important to highlight that WPs 4-6 are currently actively working on the further development of use cases and their integration with 6G technological enablers (WP3), which will be assessed in the second phase of the project. This impact of technological enablers, in particular, is expected to bring benefits that will result in meeting all target KPIs.

5.2 Trial Planning

As already mentioned in this deliverable, the trialing activities are planned as a phased process spanning 2026 and 2027, covering two distinct phases: pre-trial and trial phase, which ensures sufficient time for reaching maturity gradually for both the network technological enablers and applications associated with different use cases.

To visualize the overall timeline, we showcase the major groups of trial-related activities in Figure 5-4. The first phase focuses on pre-trial execution and initial demonstrations, enabling early validation of the technological enablers and use cases, and identification of potential integration issues. In parallel, application development continues throughout the project, with the final versions becoming available before the large-scale trial campaign. The pre-trial execution phase along with the initial KPI and KVI analysis is covered by this deliverable, whereas the subsequent activities will be reported in the final deliverable, i.e., D7.2.

During the final application development, the individual components are expected to reach the required maturity, after which the project will proceed with the full trial integration, followed by comprehensive trial execution across all trial sites. Throughout the entire process, KPI and KVI analysis is performed continuously to monitor technical performance, evaluate societal, environmental, and economic impact, and provide feedback for iterative improvements.

Finally, WP7 will conclude with final demonstrations and dissemination activities, showcasing the achieved results to stakeholders and maximizing the impact of the developed solutions.

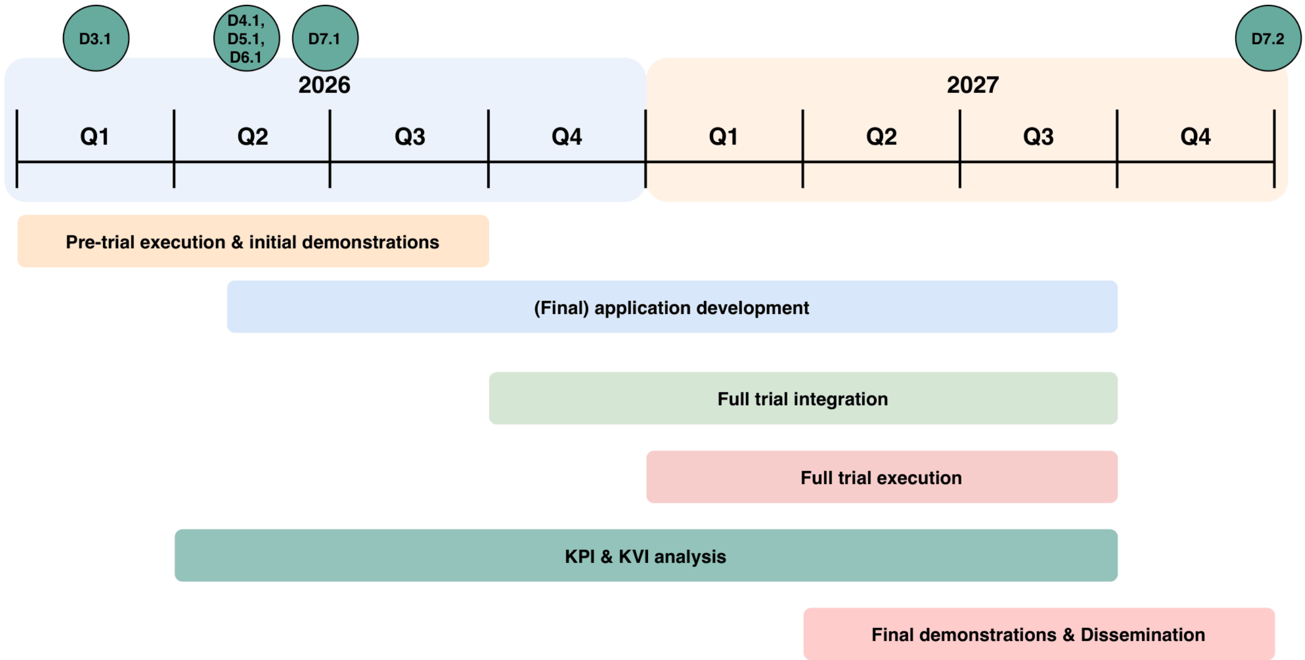

Figure 5-4 Overall planning of pre-trial and trial activities in AMAZING-6G.

It is important to note that AMAZING-6G is present in the SNS JU Test, Measurement and KPIs Validation (TMV) Working Group (WG), where lessons, insights, and KPI & KVI analysis from the large-scale trials covering 15 use cases will be shared with other SNS JU projects for the purpose of gaining broader visibility and exchange of experience and learnings.

5.3 Large-scale aspects in AMAZING-6G

Given the large-scale nature of AMAZING-6G trials, the overall trial campaign has been carefully designed to go significantly beyond small-scale proof-of-concept tests by addressing the complexity, scale, and operational conditions expected in future B5G/6G deployments.

Therefore, after careful elaboration of large-scale aspects in all 15 use cases across all vertical domains, and in close collaboration with WP4, WP5, and WP6, we distinguish below the main aspects that define AMAZING-6G large-scale trials. These aspects refer to validation of integrated end-to-end systems under realistic operational environments, combining advanced network and service capabilities with large-scale experimentation. This includes long-term data collection, stringent performance targets, geographically distributed trial sites, heterogeneous deployment configurations, and high technology readiness, ensuring that the results provide strong evidence of deployment feasibility and operational maturity.

- **Large data volume & data longevity**
  - Health-related use cases like H1 and H2 have very stringent availability and reliability requirements, which implies at least 1 month trial duration;
  - For public safety use cases like P1 and P2, the dynamic orchestration and network slicing performance will be evaluated under stress;
  - E3 will perform continuous data acquisition and analysis over several months of operation in the operational real-life solar park environment;
  - In case of T1 and T2, large amounts of data will be collected using emulated devices that mimic the presence of visually impaired traffic participants at complex junctions, triggering the invocation of technological enablers and implied network, compute, and energy resource optimizations;

    - Similarly in T4, stress testing utilizing emulated teleoperated vehicles will yield large amount of data, assessing the robustness of the slice orchestrator and Zero-touch Network and Service Management (ZSM) framework.
- **End-to-end system validation**
    - The T4 use case will proceed with the employment of end-to-end slice management across all network segments, such as Radio Access Network (RAN), transport, and core, as well as dynamic orchestration under load, and realistic teleoperation traffic from cameras and sensors, which are all indicators of a trial that aims at deployment-relevant validation at the system level.
- **Significant KPI enhancements**
    - Stringent End-to-end KPIs such as sub-10 ms latency and high reliability (up to 99.999%) with fast recovery times during mobility or failures, especially in PPDR and transport scenarios;
    - E1 focuses on extensive energy savings within Extended Renewable Energy Community with federated Smart Building Energy Management System (SB-EMS) across a diverse network of interconnected residential and commercial buildings.
- **Real-life and complex testing settings**
    - P2, P3 and P4 will perform continuous service delivery under harsh and real disaster-like/extreme conditions;
    - All PPDR use cases will adopt concepts of emulation of emergency scenarios (search and rescue, disaster response, arctic operations, etc.) and involvement of multiple stakeholders and first responders. Also, stress-test systems under worst-case conditions (network outages, satellite dependency, high congestion, mobility extremes) and real-life complexity (weather conditions, etc.) will be deeply embedded into the full trials;
    - E2 will use a full-scale, decommissioned industrial blade sourced directly from an operational wind farm, as an actual physical dimension and real-world structural defects as found in an offshore wind farm (Zephyros Field Lab in Vlissingen);
    - T1 and T2 will focus on complex junction involving vehicles and visually impaired persons;
    - T3 integrates a complex heterogeneous railway architecture that combines on-board train subsystems, track-side Leaky Coaxial Cable (LXC) sensing infrastructure, ORAN-based radio access, 5G core functions, Integrated Sensing And Communication (ISAC) processing, and train-to-train / train-to-ground communications within a single operational setup;
    - T4 is integrating B5G/6G networking, edge/cloud compute, decision logic, dynamic slice orchestration, and zero-touch service management, focusing on full-scale integrated system for teleoperation, rather than validating a single isolated component;
    - T5 is particularly exhibiting properties of complex port settings, where the installed network equipment and infrastructure will support connectivity over large operational areas, enabling all connected assets, IoT devices, cameras, and port equipment to reliably access the B5G/6G network.
- **Large coverage**
    - P1 and P5 will focus on expansion of coverage area through multiple technologies;

    - In E3, Ultra Reliable Low Latency Communication (URLLC)-like slice characteristics, automated control/forecasting workflows, and integrated AI-driven prediction and optimization will be validated in the operational solar park environment, spanning hundreds of square meters, and integrating and managing more than 100 Photovoltaics (PV) panels;
    - T5 will utilize the deployment of the private B5G/6G network across the full port area and ensure wide-area coverage and seamless connectivity for port operations.
- **Large technological maturity**
    - Majority of use case components integrated with technological enablers reaching TRL 7;
    - Use of operator grade (P5) or near commercial networks (P1) and private testbeds (All use cases).
- **Multi-pilot & multi-country trials**
    - Using pre-trial site in Poland and full trial site in Germany, in case of T3, as well as pre-trial in Belgium and trial activities in Germany in case of T4, giving the experimentation a broader geographic and operational scope.
- **Multiple deployment configurations**
    - P1, P2, and P5: Interoperability across large number of network technologies (5G, Wi-Fi, satellite/NTN, private tactical networks);
    - In T3, Frequency Range (FR) 1 LCX-based distributed sensing and FR2/mmWave communication and sensing, which broadens the technical scope and demonstrates applicability across different railway environments;
    - T5 will adopt multi-deployment configurations through digital twinning. The Digital Twin environment will provide the capability to monitor, analyze, and evaluate system behavior, operational efficiency, safety improvements, communication requirements, and potential bottlenecks under different deployment scenarios.

6 Conclusion

This deliverable presented the intermediate progress of WP7, focusing on the detailed KPI & KVI methodology, as well as planning and preparation of trial activities across the AMAZING-6G project. The document established a unified overview of the trial infrastructure, documented the capabilities of the participating trial and pre-trial sites, and defined a harmonized framework for evaluating technical performance and broader impact through KPIs and KVIs for all 15 use cases.

The trial site analysis, presented in Section 2, confirms that AMAZING-6G benefits from a diverse and complementary experimental ecosystem comprising sixteen trial and pre-trial sites distributed across ten European countries. The combination of private, public, and hybrid 5G infrastructures, advanced Beyond 5G/6G technological enablers, heterogeneous deployment configurations, and multiple vertical domains provides a solid foundation for validating innovative solutions in health, public safety, energy, and transport under realistic operational conditions. In addition, the preliminary pre-trial activities, shown and discussed in Section 5, demonstrate that the trial sites are operational and ready for the next phase of the project, as those initial measurements confirm the feasibility of multiple technological enablers and use cases, which are an essential starting point for full trials planned for the second half of the project.

One of the core contributions of this deliverable, as WP7 in general, is the establishment of a unified KPI and KVI framework that enables consistent evaluation across all verticals (Sections 3 and 4). Beyond assessing technical performance, the adopted KVI methodology embraces the SNS JU vision of both Sustainability for 6G and 6G for Sustainability, as discussed in Section 4.4. On one hand, the project evaluates how advanced 6G technologies contribute to more sustainable network operation through energy-aware orchestration, resource-efficient communication, trustworthy AI, and optimized edge-cloud deployments. On the other hand, the project assesses how these technologies embedded into 15 vertical use cases create positive societal, environmental, and economic impact by improving healthcare services, strengthening public safety, enabling more sustainable energy systems, and increasing efficiency in transport and logistics. This cross-pillar perspective ensures that the evaluation extends beyond network performance to capture the broader value created by 6G.

The deliverable also demonstrates that the AMAZING-6G trial campaign goes well beyond conventional proof-of-concept experimentation. The large-scale nature of the project is reflected in the validation of integrated end-to-end systems under realistic operational environments, involving geographically distributed trial sites, heterogeneous infrastructures, long-term experimentation, large volumes of collected data, demanding performance targets, advanced technological maturity, and multi-country testing setups. Together, these characteristics provide strong evidence of deployment feasibility and increase confidence in the scalability and operational readiness of the developed solutions for future B5G and 6G networks.

Finally, as indicated in Section 5.2, during the second half of the project, the consortium will complete the remaining pre-trial activities and execute the full-scale trials across all trial sites and use cases. The resulting KPI and KVI measurements, together with the cross-use-case analysis of technological enablers and lessons learned from the large-scale experimentation campaign, will be presented in Deliverable D7.2. Furthermore, the insights generated through

WP7 will contribute to the SNS JU TMV WG, facilitating knowledge exchange with other SNS projects and supporting the broader European 6G research and innovation ecosystem.

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Annex A

Table 8-1 Full list of definitions of vertical-agnostic KPIs per use case.

KPI Name	Definition	UCs
Service availability	- **Percentage of time the service can be delivered** (H1, H2, P2, P3, P4) - Percentage of time the service can be delivered, when running the trial for 1 week (P1) - Percentage of time when B5G connectivity is available between the drone and the network slice assigned to drone traffic (E2) - Percentage of time the service can be delivered within the building or REC according to defined SLA; includes coverage, slice availability, and connectivity of IoT devices (E1) - Percentage of time the B5G service is available and capable of delivering telemetry and control traffic within defined latency thresholds (E3) - Ability to maintain connectivity to public network as a backup and/or use of public resources (T5)	P1, P2, P3, P4, H1, H2, E1, E2, E3, T5
Service reliability	- **Period of time for which the service satisfies the required performance constraints** (DL/UL throughput, end-to-end service latency, etc.) (H1, H2, T4) - Period of time for which the service satisfies performance constraints (DL/UL throughput, E2E latency) in the building or REC (E1) - Percentage of time the service continuously satisfies performance constraints (latency, throughput) without packet loss affecting control or telemetry flows (E3) - Ability to monitor network configuration remotely (T5) - Percentage of time during which the enablers supporting the UC vertical service are operational and able to deliver the expected functionalities (T1, T2)	H1, H2, T4, E1, E3, T5, T1, T2
End-to-end Network service latency	- **Time between the source node sends a data packet to when the destination node receives it** (H1, H2, E2, T4: UE-edge, P2, P3) - Time between a source node sending a data packet (e.g., IoT sensor) and the destination node receiving it (edge/cloud SB-EMS platform), including RAN, UPF, and edge processing delays (Layers: Infrastructure, Orchestration; Segments: UE → RAN → Edge → Cloud) (E1) - Time between the source node sending a data packet and the destination node receiving it within the local tactical B5G/6G network. Measured end-to-end between UE and edge-hosted MCx services (UE ↔ RAN ↔ Local Core ↔ Edge) (P5) - Latency of the communication service in provisioning the feedback from the RLDT service toward VRU (Cloud->UE) (T1) - Latency of the communication service in provisioning the feedback from the Object warning service toward VRU (T2) - RTT (ms) measurement (T5) - Time between the source application/node sending a data packet and the destination application/node receiving a data packet in ms for all applications for both scenario 1 (UE-RAN-Local Core-Edge) and scenario 2 (UE-RAN-Core) (P1) - Time between the drone sending a data packet and the Digital Twin system or control room receiving it. Includes processing delay at edge UPF (Layers: Infrastructure, Orchestration / Segments: UE → RAN → Edge → Core → Control) (E2) - The total of “Service latency” and “AI Service RTT”, where applicable for obstacle detection (T3)	H1, H2, E2, T4, P2, P3, P4, E3, E1, P5, T1, T2, T5, P1, T3

	- End-to-end latency of the RLDT service from sensor data provisioning to VRU notification (T1) - End-to-end latency of the Object warning service from sensor data provisioning to VRU notification (T2) - End-to-end application-level latency between command generation at the energy management application and execution acknowledgment returned by the edge gateway. Includes processing and transmission delays (Application → Edge → Application) (E3)	
One-way application latency	- **Time it takes for a message or command to travel from the source application to the destination application (e.g., SB-EMS app to actuator), including any processing at edge or cloud** (Layers: Application, Edge, Cloud; Segments: App → Edge → App) (E1) - Latency of the communication service in provisioning the feedback from the RLDT service toward VRU: Cloud->UE (T1) - Latency of the communication service in provisioning the feedback from the Object warning service toward VRU: Cloud->UE (T2)	E1, T1, T2
Slice provisioning time	- Service Configuration/slice provisioning for each MCx and non MCx services (P1) - **The time elapsed between a vertical request and an active slice ready to carry traffic** (T4)	P1, T4
Satellite Backhaul Latency (one-way latency)	One-way latency introduced by the satellite backhaul segment, measured as the time for a packet to traverse the satellite link between the local edge/core and the remote macro network (Local Core/Edge ↔ Satellite Backhaul ↔ Remote Core) (P5)	P5
Multi-RAT handover latency	Time elapsed during handover between 5G NR and Wi-Fi connectivity within the port operational area, ensuring service continuity for teleoperation and IoT data flows. Measured as the interruption time perceived at the application layer during RAT switching (T5)	T5
Orchestration latency	- **Time elapsed between transmission of a control packet from the cloud/edge orchestration platform and reception at the edge gateway controlling the inverter, measured over the URLLC slice under operational conditions** (Application → Core → Edge (URLLC slice, local UPF)) (E3) - Service deployment time/Service scaling time for network service orchestrator.	E3, T4
Application migration latency	- Time needed to migrate the task between the RSU and the MEC server (T1, T2) - **Time needed to migrate/relocate an edge application from one edge node to another (T4)**	T1, T2, T4
QoS restoration time	The elapsed time between the detection of an SLA violation and the restoration of compliant service conditions (T4)	T4
User experienced data rate/Throughput – downlink	- **Number of bits, originating from the source node, correctly received by the destination node over a certain period of time** (H1, H2, P3, P4) - Downlink achievable data rate available to the edge gateway for receiving configuration updates, dashboards data, and AI model updates over the eMBB slice: Core-->RAN-->Edge (E3) - Downlink achievable data rate available to a device (IoT sensor or user terminal) in the smart building, measured between device and edge/cloud SB-EMS platform, capturing throughput of sensor data and control commands (E1) - DL data rate (T3)	H1, H2, P3, P4, E3, E1, T3, P5, T5

	- Maximum achievable data rate successfully delivered to the UE in downlink direction from the local tactical network for MCx services (voice, video, data) - DOWNLINK (P5) - Uplink and downlink data rates achieved over the public-private integrated B5G network, measured between UE and edge/cloud services during port operations. Validates seamless data plane continuity across private and public network domains (T5)	
User experienced data rate/Throughput – uplink	- **Number of bits, originating from the source node, correctly received by the destination node over a certain period of time** (P2, P3) - Uplink data rate measured between the drone 5G UE and the edge/core UPF, capturing throughput of ultrasound and sensor data transmitted in real-time: Infrastructure: RAN, Edge, Core / Segments: UE → Edge → Core (E2) - Uplink achievable data rate available to the edge gateway for transmitting inverter telemetry, sensor data, and logs to the cloud platform: Edge-->RAN-->Core (E3) - Uplink achievable data rate available to a device (IoT sensor or actuator) in the smart building, measured from device to SB-EMS edge/cloud platform, capturing energy data uploads and command signaling (E1) - UL data rate (T3) - Minimum amount of data that needs to be transferred from a single device (sensor or camera installed on the teleoperated vehicle) to the network over a certain period of time - UPLINK (UE-edge) (P1, T4) - Maximum achievable data rate successfully transmitted from the UE to the network in uplink direction toward edge-hosted MCx services - UPLINK (P5) - Maximum achievable data rate in the uplink connection when RSU is granted for improved quality (T1) - Uplink and downlink data rates achieved over the public-private integrated B5G network, measured between UE and edge/cloud services during port operations. Validates seamless data plane continuity across private and public network domains (T5)	P2, P3, E2, E3, E1, T3, T4, T1, T2, T5, P5
Uplink data rate	Maximum achievable data rate successfully transmitted from the UE to the network in uplink direction toward edge-hosted MCx and non MCx' services and for VR-enabled services (Scenario 1: UE ↔ RAN ↔ Local Core ↔ Edge, Scenario 2: UE ↔ RAN ↔ Core) (P1)	P1
Connection density	- Number of concurrently connected field devices (inverters, sensors, gateways) supported per square meter without degradation of service (E3) - Number of devices (IoT sensors, actuators) that can be simultaneously connected per square meter in the smart building environment (E1) - **Number of connected devices per area** (H1) - Maximum number of UEs connected from one private and one public network or two private networks which may connect to the 6G System within a defined area while satisfying the other KPIs (P1)	E3, E1, H1, H2, P1
Internet throughput	- Achievable downlink data rate between the local tactical network and external IP networks via satellite backhaul - downlink: Local Core ↔ Satellite Backhaul ↔ Internet (P5) - Achievable uplink data rate from the local tactical network to external IP networks via satellite backhaul - uplink: Local Core ↔ Satellite Backhaul ↔ Internet (P5)	P5
Scalability	- Availability of RLDT service in stressed scenarios (e.g., when number of devices and/or data volume increases) (T1)	T1, T2

	- Availability of object warning service in stressed scenarios (e.g., when number of devices and/or data volume increases) (T2)	
(Device) energy efficiency	- The capability of the RIT/SRIT to minimise the power consumed by the device modem in relation to traffic characteristics (H1, H2) - Energy consumption reduction in the edge-cloud compute continuum where vertical applications are running (T4) - **Power/energy consumption reduction in the source/destination nodes (W/J) per bit or bit per W/J))** (P2) - Energy consumption reduction due to the active management of the sleeping/idle mode of the RAN equipment (T3)	H1, H2, T4, P2, T3
Power consumption reduction vs Sub-6 GHz baseline	Average electrical power drawn by the mmWave RU during data transfer (T1, T2)	T1, T2
Watt per Throughput	Power-to-performance efficiency metric (T1, T2)	T1, T2
Run time	- The execution time of the algorithm on one second of input data, including overhead of the container (e.g., TLS session termination) (H1) - **The execution time of the algorithm, including overhead of the container** (e.g., TLS session termination) (H2)	H1, H2
Coverage	- **Geographic area where a network signal can be received and used by a device (H1, H2, P2)** - Percentage of the solar park area where the 5G signal is available and usable by the RedCap gateway with stable connectivity (E3) - Percentage of indoor area within the smart building where network signal can be received and used by devices (sensors, actuators, user terminals) (E1)	H1, H2, P2, E3, E1
Mobility	Max. speed, at which a defined QoS and seamless transfer between radio nodes which may belong to different layers and/or radio access technologies (multi-layer/multi-RAT) can be achieved (H1)	H1
Positioning accuracy	- **Difference between the calculated position and the actual position of the device** (E2) - Positioning accuracy of UC actors (T1, T2)	E2, T1, T2
Service area	Description of the area within which the UE could find itself while satisfying the other KPIs with and without enabler (P1)	P1
Inference speed	Latency incurred in the computation of an AI model in inference model (E1, E3)	E1, E3
ML accuracy	- **Accuracy of ML model** (RMSE, F1-score,..) (E1, E3) - Accuracy of detection of PPDR incidents (e.g. fire etc) (P1) - Accuracy of detection of transport safety incidents (e.g. usage of seatbelts etc) (T5)	E1,E3, P1, T5
Time for detection of incident	Time for detection of PPDR incident (e.g. fire etc) (P1)	P1
False positives rate	False positives for detection of PPDR incident (e.g. fire etc) (P1)	P1

Operational Continuity Index (OCI)	Measures the level of gradual and linear response of the DT model to input changes with only minor deviations from linearity, under normal circumstances.	T5
Boundary Logic Compliance Rate (BLCR)	Evaluates the fraction of degenerate or extreme scenarios for which the model produces outputs that match analytically expected results.	T5