Smart Networks and Services International and European Cooperation Ecosystem

D3.3 Updated Trends Analysis in Vertical Sectors

Document Summary Information

Start Date	01/01/2023	**Duration**	27 months
Project URL	https://smart-networks.europa.eu/csa-s/#SNS-ICE		
Deliverable	D3.3 Updated trends Analysis in Vertical Sectors		
Related Work Package	WP3	**Related Task**	T3.2
Contractual due date	31/01/2025	**Actual submission date**	27/01/2025
Type	Report	**Dissemination Level**	Public
Deliverable Editor	Claudio de Majo (Trust-IT Services)		

This project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101095841

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Revision history (including peer reviewing & QA)

Version	Issue Date	% Complete	Changes	Contributor(s)
v0.1	16-17/12/2024	20%	Initial structure, section 4	Claudio de Majo (Trust-IT Services)
v0.2	19-20/12/2024	50%	Sections 1 and 4	Claudio de Majo, Maria Giuffrida (Trust-IT Services)
v0.3	23/12/2024	70%	Sections 1 and 2	Claudio de Majo (Trust-IT Services)
v0.4	30/12/2024	80%	Sections 1, 2 and 4	Claudio de Majo (Trust-IT Services)
V0.5	10/01/2025	85%	Review of all sections & quality check	Raffaele De Peppe (TIM), Claudio de Majo (Trust-IT Services)
V0.6	13/01/2025	95%	Support with verticals analysis in sections 2 and 3	Kostas Trichias, Alex Kaloxylos (6G-IA)
V0.7	14/01/2025	95%	Document review	Kostas Trichias (6G-IA), Aija Vorslava (VASES)
V0.8	24/01/2025	99%	Comments addressed	Claudio de Majo (Trust-IT Services)
V1.0	27/01/2025	100%	Final review and submission	Kostas Trichias (6G-IA)

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Abbreviations List

Abbreviation / Term	Description
3GPP	3rd Generation Partnership Project
5GAA	5G Automotive Association
5G MAG	5G Media Action Group
5G PPP	5G Public Private Partnership
6G-IA	6G Smart Networks and Services – Industry Association
AI	Artificial Intelligence
AIOTI	Alliance for Internet of Things Innovation
CPE	Customer-Premises Equipment
DMR	Digital Mobile Radio
ESA	European Space Agency
EIM	European Rail Infrastructure Managers
eMBB	Enhanced Mobile Broadband
ERTICO	European Road Transport Telematics Implementation Coordination Organisation
IoT	Internet of Things
MCPTT	Mission-Critical Push-To-Talk
ML	Machine Learning
MoU	Memorandum of Understanding
mMTC	Massive Machine-Type Communications
NTN	Non-Terrestrial Networks
PPDR	Public Protection and Disaster Relief
PSCE	Public Safety Communication Europe
RAN	Radio Access Network
R&D	Research and Development
R&I	Research and Innovation
RIS	Reconfigurable Internet Surfaces
RTLS	Real-time Location Systems
SLAs	Service-Level Agreements
SNS	Smart Networks and Services
ThZ	Terahertz
UC	Use case
UPF	User Plane Functionality
URLLC	Ultra Reliable and Low Latency Communications
US	United States
VET	Vertical Engagement Tracker
xR	Extended Reality

Executive Summary

This deliverable provides an in-depth analysis of vertical industry and use case trends in the context of the Smart Networks and Services Joint Undertaking programme. As such, it focuses on the integration of 5G technologies and the anticipated advancements of 6G. The study combines insights from a survey of industry stakeholders and an extensive review of data from the SNS Vertical Engagement Tracker (VET), which catalogues over 247 use cases across various R&I projects funded under SNS Calls 1 and 2 for a total of 52 projects overall.

The survey highlighted varying levels of 5G adoption across sectors, with automotive and Industry 4.0 demonstrating higher levels of integration due to critical applications such as autonomous vehicles and advanced manufacturing systems. Key functionalities of 5G, such as enhanced mobile broadband, ultra-reliable low-latency communication, and massive machine-type communications, are widely applied in use cases, including real-time telepresence, smart city operations, and connected healthcare. Challenges, including infrastructure gaps, high costs, and regulatory barriers, pose significant hurdles to wider adoption Future expectations for 6G include advancements such as integrated sensing and communication, satellite-terrestrial network integration, and AI-driven network services, which are expected to enable transformative applications across vertical sectors. However, addressing issues such as standardisation, spectrum allocation, and infrastructure development will be critical to progress in these areas.

Moreover, a comprehensive mapping of the use cases developed across SNS JU R&I projects was added to the VET online tool, revealing the current state-of-the-art linked to use cases, underscoring key vertical sectors geographical distribution, maturity of use cases, key trends and adoption gaps across the whole European R&D ecosystem.

Overall, the analysis identified key trends across vertical industry domains, current deployment maturity across different industrial domains, and emerging key functionalities. At the same time, challenges were noted, particularly concerning the high costs of deployment, delays in regulatory harmonisation, and the readiness of supporting technologies. Complementary technologies such as Cloud/Edge Computing, AI/ML, Digital Twins, and cybersecurity were recognised as critical enablers for scaling connectivity solutions while emerging technologies like generative AI and immersive platforms hold promise for reshaping industries but require further maturity. By aligning connectivity advancements with industry-specific needs, this document provides a strategic framework for guiding future initiatives and supporting the development of advanced connectivity solutions across the SNS ecosystem.

1 Introduction

1.1 Purpose and scope

This deliverable presents a trend analysis of the vertical industry domains mapped in the context of the SNS ICE project, supporting the international engagement of the SNS JU office since January 2023. During 2024, a large collection of use cases targeting vertical industry domains developed by SNS JU R&I projects were collected and mapped through the VET online tool. Moreover, an updated trends analysis on vertical associations was conducted through an online survey highlighting the current adoption of state-of-the-art 5G and beyond technologies, adoption challenges and barriers and the expectations linked to 6G applications. Together, this combined set of actions allows for a thorough evaluation of the current status of engagement and maturity of the telco ecosystem (both 5G and beyond and 6G) across several vertical industry domains.

1.2 Structure of the document

The document is structured as follows:

- **Section 1** introduces the document
- **Section 2** analyses the datasets of the SNS ICE survey circulated among relevant vertical associations. The survey analyses vertical trends and use case priorities across industries by addressing key questions on the adoption, application, and future expectations of 5G and 6G technologies. It provides insights into respondents' predictions for 5G adoption rates, identifying varying levels of integration and critical factors such as infrastructure availability and sector-specific needs. It highlights industry use cases leveraging 5G functionalities, including low-latency communication, massive IoT connectivity, and enhanced broadband, while identifying areas requiring further technological maturity, such as 3GPP Release 16/17 applications in automotive and advanced sensing in healthcare. The section also outlines expectations for Beyond 5G/6G technologies, focusing on improved bandwidth, global coverage, AI-powered services, and sustainability. Additionally, it evaluates responses to the relevance of complementary technologies, such as Cloud/Edge Computing, AI/ML, and Digital Twins, emphasising their transformative potential in enhancing scalability, efficiency, and security across various sectors. The analysis provides a roadmap for aligning connectivity advancements with industry demands while addressing existing gaps and challenges.
- **Section 3** provides a thorough analysis of the datasets entered in the VET online tool. By December 2024, 247 use cases from Calls 1 and 2 had been catalogued, analysed, and classified into industry sectors Industry 4.0/Manufacturing, Media/xR (Augmented and Virtual Reality), Automotive/ Transport / Logistics, Smart Cities, Smart Health, Security/Public Protection and Disaster Relief (PPDR), Tourism and Culture, Smart Agriculture, Non-Terrestrial Networks (NTN), Education, Smart Energy, and an additional category labelled "Other" for diverse or unspecified verticals. These sectors are analysed for trends, distribution, and innovation under the SNS JU initiatives. The section also highlights trends across sectors, geographical distribution, and project streams. Use cases span trials, demonstrations, proof of concept, and prototypes, with ongoing updates ensuring quality and relevance. Finally, a gap analysis is performed with the aim of staying abreast of existing trends and suggesting potential measures to boost lagging ones.
- **Section 4** concludes the document and outlines the way forward, leading to the drafting of deliverable D3.4 Position Paper.

1.3 Relation to other documents

This document further develops the groundwork laid by the D3.1 Vertical Engagement Tracker, describing the inception of the VET online tool from both a conceptual and technical perspective [1]]. Moreover, it continues and further deepens the vertical trends analysis initiated by D3.2 Initial Trends Analysis in Vertical Sectors, bringing first-hand data through a survey circulated among relevant associations [2]]. A further and final update of this deliverable will be the D3.4 Position Paper, summarising the vertical industry domains-related work carried out in the context of the SNS ICE project over its 27-month lifetime.

2 Survey analysing vertical trends and use case priorities across associations

To continue the trends analysis initiated in D3.2 Initial Trends Analysis in Vertical Sectors, a questionnaire was created in July 2024 and circulated among relevant vertical associations.

2.1 Concept

This questionnaire was designed to collect detailed insights from key stakeholders across various vertical sectors regarding the adoption, implementation, and future expectations of 5G and 6G technologies. The survey seeks to understand the current landscape and identify critical trends, gaps, and opportunities related to these transformative technologies. It addresses both immediate applications of 5G and forward-looking perspectives on the evolution toward 6G. Such a qualitative analysis reflects the challenge of understanding diverse requirements across vertical industry domains to bridge the gap between technology developers and industry stakeholders across Europe, boosting innovation and competitiveness [3].

Part 1: 5G Adoption and Use Cases

The first section of the survey sought to provide a detailed understanding of the current state of 5G integration across various industries, as well as identify existing challenges and opportunities for further development. This included gathering data on the following:

- **5G Adoption and Use Cases**: insights into the extent of 5G integration within specific industries, including adoption rates, common use cases, and the metrics used to measure success.
- **Technological Functionalities:** how 5G-specific functionalities like enhanced mobile broadband (eMBB), massive machine-type communications (MTC), and ultra-reliable low-latency communication (URLLC) are applied in various contexts.
- **Trends and Challenges**: Identifying major trends shaping vertical industries, evaluating the role of supporting digital technologies, and understanding barriers to 5G market adoption.

Part 2: Future Expectations for 6G

The second section of the survey transitioned to exploring the anticipated evolution of connectivity and the role of 6G in addressing unmet needs. The main themes included:

- **Future Expectations for 6G**: perspectives on the use cases and technological features that 6G could enable, which are currently unattainable with 5G.
- **Challenges and Barriers**: Identifying obstacles to the deployment and adoption of 6G technologies, including economic, regulatory, and technological constraints.
- **Cross-Sectoral Insights**: overlooked issues and valuable cross-sector digital technologies that could complement or rely on advanced connectivity solutions.

2.2 Target Audience

The questionnaire targeted a wide range of stakeholders, including industry experts, associations, and organisations operating across diverse vertical sectors such as automotive, healthcare, manufacturing, smart cities, and media/xR. Its purpose was to comprehensively assess the current and future impact of 5G technologies and explore expectations for the evolution to 6G.

Respondents included 18 unique contacts from different types of member enterprises of the following associations:

- **ERTICO** - European Road Transport Telematics Implementation Coordination Organisation[1].

[1] https://ertico.com/

- **5GAA** - 5G Automotive Association.[2]
- **PSCE** - Public Safety Communication Europe.[3]
- **6G Health Institute**[4]
- **5G MAG** - 5G Media Action Group.[5]
- **ESA** - European Space Agency.[6]
- **EIM** - European Rail Infrastructure Managers.[7]
- **AIOTI** - Alliance for Internet of Things Innovation.[8]

While three respondents were representatives from vertical associations, among the remaining ones, large enterprises emerged as the most prominent ones, with nine respondents (also including three large academic institutions). Conversely, medium companies and SMEs were underrepresented, with 3 and 2 respondents, respectivelyFigure 1).

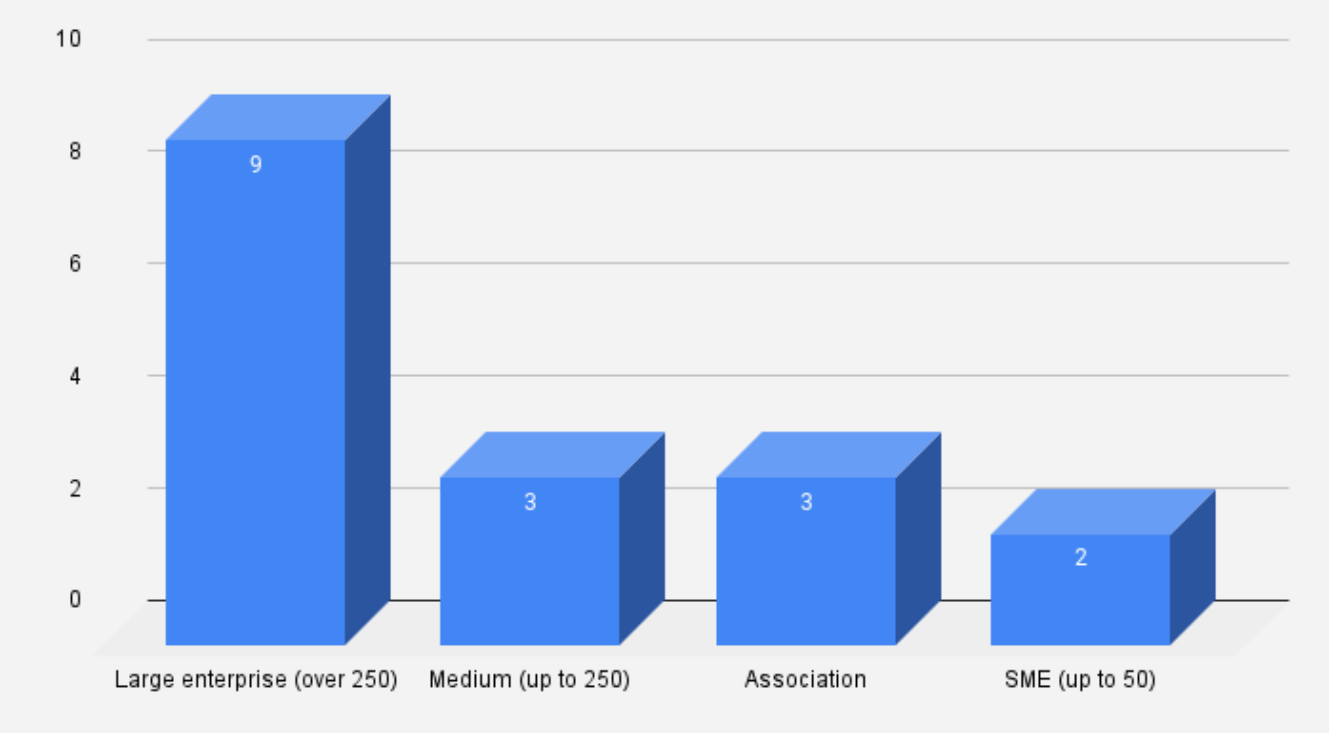

Figure 1. Survey respondents per company type

In terms of targeted vertical sectors, distribution patterns show a concentration of respondents in logistics and manufacturing-related sectors, with limited input from others. The Automotive/Transport/Logistics sector led with five respondents, followed by Industry 4.0/Manufacturing with 4. Education was the third most represented sector, with three respondents. Security/PPDR, Smart City, and other categories each accounted for two respondents. Finally, sectors such as Smart Energy, Media/xR, Smart Health, and Space/Non-Terrestrial Networks (NTN) were unrepresented, with only one respondent each Figure 2).

[2] https://5gaa.org/
[3] https://www.psc-europe.eu/
[4] https://6ghi.info/en/
[5] https://www.5g-mag.com/
[6] https://www.esa.int/
[7] https://eimrail.org/
[8] https://aioti.eu/

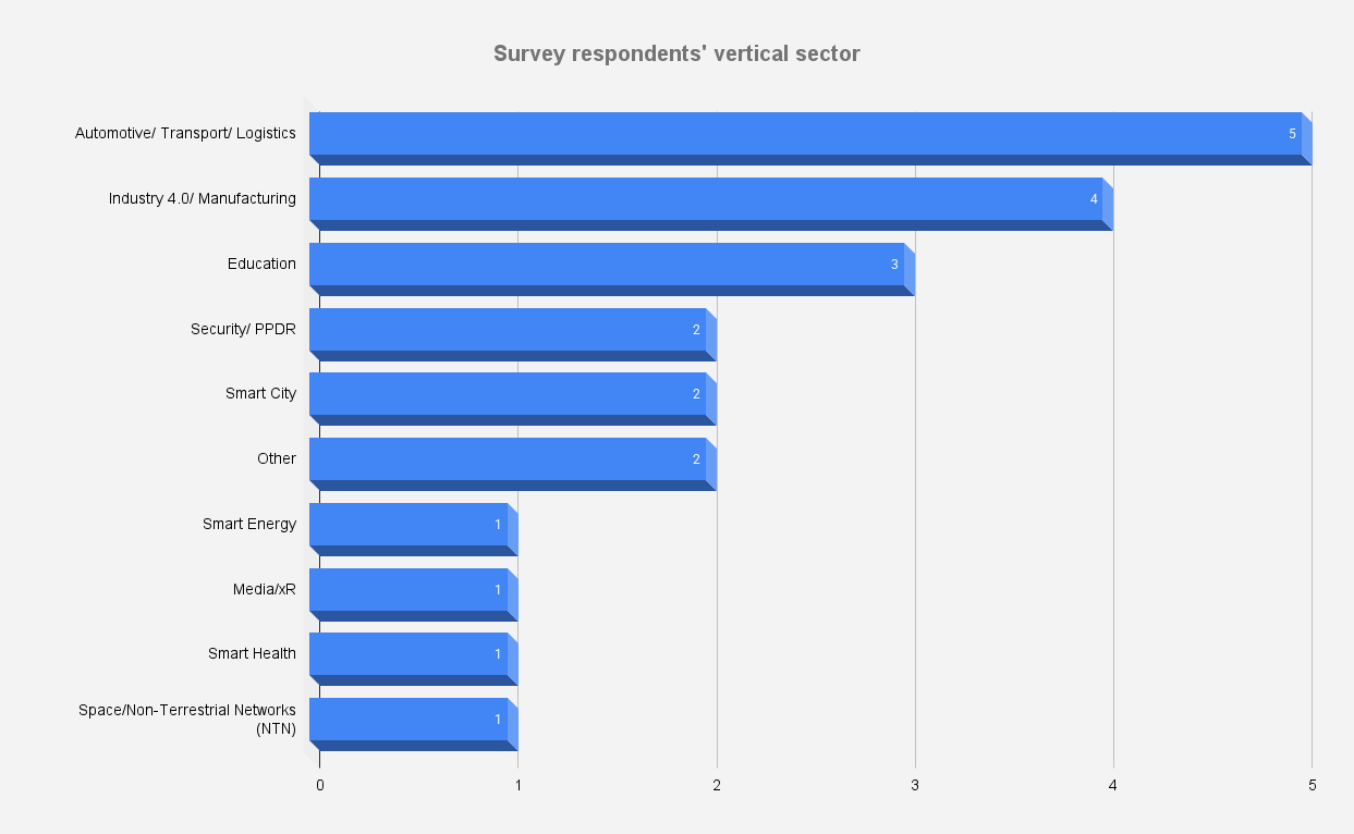

Figure 2. Survey respondents per vertical sector

2.2.1 2030 trends for 5G and beyond

2.2.1.1 5G Connections and Factors

Respondents predicted a wide range of 5G penetration levels across industry verticals by 2030, spanning from 0% to 100%. Several respondents estimated moderate adoption rates, such as 30% to 70%. Such a figure reinforces the current state of adoption of 5G across Europe and globally over the last few years [4]. More precisely, while 5G applications are still considered a potentially dominant connectivity technology due to the multiple potential applications, widespread adoption will depend on critical factors such as the availability of supporting infrastructure and relevant services. Some industries, particularly automotive, emphasised the role of 5G in enabling autonomous, connected vehicles. For instance, one respondent noted that while all new vehicles manufactured by 2030 would be equipped with 5G capabilities, only 30-40% of vehicles on the road would be actively utilising 5G, given the transitional nature of technological adoption.

In other domains, such as connected vehicles and drones, adoption rates hovered around 25% to 50%, reflecting slower integration due to challenges like infrastructure gaps and reliance on complementary technologies such as low-Earth orbit (LEO) satellite constellations. Notably, sectors emphasising on-the-move scenarios or advanced use cases like autonomous machines showed greater optimism for 5G integration, citing the necessity of reliable, high-speed connectivity for such applications and their integration with AI and ML applications.

When identifying common 5G form factors, respondents highlighted specific devices and applications that would dominate their respective industries by 2030. Autonomous connected machines, such as cars, were frequently mentioned as a primary form factor, reinforcing the automotive industry's reliance on 5G for enabling advanced features like real-time data exchange, predictive maintenance, and autonomous driving. Similarly, sensors emerged as a widely anticipated form factor across multiple sectors, underscoring the importance of IoT (Internet of Things) devices in collecting and transmitting data for smart applications.

Other form factors, such as drones, robots/cobots, and 5G modules, were also cited, but their prominence varied depending on the industry. For instance, robots and cobots were more commonly associated with manufacturing and logistics, while drones were expected to play a key role in transportation, agriculture, and infrastructure monitoring. Interestingly, some respondents noted uncertainty in identifying a dominant form factor, emphasising that the adoption trajectory would heavily depend on technological advancements, market demands, and the success of enabling innovations like network slicing and private 5G networks. Overall, the answers align with the main market forecast, with 5G as a financially impactful technology on global GDP in the next five years [5].

2.2.1.2 5G Advantages

In terms of 5G's impact on industrial use cases not feasible with 4G, listed 5G-enabled advancements mainly included latency, bandwidth, and reliability. These span various sectors and broadly align with trend analyses highlighting the transformative potential of 5G in areas previously constrained by the limitations of 4G.[6]

One notable category includes applications in **telepresence and immersive experiences**, such as holoportation-based teleconferences with multiple participants and live artistic shows performed across different distant scenarios. These use cases rely heavily on 5G's low latency and high reliability to enable real-time, seamless interactions previously unattainable with 4G [6].

In the **automotive** sector, examples like automated valet parking, automated vehicle manoeuvring, and HD map data collection for Level 3 autonomous vehicles emphasise the crucial role of 5G in enabling vehicle-to-everything (V2X) communication. However, several responses noted that the full realisation of these use cases depends on deploying newer 5G releases, such as Release 16 (5G-V2X direct) and Release 17 (NTN IoT). This illustrates the lag between standardisation and industry-wide implementation, particularly for advanced vehicle connectivity.

For **healthcare**, integrating 5G hybrid slices has enabled medical devices like infusion pumps, ECG machines, and syringe drivers to connect wirelessly. These devices, previously not air-interface enabled, now benefit from 5G/RedCap-enabled connectivity, offering enhanced monitoring and control capabilities critical in clinical environments.

In **smart city** applications, 5G has facilitated multiple sensor monitoring systems and improved services like real-time location systems (RTLS) for vehicle-human collision avoidance and human-robot collaboration. Additionally, 5G's support for high throughput has enabled advancements in real-time video analysis, including platforms like Edgybees' 3D real-time systems, which integrate low-latency and high-data-rate features for enhanced situational awareness.

Other responses highlighted the role of **network infrastructure** enhancements, such as using satellite communication to backhaul 4G networks in remote areas. With 5G, this has evolved to allow direct end-user device connections, thanks to 3GPP standardisation. Additionally, 5G has enabled improved network security and local user plane functionality (UPF), which are critical for maintaining service-level agreements (SLAs) and robust system monitoring.

For **entertainment and interactive technologies**, the ability to deploy real-time VR and AR applications and coordinate autonomous vehicle movements represents another significant advancement. While some respondents noted that these applications were technically feasible with 4G, 5G's enhancements in bandwidth and latency have significantly improved their performance and user experience.

2.2.1.3 Priority use cases and functionalities

Significant 5G Use Cases

The reported use cases highlight the critical role of 5G in enabling applications that demand high reliability, low latency, and enhanced connectivity. Insights are also aligned with previous studies highlighting the centrality of 5G in facilitating seamless real-time data exchange, massive device interconnectivity, and robust network performance. Such applications make 5G ideal to support mission-critical operations, drive innovation across industries, and enable previously unattainable advanced digital services. Its transformative capabilities allow businesses to adopt new models and enhance operational efficiency, fostering economic growth and technological progress [7].

Specific examples of 5G applications mentioned in the survey include:

- In the **media/xR** sector, 5G is utilised to improve reliability, enhance bandwidth symmetry (particularly uplink performance), and provide real-time visibility of network conditions. Metrics like live and accurate visibility for applications and services measure success in these use cases.
- The **automotive** sector showcases use cases like data collection for HD maps, automated vehicle manoeuvring, and V2X communication. These applications benefit from enhanced broadband and low-latency functionalities of 5G. However, implementing advanced features like 5G Release 16 (direct communication) is still in development, with rollout anticipated shortly.
- For **healthcare**, 5G-enabled medical technology is a significant focus, with devices such as infusion pumps and robotic surgery systems leveraging 5G connectivity. Success is measured in terms of efficiency gains, such as time saved for medical professionals. Studies suggest 15-20% potential time savings for nurses through digital solutions.
- In **smart cities**, urban platforms connecting multiple verticals allow local authorities to manage city operations and respond promptly to issues. These applications rely on massive machine-type communications (mMTC) to connect a wide array of sensors and devices.
- Industrial **manufacturing** uses 5G for monitoring machines, operators, and internal logistics. Applications such as monitoring stress levels in operators through wearable sensors and managing Automated Guided Vehicles (AGVs) demonstrate 5G's capacity for low-latency and private network applications.
- **Energy** management benefits from 5G's ultra-reliable low-latency communication (URLLC), enabling smart grid monitoring and control. Success is measured by latency, reliability, and optimisation levels achieved through these applications.

Application of 5G Functionalities

The implementation of specific 5G functionalities across verticals varies based on the unique requirements of each sector. **Enhanced Mobile Broadband** (eMBB) is widely used for video analysis, telemetric connectivity, and broadband communication. At the same time, **Ultra Reliable and Low Latency Communications** (URLLC) support mission-critical applications such as collision avoidance in automotive use cases and control loops in industrial monitoring. **Massive Machine-Type Communications** (mMTC) connects devices and sensors in smart cities and healthcare.

Some responses highlighted gaps and ongoing challenges. For instance, in the **media/xR** sector, uplink performance and real-world latency (far from 1 ms) still fall short of expectations. Similarly, while data collection and manoeuvring rely on current 5G functionalities in the **automotive** sector, the absence of Release 16 chipsets limits more advanced capabilities. In industrial contexts, efforts are underway to integrate technologies like ultra-wideband for positioning, but challenges remain in achieving seamless integration with 5G.

Overall, the reported use cases and functionalities highlight the diverse ways in which 5G is being utilised across sectors. At the same time, the remaining gaps provide a roadmap for future innovation and deployment, pointing to the areas requiring further technological advancement and standardisation.

2.2.1.4 Future relevant trends and technologies

In terms of observed trends, the responses to the questions on trends shaping vertical sectors and the technologies influencing those trends provide a detailed overview of how industries foresee the evolution of their operations in the coming years. The insights highlight technological advancements, sector-specific challenges, and overlooked issues that could significantly impact the adoption and implementation of 5G and beyond.

Overall, respondents indicated a broad range of transformative trends across sectors, such as human-machine collaboration, non-terrestrial networks (NTN) integration, real-time optimisation in energy networks, and advanced automation in industrial settings. For example, the growing complexity of energy networks necessitates the handling of large datasets, optimisation processes, and extremely low latency for effective operation. Similarly, in manufacturing, human-centric processes and collaborative robotics reflect efforts to address demographic shifts, such as an ageing workforce, while maintaining productivity. Other trends include mixed gaming and distributed live media sources in the media/xR sector, where high-density user environments and advanced presence technologies are becoming pivotal. Similarly, transitioning from digital mobile radio (DMR) to mission-critical push-to-talk (MCPTT) in public safety highlights a shift towards more robust and reliable communication frameworks.

Key technologies

Across verticals, several key technologies are consistently identified as enablers of these emerging trends:

- **Advanced Connectivity (5G and Beyond 5G)**: widely regarded as a foundational technology, advanced connectivity enables seamless integration of NTN, eMBB, and URLLC.
- **Artificial Intelligence (AI) and Generative AI**: AI is posed to play a crucial role in automation, predictive analytics, and optimisation, particularly in industrial automation and energy management.
- **Edge Cloud and IoT for Big Data Analytics**: integrations at the computing continuum level facilitate real-time data processing and decision-making, which are critical for sectors such as manufacturing, healthcare, and energy.
- **Cybersecurity Technologies**: with increasing reliance on interconnected systems, robust cybersecurity measures are essential across all sectors.
- **Digital Twins**: Used extensively for simulation, predictive maintenance, and resource optimisation, digital twins are particularly relevant in the manufacturing, healthcare, and energy sectors.
- **Extended Reality (xR) and the Metaverse**: These technologies are pivotal in media, education, and manufacturing for immersive experiences and training.

Key challenges

Several respondents highlighted overlooked issues and challenges that could hinder the widespread adoption of 5G and related technologies:

- **Cost and Licensing**: the cost of customer-premises equipment (CPE) and regulatory licensing are significant barriers, particularly for smaller enterprises and emerging markets.
- **Standardisation and Compatibility**: delays in standardising technologies, such as Open RAN and railway 5G, can slow adoption and increase implementation complexity.
- **National Regulations and Geopolitical Factors**: such factors could influence the deployment of 5G infrastructure and spectrum allocation, particularly in regions with stringent regulatory environments.

Overall, the key trends and gaps observed underscore the interconnectedness of sectors and the need for collaborative solutions. While technologies like AI, edge cloud, and digital twins drive innovation, challenges such as cost, licensing, and regulatory frameworks must be addressed to ensure equitable and efficient

implementation. Although these insights provide a roadmap for industry stakeholders to prioritise investments and strategies in line with the evolving demands of their sectors, these should also be combined with other key discussions on scalability and regulation that need to take place in the EU context over the next years. These include consolidating national telecom markets through mergers tied to rapid 5G deployment, harmonising spectrum licensing to balance auction revenues with long-term investment in network quality, and leveraging targeted, technology-neutral public investments to support connectivity where market dynamics fall short. Additionally, a harmonised approach to 5G cybersecurity, including consistent implementation of the EU 5G toolbox, is essential for building trust and ensuring resilience as industries and public services become increasingly digitalised [8].

The overall key trends, challenges and technologies are described in Table 1 below.

Table 1: 5G-related trends, challenges and technologies

Key Trend	Description	Challenge	Technologies
5G adoption and impact	Diverse adoption rates across industries, ranging from 0% to 100% by 2030, with moderate estimates (30%-70%) reflecting transitional adoption phases	High costs of customer-premises equipment (CPE) and regulatory licensing create barriers for SMEs and emerging markets	**Advanced Connectivity:** Integration of eMBB, URLLC, and mMTC enables diverse 5G applications.
5G Applications	Autonomous machines, connected vehicles, and IoT devices as key 5G use cases for real-time data exchange and predictive maintenance	Infrastructure gaps, especially in rural and underserved areas, limit coverage and delay adoption	Artificial Intelligence (AI): Powers predictive analytics, automation, and real-time decision-making
Low-Latency Solutions	Low-latency applications like telepresence, holoportation, and real-time XR experiences are driving demand for 5G capabilities	Standardisation delays for technologies like Open RAN and 5G-V2X limit the implementation of advanced use cases	**Edge Cloud and IoT:** Support big data analytics, real-time monitoring, and distributed decision-making across sectors
Smart City Integration	Industry-specific use cases, including remote healthcare monitoring, automated valet parking, and smart grid energy management	Limited integration of complementary technologies like satellite communication for ubiquitous 5G coverage in remote areas	**Digital Twins:** Enable simulation, predictive maintenance, and resource optimisation for manufacturing, healthcare, and energy
Enhanced Infrastructure	Enhanced network infrastructure (e.g., 5G hybrid slices) supports seamless connectivity for critical applications like medical devices and industrial automation	Uplink performance and real-world latency (far from 1 ms) fail to meet expectations in high-demand applications like media and automotive sectors	**Extended Reality (XR):** Provides immersive experiences and real-time interactions for education, media, and industrial training
Collaboration and growth	Collaboration across sectors, such as automotive, healthcare, and energy, drives innovation and ensures cross-industry applicability	Financial barriers for SMEs and the need for targeted investments hinder equitable access to advanced connectivity	**Non-Terrestrial Networks (NTN):** Complement terrestrial 5G infrastructure to provide global connectivity
Economic Contribution	5G's impact on economic growth is increasingly recognised, with significant contributions to global GDP projected within the next five years	Complexity of deployment, including the high number of base stations and integration challenges, slows progress in scaling advanced 5G technologies	**Network Slicing and APIs:** Enable customisation and scalability of 5G networks for diverse applications, including mission-critical operations and high-bandwidth tasks

This project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101095841

2.2.2 Use cases for 6G

2.2.2.1 Relevant use cases

In terms of use cases that are not feasible with 5G but will require advancements through 5G evolution or 6G, respondents highlighted several specific needs and challenges across industries:

- **Holoportation-Based Teleconferences and Live Performances**: real-time, immersive teleconferencing and distributed artistic performances demand extremely low latency and high data throughput to enable seamless interaction among multiple participants and distant scenarios.
- **NTN/TN Wideband Integration**: ubiquitous coverage across all roads and remote areas is essential for applications such as vehicle health monitoring, truck maintenance, and group synchronisation for public networks. These require a seamless connection at any time and place.
- **Advanced Sensing and Routing**: minimal-invasive image capturing, sub-network slicing, and semantic routing are key for privacy-sensitive applications, especially in rural or remote locations requiring satellite connectivity.
- **Immersive Augmented Reality and Metaverse Use Cases**: full sensory experiences in the metaverse and immersive AR demand ultra-low latency and high bandwidth to enable real-time interaction and hyper-personalized applications like remote surgery.
- **Mission-Critical Applications**: seamless roaming between networks, ubiquitous coverage, and enhanced network reliability are required for public safety, emergency response, and other mission-critical scenarios.
- **Automotive Use Cases**: features such as better visibility of objects around corners, teleoperated driving and high-bandwidth video streaming from multiple cameras highlight the need for enhanced data synchronisation and network capabilities.

2.2.2.2 Market challenges and barriers

The responses regarding challenges and barriers to market deployment and adoption of promising 5G evolution and 6G use cases highlight a broad spectrum of critical issues that extend well beyond technological limitations. These challenges encompass economic, regulatory, and operational aspects that could significantly hinder the widespread adoption of advanced connectivity solutions. Addressing these barriers is essential to unlocking the full potential of next-generation networks and ensuring their successful integration across various vertical sectors.

- **Limited Availability and Affordability**: There is a lack of affordable offers from commercial networks for specific applications such as events. Furthermore, NTN service providers are currently non-existent in Europe, with availability primarily centred in the US.
- **Insufficient Technological Maturity**: Many technologies are still in the early development stages (e.g., TRL2 for low-energy networking), especially in domains like healthcare, where current funding levels are inadequate.
- **Spectrum and Regulatory Constraints**: Challenges include frequency spectrum allocation, potential interference, and the need for compliance with equipment regulations. The global availability of 5G capabilities also poses significant hurdles for industries like automotive, which operate on a global scale.
- **Financial and Economic Barriers**: High costs associated with customer premise equipment (CPE), licensing, and development time are significant barriers. Additionally, economic constraints impede the proper optimisation and deployment of these technologies.

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- **Infrastructure and Deployment Complexity**: The number of 6G base stations required is expected to be very high, contributing to infrastructure and deployment challenges.
- **Operator and Supplier Dependency**: Policies of network operators, cost structures, and the limited availability of suppliers for edge devices and killer applications are other critical bottlenecks.

2.2.2.3 Impactful features (game-changing factors)

As far as impactful features are concerned, respondents emphasise a wide range of cutting-edge 6G features poised to revolutionise various vertical sectors, showcasing the significant potential these advancements hold for addressing current technological limitations and enabling entirely new applications across industries. These are aligned with key trends observed across the global telco R&D landscape as demonstrated by recent trends analyses [9].

- **Integrated Sensing & Communication**: frequently highlighted, this feature enables simultaneous communication and environmental sensing, which could improve applications like autonomous vehicles, smart cities, and industrial automation by improving real-time data acquisition and decision-making.
- **Integration with Satellite Connectivity**: this feature addresses connectivity gaps in remote and rural areas, providing ubiquitous coverage and supporting use cases such as global logistics, remote healthcare, and emergency response scenarios.
- **Network APIs** (Network as a Service): by offering flexible and programmable network functionalities, Network APIs are expected to facilitate customisation and scalability for sectors like telecommunications, manufacturing, and smart energy, enhancing efficiency and reducing operational complexity.
- **Integrated AI & Communication** (AI Network Services): AI-driven network services promise to optimise resource allocation, enhance predictive maintenance, and enable advanced automation, particularly benefiting sectors like automotive, healthcare, and Industry 4.0.
- **Cloud-Native Communications** ("Cloud Networks"): this feature supports seamless scalability and flexibility, particularly for enterprises leveraging edge computing and IoT applications, ensuring cost-effective deployment and dynamic resource management.
- **Low Energy Communications**: essential for sustainability goals, this feature allows energy-efficient operations in IoT devices and sensors, making it crucial for sectors focusing on environmental monitoring and smart agriculture.
- **RIS** (Reconfigurable Intelligent Surfaces): because they can dynamically enhance signal quality and network coverage, RIS can significantly improve connectivity in dense urban areas and complex industrial environments.
- **Terahertz (Thz) Communications**: this feature holds promise for ultra-high-speed data transfer and low-latency applications, potentially transforming sectors like media, entertainment, and scientific research.

2.2.2.4 Expectations

In terms of various expectations from Beyond 5G/6G that could address the limitations of 5G and enable new advancements across different sectors. In line with the expectations of the SNS R&D community, mainly focusing on ultra-low latency, energy efficiency, enhanced reliability, RAN-core convergence and IoT integration [10], the expectations gathered in this survey emphasise a combination of technological enhancements, improved operational capabilities, and broader coverage:

- **Sufficient Bandwidth**: increased capacity to support data-intensive applications and an expanding number of connected devices, ensuring seamless performance even in dense network environments.
- **Global Coverage**: Addressing connectivity gaps in remote and underserved areas will enable worldwide access to critical services such as telemedicine, smart agriculture, and global logistics.

- **Very Low Latency**: supporting real-time applications, including autonomous vehicles, remote surgeries, and industrial automation, by reducing delays in data transmission.
- **AI-Powered Services** (Delivered from Within the 5G Network): leveraging integrated artificial intelligence to enhance network performance, provide predictive analytics, and support advanced use cases like cognitive radio and intelligent automation.
- **Simplicity & Maintainability**: simplifying network management through features like automated slice setting and user-friendly configuration tools, making advanced networks accessible to more sectors.
- **Security/Resilience**: enhancing protection against cyber threats and ensuring network reliability for mission-critical applications such as public safety and financial transactions.
- **Economic Sustainability**: reducing deployment and operational costs to make advanced connectivity solutions viable for small and medium enterprises and developing regions.
- **Environmental Sustainability**: lowering energy consumption and carbon footprints of communication networks to support global climate goals.
- **New Device Form Factors**: enabling innovative and compact hardware designs for a variety of applications, from wearable health monitors to IoT devices.

2.2.2.5 Valuable technologies

In terms of other digital technologies considered valuable in conjunction with telco connectivity applications, the survey reveals distinct preferences and priorities for digital technologies to be integrated into the Beyond 5G/6G connectivity landscape, ranking preferred technologies through average grade criteria (see Table 2). **Cloud/Edge Computing** and **AI/ML** consistently emerge as the most highly valued technologies, reflecting their critical role in enhancing real-time decision-making, data processing, and scalability across various verticals. Technologies such as **Digital Twins** and **Immersive Communications** also received notable scores, signalling their growing importance in transforming industries like manufacturing, healthcare, and smart cities. Digital Twins, in particular, promise advancements in predictive maintenance, simulation, and operational efficiency, while immersive technologies, including Augmented and Virtual Reality, are key to redefining user experiences in sectors like education, media, and entertainment. **Generative AI** also received strong average grades, showcasing its potential to reshape industries by offering creative, context-aware solutions that leverage vast data sets for innovation. This result indicates the increasing recognition of generative AI's capabilities, especially in areas like content creation, personalised experiences, and problem-solving. **Cybersecurity technologies** also rank prominently as well, reflecting the heightened awareness of security and resilience in increasingly interconnected digital ecosystems. As networks expand with more IoT devices and edge-based architectures, safeguarding sensitive data and ensuring secure communications are seen as indispensable.

Interestingly, **Quantum Computing**, **Blockchain**, and the **Metaverse** received moderate average scores, indicating mixed perspectives on their immediate impact. While these technologies are recognised for their potential, their relatively lower scores suggest that they are seen as more long-term or niche solutions that may require further maturity and adoption to achieve broader significance. The low scores for **Smart Connectivity** indicate a narrower application scope or less familiarity with their transformative potential compared to more widely discussed technologies like AI/ML and Cloud/Edge Computing. This could also reflect the survey participants' focus on immediate, actionable technologies rather than speculative or less-defined concepts.

In conclusion, respondents seem to clearly prioritise technologies that directly support scalability, efficiency, and innovation across industries while also acknowledging the need for robust cybersecurity and the exploratory potential of emerging domains like generative AI and immersive communications. These findings underscore the critical importance of aligning connectivity advancements with technological integration to enable meaningful, industry-wide transformations.

Table 2: Technology evaluation

Key technology	Average priority rate
Cloud/Edge Computing	5.6
Cybersecurity Technologies	4.8
AI/ML	4.6
Smart Connectivity	4.5
Digital Twins	4
Generative AI	3.8
Immersive Communications	3.5
Quantum Computing	2.6
Blockchain	2.5
Metaverse	2.5
Others	0.5

Key information on use cases, barriers, game-changing factors and expectations can are summarised in Table 3 below.

Table 3: 6G-relevant use cases and barriers, game-changing factors and future expectations

Relevant use cases	Barriers	Game-changing factors	Expectations
Holoportation Teleconferences: Real-time immersive telepresence for artistic performances and multi-user interactions	• **Limited Availability:** Lack of affordable network solutions and NTN service providers, especially in Europe. • **Spectrum Constraints:** Allocation and interference issues	**Integrated Sensing & Communication**: Real-time data acquisition for applications like autonomous vehicles and smart cities	**Sufficient Bandwidth:** Support for data-intensive applications and dense device networks
NTN/TN Wideband Integration: Ubiquitous coverage for remote areas, enabling vehicle health monitoring and truck maintenance	• **Technological Maturity:** Early-stage development of low-energy networking and other enabling technologies • **High Costs:** Customer-premises equipment (CPE) and infrastructure expenses	**Satellite Connectivity Integration:** Provides global coverage for remote healthcare, logistics, and emergency responses	**Global Coverage:** Connectivity in underserved and remote areas for critical applications like telemedicine and smart agriculture
Metaverse & Immersive AR: Full sensory experiences requiring ultra-low latency and high bandwidth for hyper-personalized applications like remote surgery	• **Economic Barriers:** Development and deployment costs hinder accessibility for SMEs • **Supplier Dependency:** Limited edge device and application providers	**Reconfigurable Intelligent Surfaces (RIS):** Enhances signal quality and connectivity in dense environments	**Very Low Latency:** Real-time applications like autonomous vehicles, remote surgery, and industrial automation become feasible
Mission-Critical Applications: Enhanced network reliability for public safety and emergency response scenarios.	• **Infrastructure Complexity:** High number of required base stations for widespread 6G deployment • **Operational Challenges:** Managing complex deployments across diverse verticals	**Network APIs (Network as a Service):** Customisable network functionalities for scalability and efficiency across multiple sectors	**AI-Powered Services:** Intelligent automation, cognitive radio, and predictive analytics integrated into network operations

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Automotive Use Cases: Better visibility around corners, teleoperated driving, and high-bandwidth video streaming for enhanced safety and monitoring	**Regulatory Challenges:** Delays in standardisation for key technologies like Open RAN and global interoperability	**Terahertz Communications:** Supports ultra-high-speed data transfer for media, entertainment, and scientific research	**Simplicity & Maintainability:** Automated configuration tools and simplified management make advanced networks accessible to more industries
Advanced Sensing and Routing: Privacy-sensitive applications with minimal-invasive image capturing and sub-network slicing for remote or rural areas	**Dependency on Complementary Technologies:** Applications relying on satellite communication and advanced sensing face adoption hurdles in rural areas	**Cloud-Native Networks:** Seamless scalability and flexibility, especially for enterprises leveraging edge computing and IoT applications	**Security and Resilience:** Enhanced protection against cyber threats and improved reliability for mission-critical applications
Smart City Solutions: Real-time location systems (RTLS), collision avoidance, and urban platform integration	**Financial Barriers:** Limited funding for early-stage technologies and implementation in developing markets	**Low Energy Communications:** Supports sustainability goals with energy-efficient IoT devices and sensors	**Economic Sustainability:** Reduced deployment and operational costs to make connectivity solutions viable for SMEs and emerging markets

2.3 Discussion

The survey offered a detailed overview of vertical trends and use case priorities, focusing on the current state of 5G adoption and the expectations for 6G technologies. Overall, the Automotive/Transport/Logistics and Industry 4.0/Manufacturing sectors were the most represented, followed by Education and Security/PPDR. Sectors such as Smart Energy, Media/xR, and Smart Health were underrepresented.

Key findings from the survey demonstrated the increasing role of 5G in enabling applications across diverse sectors, including autonomous driving, urban platform integration, real-time telepresence, and connected healthcare systems. The survey also identified the functionalities that 5G offers, such as enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC), and massive machine-type communications (mMTC), as critical in meeting the needs of these use cases. However, respondents also highlighted several current challenges, including infrastructure costs, regulatory barriers, and delays in standardisation, which could limit the adoption of these technologies across sectors.

The survey also explored expectations for 6G technologies, which are anticipated to address some of the limitations of 5G. Respondents highlighted potential use cases such as integrated sensing and communication, satellite-terrestrial network integration, and AI-driven networks. These advancements are expected to support emerging applications like real-time monitoring, advanced automation, and global connectivity. However, respondents emphasised the need for significant progress in areas such as standardisation, spectrum availability, and infrastructure deployment to ensure the feasibility of these technologies. Similarly, the survey provided insights into the most important complementary technologies for the deployment of telco applications across several industry verticals. The most prominent key enablers of future connectivity solutions include Cloud/Edge Computing, AI/ML, and cybersecurity, which are essential for supporting scalable and efficient applications, particularly in manufacturing, healthcare, and logistics. Other emerging technologies, such as digital twins and immersive communications, were also noted as promising but less mature in their adoption.

Overall, while the survey's findings highlight the importance of telco applications for all vertical industry domains, several challenges still remain in adopting 5G telco applications and preparing the breeding ground for the transition to 6G. As the survey highlighted several critical factors shaping connectivity trends across vertical sectors, it provided key stakeholders with valuable insights to build a roadmap to align strategies. A key trend observed was the varying pace of 5G adoption across industries, influenced by sector-specific requirements and technological readiness. For example, sectors like Automotive/Transport/Logistics and Industry 4.0/Manufacturing are more advanced in their 5G integration, driven by the need for high-speed, reliable connectivity to support use cases such as autonomous vehicles, automated guided vehicles (AGVs), and predictive maintenance. In contrast, sectors like Smart Energy and Smart Health, while acknowledging the benefits of 5G, face challenges such as high implementation costs and limited supporting infrastructure.

The importance of addressing regulatory and standardisation issues that continue to act as barriers to widespread 5G and future 6G adoption was also highlighted. For example, delays in spectrum allocation and the lack of international standards for technologies such as Open RAN and NTN (Non-Terrestrial Networks) were cited as key obstacles. These barriers not only affect the pace of adoption but also create additional costs and operational complexities for stakeholders, particularly in sectors requiring global interoperability, such as automotive and logistics. Furthermore, the role of cross-industry collaboration in overcoming these barriers was emphasised. For instance, the deployment of 5G and 6G technologies in smart cities requires cooperation between municipalities, private technology providers, and telecom operators to ensure efficient infrastructure development and resource allocation. Similarly, in the healthcare sector, partnerships between medical device manufacturers, hospitals, and connectivity providers are crucial for enabling applications such as remote surgery and real-time patient monitoring. Similarly, the need for targeted investment in enabling technologies like AI/ML, Cloud/Edge Computing, and cybersecurity was also underscored. These technologies were identified as

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foundational to unlocking the potential of advanced connectivity solutions across sectors. For example, Cloud/Edge Computing was noted as critical for real-time data processing in applications like smart manufacturing and urban management, while cybersecurity remains essential for maintaining the integrity and reliability of interconnected systems. Just as importantly, the importance of addressing economic challenges, particularly for small and medium enterprises (SMEs) that may struggle to afford the high costs of 5G infrastructure and devices, was highlighted. Policymakers and industry leaders were urged to explore funding mechanisms, subsidies, and collaborative frameworks to make advanced connectivity solutions more accessible.

3 SNS JU Vertical Engagement Tracker

This section complements the previous ones about current vertical industry trends in the telco industry with insights from the SNS R&D community. Such an analysis is carried out through a collection of 247 use cases developed by SNS JU Call 1 and 2 R&I projects. These have been uploaded in the SNS JU Vertical Engagement Tracker, an online platform aiming at mapping and monitoring the use cases developed by the SNS JU R&D across several industry domains. These are also interlinked to relevant vertical associations also mapped in the tool.[9]

While the technical creation and implementation of the tool have been thoroughly described in D3.1 Vertical Engagement Tracker [1], this section describes the process of populating the tool with relevant use cases from the SNS community up to 15 December 2024. Also, an analysis of the available datasets is provided, both through a high-level view of all use cases (see 3.2), a sub-sector analysis of the most popular vertical industry domains (3.3) and third-party funded projects (3.4).

3.1 Data input methodology

Call 1 inputs gathering was initiated in October of 2023, and the tool launched in February 2024 after reaching about 80 entries. To collect the needed datasets to populate the tool, a survey was circulated among projects through multiple alignments with the SNS JU Steering Board (SB) and Technology Board (TB). Moreover, both collective and one-to-one reminders were sent to project coordinators and technical managers, which allowed constant updates on projects.[10] Conversely, for Call 2, the input-gathering phase was initiated in October 2024 and was finalised in December 2024.

As shown in Table 4, 247 total use cases were submitted and mapped in the tool. Out of these, 187 belonged to 30 R&D projects funded under Call 1 and 60 use cases belonged to 22 projects funded under Call 2. Finally, 64 use cases were submitted by third-party actors sponsored by SNS project-related open calls.

Table 4: Use case inputs submitted to VET as of 15 December 2024

SNS JU Call	Number of projects	Total inputs
Call 1 and 2	52	247
Call 1	30	187
Call 2	22	60
Open Call 3rd party funding Experimenters (cumulative for calls 1 and 2)	5	64

Once each input was received, it was manually added to the tool after undergoing a quality and consistency check from the SNS ICE consortium. This ensured coherence and the constant updating and polishing of the datasets received. For a sector-by-sector summary of the use cases linked to the projects that replied to the survey, categorised by call and ordered alphabetically see Appendix 1 Industry verticals.

A thorough data breakdown is provided in section 3.2. Specific information on each use case can be found through the Vertical Cartography's search function or using the vertical sector filter functionality.

[9] Browse the tool at this link https://sns-trackers.sns-ju.eu/vertical-engagement-tracker
[10] The survey is available at this link https://6g-ia.eu/vertical-engagement-tracker/

3.2 Cumulative data on use cases

Drawing from the datasets collected in the tool, a quantitative analysis of the use cases mapped in the VET was performed. This followed the main taxonomies utilised to map and characterise the use cases, allowing a complete cross-domain description of the use cases mapped in the online tool. Below, a detailed analysis of the collected data is provided, including a general trends analysis across all vertical industry domains (see 3.2) and a subsector analysis mapping all the vertical sectors with over ten use cases (3.3).

It has to be stressed, that the below analysis has absolutely no competitive/comparative characteristics among projects and does not aim in ranking the SNS JU projects in any fashion or manner. The fact that some projects support / address more use cases or vertical sectors than others is dependent on multiple aspects, including the goals of the specific SNS call they are addressing, the existence or not of open calls, the orientation of their R&I activities, their consortium size and more.

3.2.1 Coverage of industry verticals

Figure 3 below presents the **247 vertical use cases**, submitted to the VET by **52 SNS JU R&I projects** in Call 1 and Call 2. Among these, TrialsNet leads with 34 use cases, followed by FIDAL with 25. 6G-XR and Hexa-X-II follow with 16 and 14 use cases, respectively. 6G-SANDBOX accounts for 13 use cases, while TARGET-X has 11. Projects like 6G-NTN, IMAGINE-B5G, and 6G-SHINE range between 7 to 9 use cases. Several projects, including TIMES, RIGOUROUS, and 5G-STARDUST, contribute between 4 and 6 use cases. The remaining projects have fewer than 4 use cases, with a significant number only contributing 1 or 2 use cases each, such as SUPERIOT, 6G-TWIN, and PROTEUS-6G.

Zooming into vertical use cases for Call 1 projects. TrialsNet leads with 34 use cases, while FIDAL follows with 25. 6G-XR and Hexa-X-II contribute 16 and 14 use cases, respectively. 6G-SANDBOX accounts for 13 cases, and TARGET-X addresses 11. 6G-NTN and IMAGINE-B5G each report 8 use cases, while 6G-SHINE and TIMES have 7. Use cases for projects like RIGOUROUS and 5G-STARDUST range between 4 and 6. Smaller projects, such as SEASON, SUPERIOT, and others, show only 1 or 2 cases, and some projects, like ACROSS and FLEX-SCALE, show no reported use cases. Conversely, for Call 2 projects, Automotive/Transport/Logistics leads with 12 instances, significantly ahead of other sectors. Media/AR and Smart City each account for seven use cases, while Industry 4.0/Manufacturing and Security/PPDR each register 6. Smart Agriculture contributes four use cases, while Smart Health, Education, and Non-Terrestrial Networks (NTN) each appear 2 times. Smart Energy appears only once, while the "Other" category accounts for 11 cases, representing diverse, unspecified verticals.

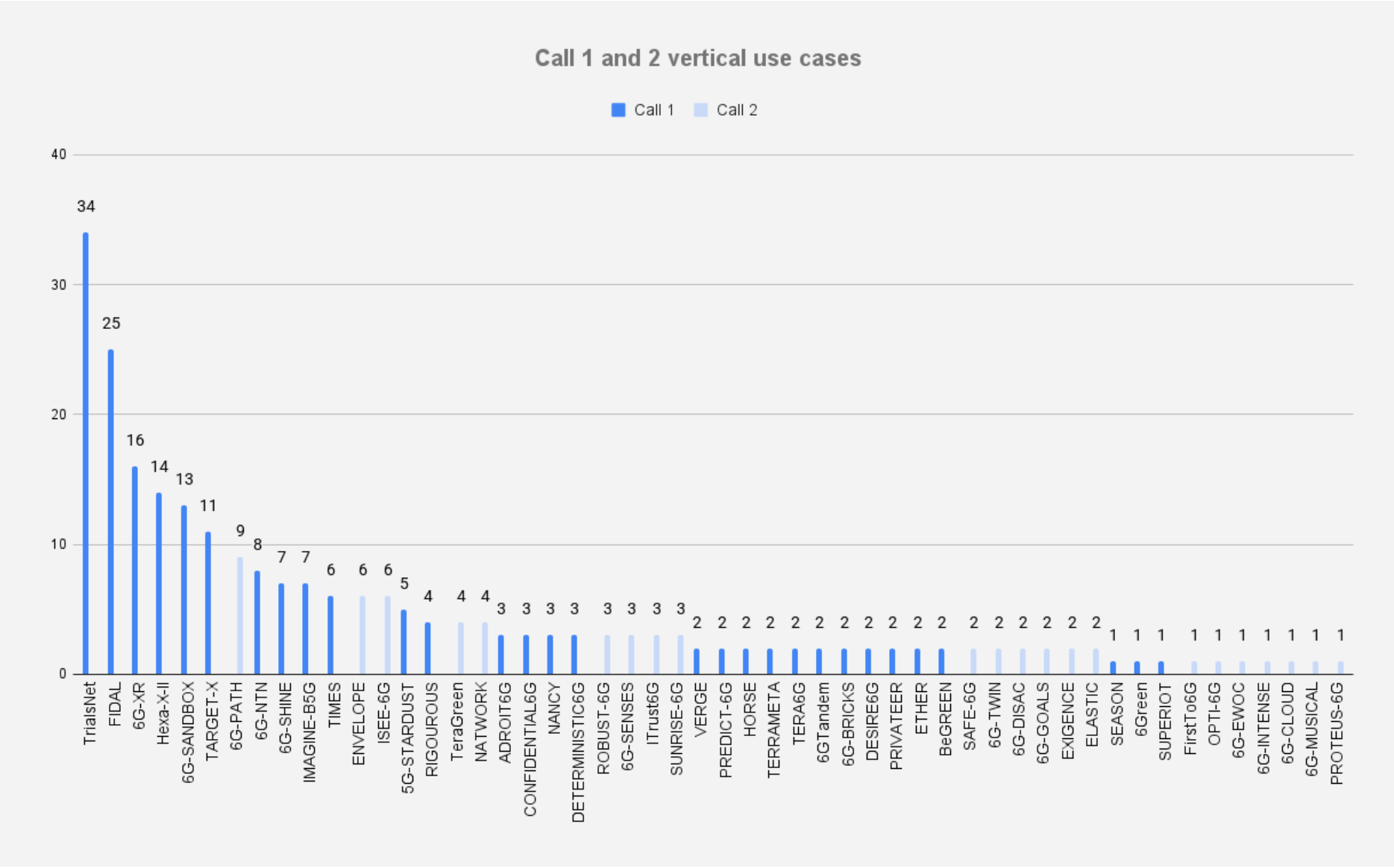

Figure 3. SNS JU Call 1 and 2 vertical use cases per project

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In terms of vertical sectors, Figure 4 highlights vertical sectors across Call 1 and Call 2 projects. Industry 4.0/Manufacturing is the leading vertical sector with 44 use cases, followed closely by Media/AR at 41. Automotive/Transport/Logistics accounts for 31 use cases, and Security/PPDR contributes 28. Smart City appears with 19 instances, while Smart Health has 12. Tourism & Culture registers 10 use cases, while Smart Agriculture and Non-Terrestrial Networks (NTN) each have 6. Education and Smart Energy are less represented, with 4 and 5 instances, respectively. The "Other" category accounts for 40 cases, reflecting a notable share outside the listed verticals.

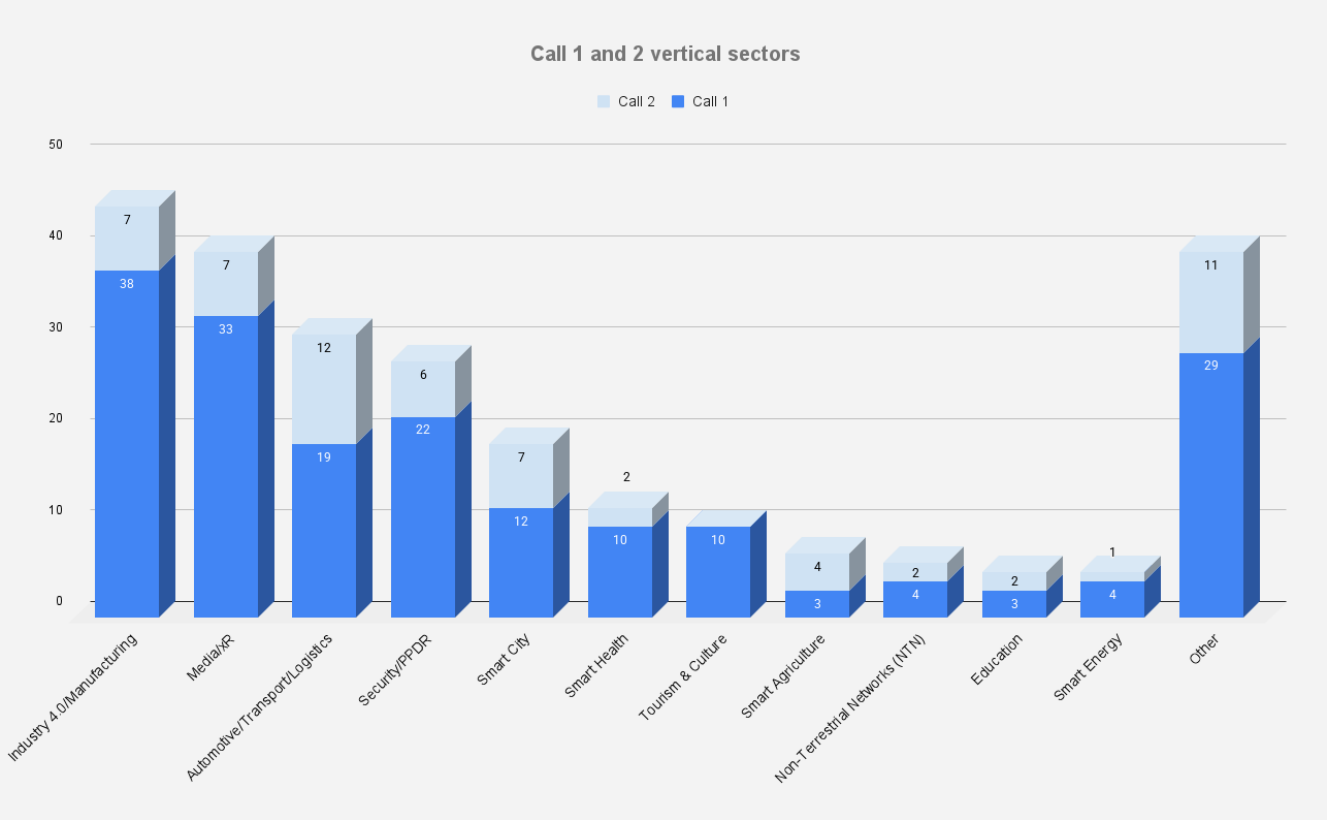

Figure 4. SNS JU Call 1 and 2 projects use cases per vertical sector

3.2.2 SNS JU Streams

In terms of Streams, when looking at data inputs from Call 1 and Call 2 projects across the four SNS JU main streams (Figure 5), the data highlights the dominance of Stream B and Stream D in the overall project distribution. In particular, Stream B represents the largest share with 106 use cases, reflecting the large number of funded projects dealing with novel technologies adoption in commercial networks in both Call 1 (19) and Call 2 (24). It is followed by Stream D with 92 use cases, spread across only 6 projects developing large-scale trials with multiple vertical sectors (4 from Call 1 and 2 from Call 2, respectively). Stream C accounts for 34 use cases from 4 projects (3 from Call 1 and 1 from Call 2) dealing with European-wide experimental infrastructures. Finally, Stream A contributes the smallest segment, with only 15 use cases from 7 Call 1 projects that are developing 5G and beyond applications.

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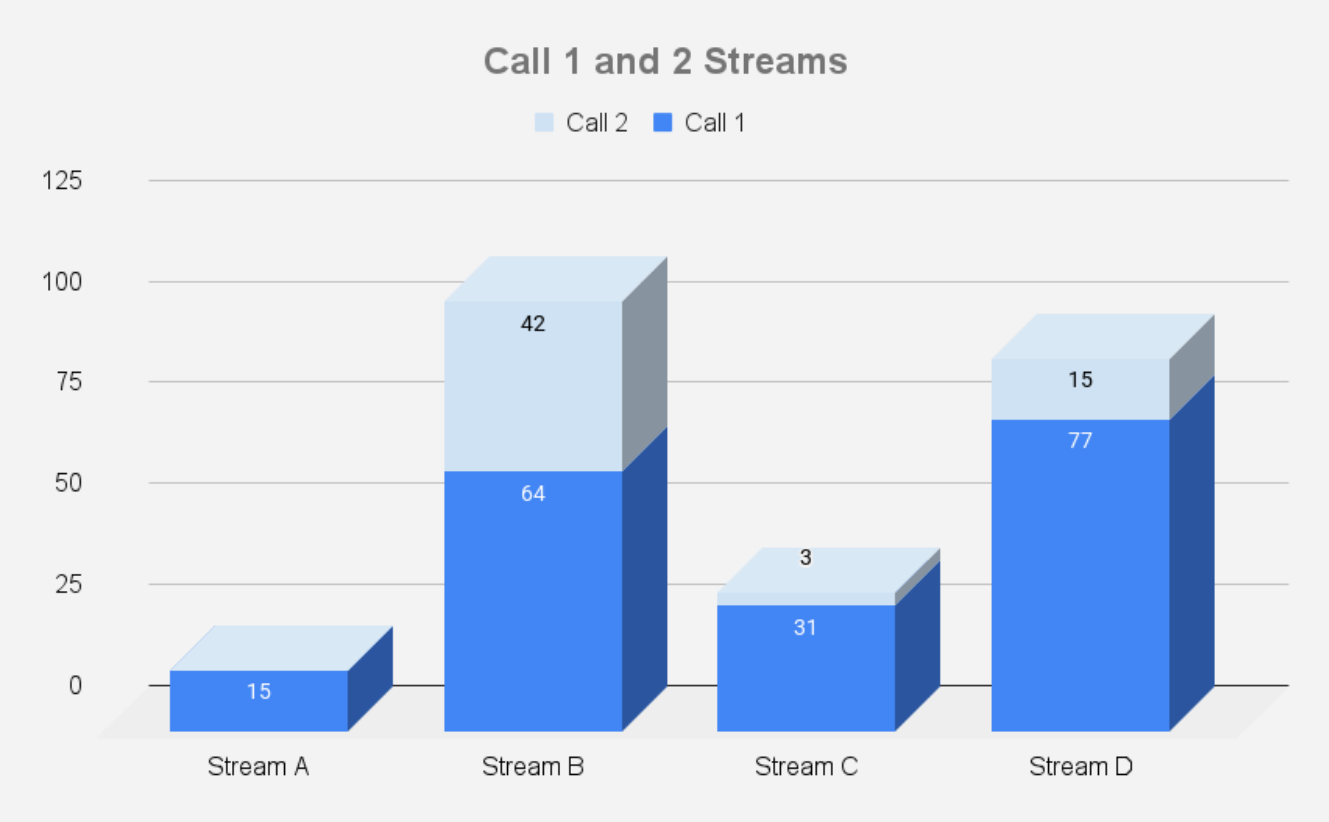

Figure 5. SNS JU Call 1 and 2 projects use cases per stream

This trend is reflected in specific calls. In Call 1 projects, vertical use cases are spread across four streams. Stream D is the largest, with 77 projects, followed by Stream B, which includes 64 projects. Stream C has 31 projects, while Stream A accounts for the smallest share with only 15 projects. Conversely, Call 2 projects present use cases across three streams. Unlike call 1, in call 2 projects, stream B is the most prominent, containing 42 projects, while Stream D follows with 15. Stream C has only 3 projects, representing the smallest segment.

3.2.3 Use cases locations

In terms of the use cases' geographical distribution across Call 1 and Call 2 projects (Figure 6), the top positions occupied by Spain, Greece and Italy, with 55, 41 and 31 use cases, respectively. These are followed by Germany accounts for 26 cases, France contributes with 15, while Romania, Finland, and Belgium each report between 10 and 13 cases. In the fourth tier, Norway and Sweden both have 9 cases, and Portugal and the UK follow with 7 and 6, respectively. In the final tier, Ireland and Hungary each report 2, while Slovenia, Serbia, and Luxembourg have 1 use case each. A notable 21 use cases are categorised as "N/A," indicating that the experiment's location was yet to be defined when the use case was submitted.

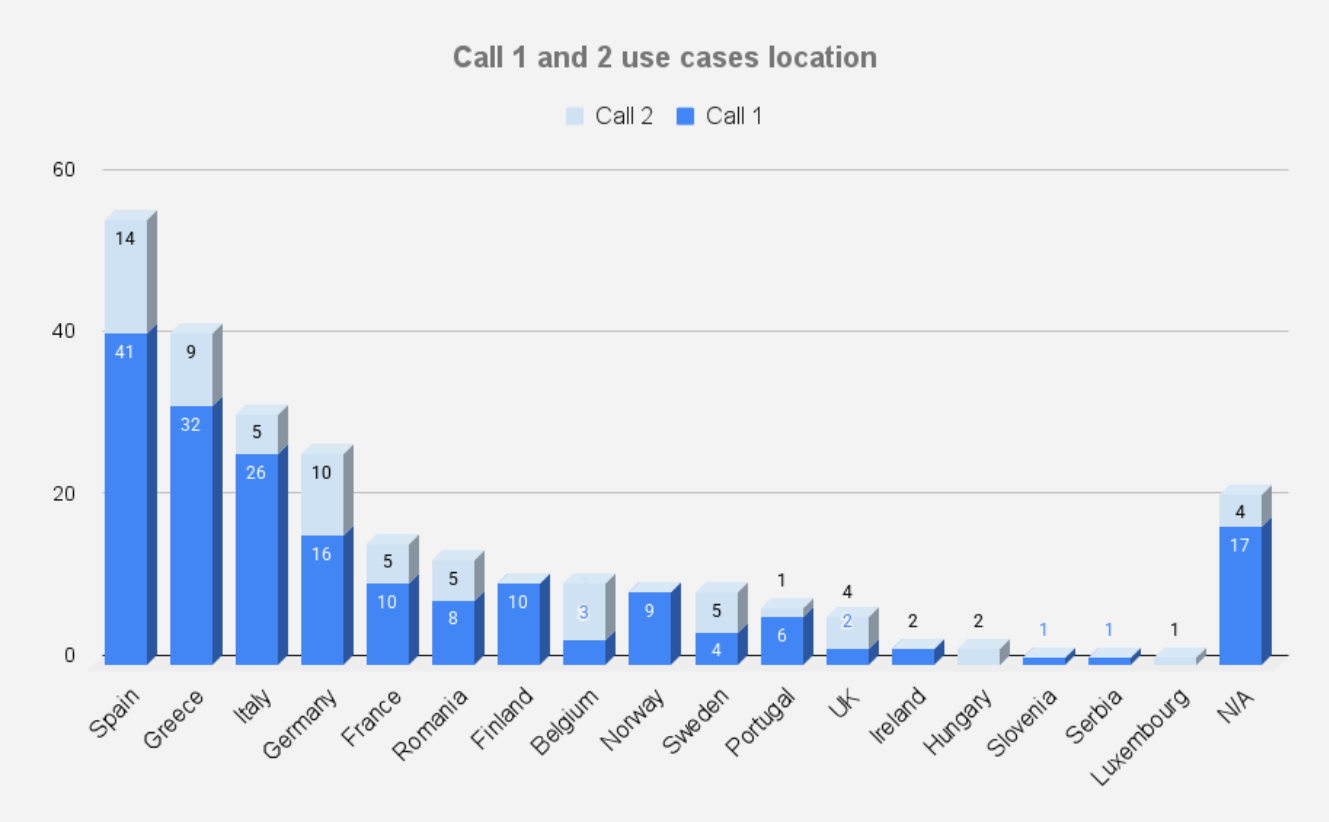

Figure 6. SNS JU Call 1 and 2 projects use cases per location

Such a trend is reflected when looking at both Call 1 and 2 use cases. For Call 1 use cases, Spain has the highest number of use cases at 41, followed by Greece at 32 and Italy at 26. Germany reports 16 use cases, while France and Finland each contribute 10. Norway has 9, and Romania adds 8 use cases. Portugal and Sweden account for 6 and 4 use cases, respectively. Belgium, Ireland, and the UK show smaller contributions, with 3, 2, and 2 cases. Slovenia and Serbia each have just 1 case. An additional 17 use cases are categorised as "N/A,".

Similarly, in Call 2 projects, Spain leads with 14 cases, while Germany follows with 10 and Greece with 9. Belgium accounts for 7 use cases, while France, Italy, Romania, and Sweden each contribute 5 instances. The UK reports four use cases, while Switzerland and Hungary each have 2. Portugal and Luxembourg have just 1 case each. Four use cases are marked as "N/A," representing unspecified locations.

One of the potential reasons for the observed dominance of south-European countries in the number of implemented use cases, may be the lack or diminished availability of National R&I funds in these areas, which push researchers and experimenters towards EU-funded programmes such as the SNS. Northen European experimenters on the other hand may have access to multiple funding sources (both National and International) which may affect their rate of participation in the Eu-funded programmes such as the SNS.

3.2.4 Type of experiment

In terms of the type of use cases developed by SNS JU Call 1 and Call2 R&D projects, looking at the combined figure allows us to gain a comprehensive view of all the developed use cases (Figure 7). In this context, low TRL type of use cases lead the overall count, demonstrating the still immature stage of 5G and beyond and 6G applications at the market level. Indeed, Demonstrations lead with 66 cases, Proof of Concept use cases rank third, accounting for 55 cases, while Simulation/Emulation contributes 28. Conversely, for higher maturity level use cases, Trials are the only high-ranked with 65 instances (second overall), while both Pilots and Prototypes have lower counts, with 17 and 16 use cases, respectively.

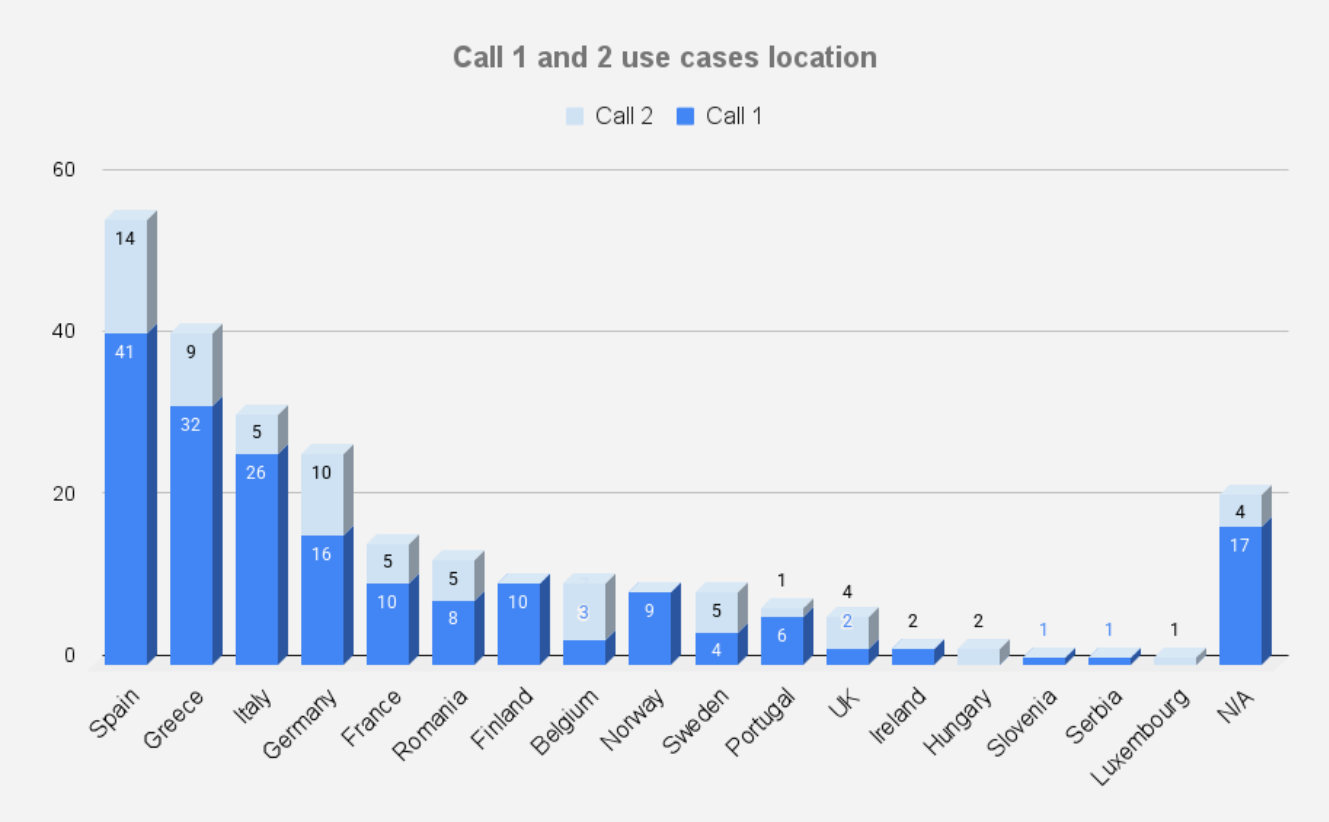

Figure 7. SNS JU Call 1 and 2 projects use cases per type

Such a trend is also reflected in specific calls. For Call 1 projects, Trials are the most common use case type, with 55 instances, followed closely by Demonstrations, which account for 51 cases. Proof of Concepts appear 38 times, while Simulation/Emulation projects are recorded 21 times. Prototypes and Pilots are less frequent, with 12 and 10 cases, respectively.

The maturity level gap is even higher in Call 2 projects, where Proof of Concept is the most common type, with 17 instances, while Demonstrations follow with 15 cases. Trials account for 10 use cases. Pilots and Simulation/Emulation each have 7 cases, and the most mature one (Prototype) is the least common type, with only 4 instances.

3.3 Subsector analysis

The same type of quantitative analysis was carried out on all the vertical sectors with over 10 use cases to highlight the main trends across specific verticals through a subsector analysis. Such a threshold ensured that insights and patterns identified were based on significant sample size, ensuring a statistically meaningful evaluation and avoiding potential biases and inaccuracies arising from overinterpreting trends in underrepresented sectors.

This approach allowed for a focused examination of the most impactful and well-documented verticals, while acknowledging the need for further data collection in less-represented areas, making use cases more reliable and representative of broader industry trends.

3.3.1 Smart Health

An emerging vertical sector, Smart Health accounts for 12 use cases from 4 different projects (Figure 8). Among these, the TrialsNet project leads with 7 use cases, while IMAGINE-B5G and 6G-PATH each contribute 2 use cases. SUPERIOT has 1 use case, making it the smallest contributor in the Smart Health category.

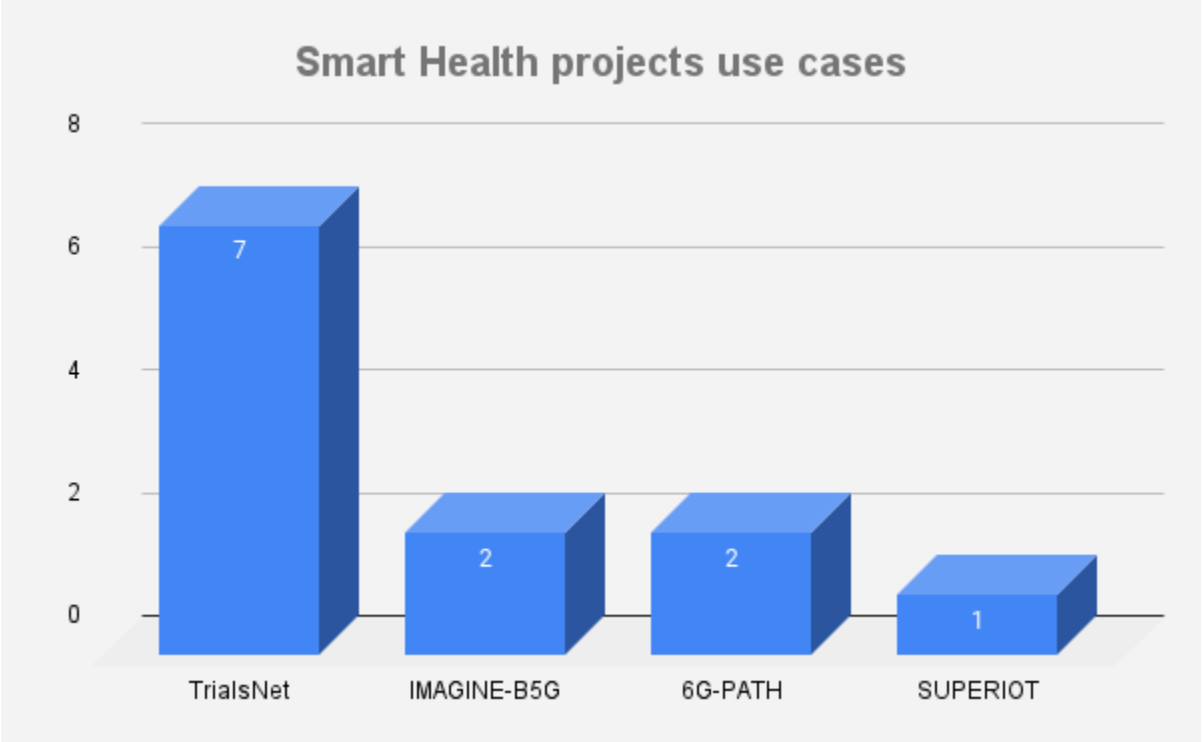

Figure 8. SNS JU Call 1 and 2 projects use cases targeting the Smart Health vertical sector

In terms of stream division, stream D accounts for the majority with 11 use cases, while stream B has only 1 use case. This highlights Stream D's dominance in supporting Smart Health projects (Figure 9).

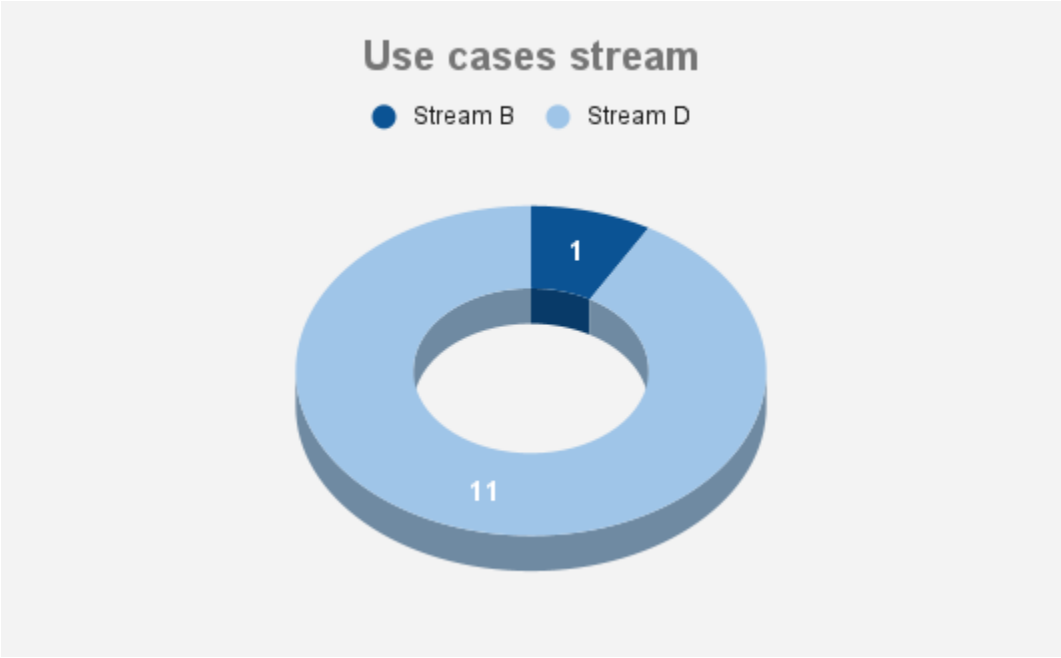

Figure 9. SNS JU Call 1 and 2 projects use cases targeting the Smart Health vertical sector per stream

In terms of use case type, the Smart Health vertical sees mostly mature types of experiments, in contrast to emerging trends (Figure 10). In fact, among the most mature use cases, trials are the most common, with 6 instances, while Pilots contribute 2, for a total of 8 mature use cases. Among less mature ones, Demonstrations account for 3 use cases, while Proof of Concept is the least represented, with only 1 case.[11]

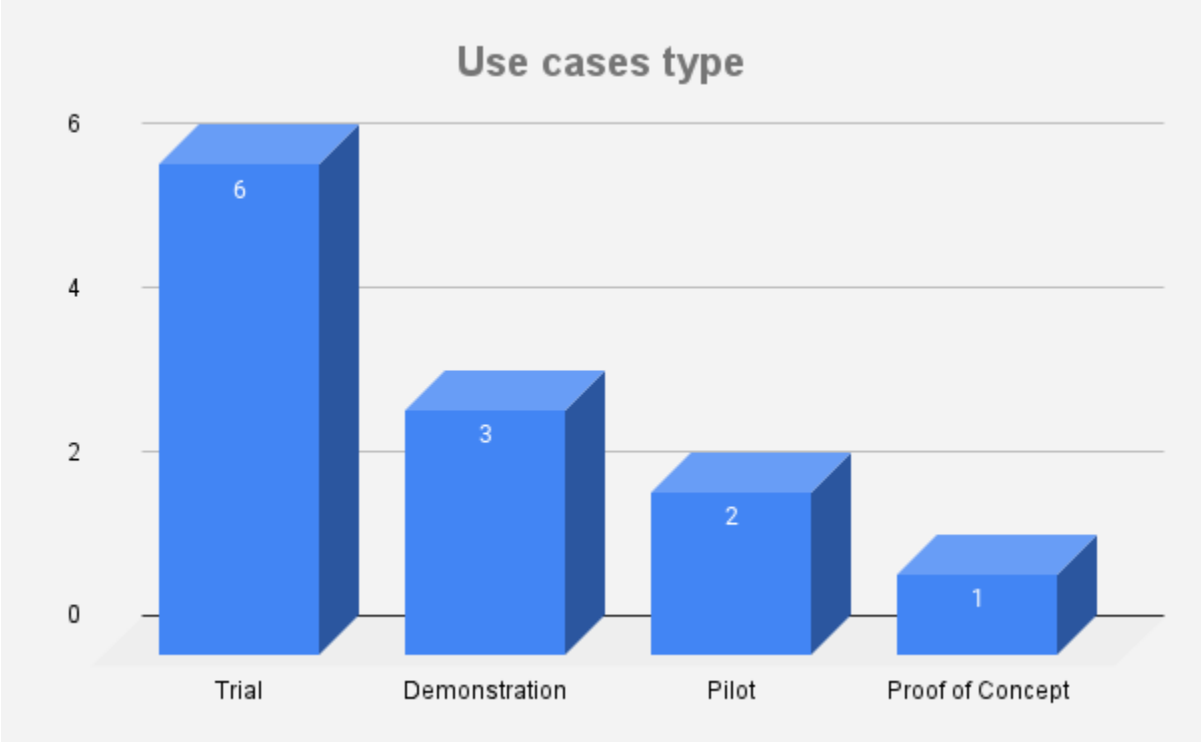

Figure 10. SNS JU Call 1 and 2 projects use cases targeting the Smart Health vertical sector per type

As for geographical distribution across the Smart Health vertical, Italy leads with 6 use cases. Portugal, Spain, and Germany each contribute 2 use cases, while Norway and Greece follow with 1 use case each (Figure 11).

[11] About maturity levels in SNS JU use cases, see the TRL scale explanation in EU-funded projects available at https://enspire.science/trl-scale-horizon-europe-erc-explained/.

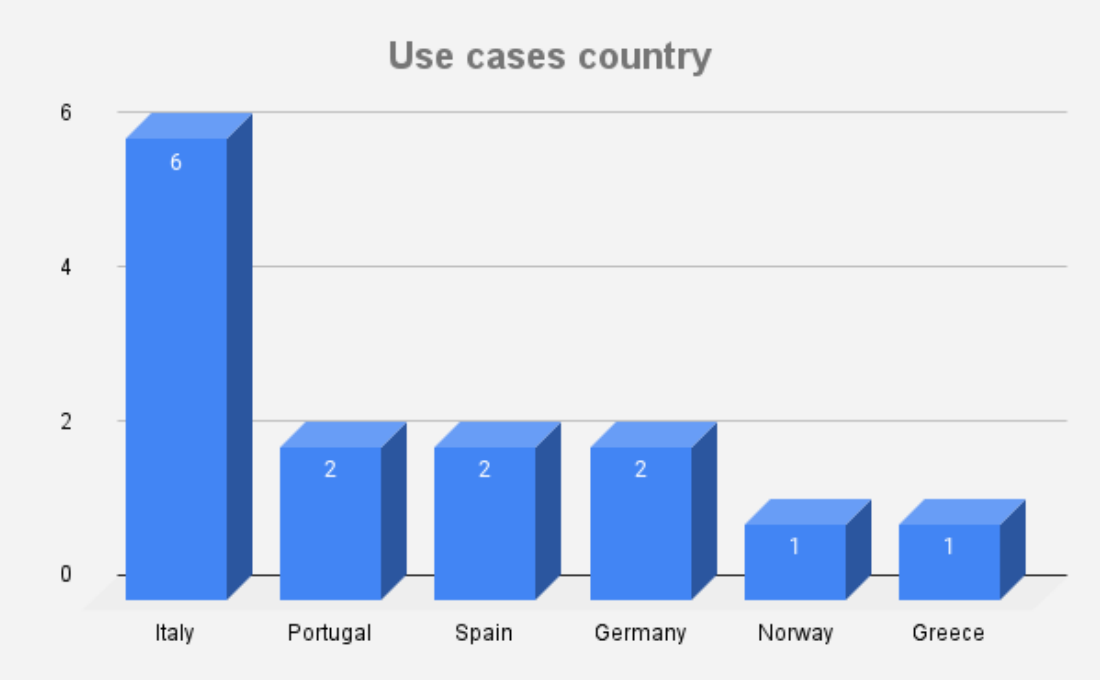

Figure 11. SNS JU Call 1 and 2 projects use cases targeting the Smart Health vertical sector per location

3.3.2 Smart City

Figure 12 displays the distribution of use cases in SNS JU projects targeting the Smart City vertical sector. Of the total 19 use cases, TrialsNet, 6G-SENSES and RIGOUROUS concentrate 12 total slots, with 7, 3. and 2 use cases, respectively. Conversely, several other projects contribute only a single instance, including FIDAL, 6G-SHINE, PRIVATEER, 6G-PATH, 6G-DISAC, NATWORK, and 6G-MUSICAL, each have 1 use case.

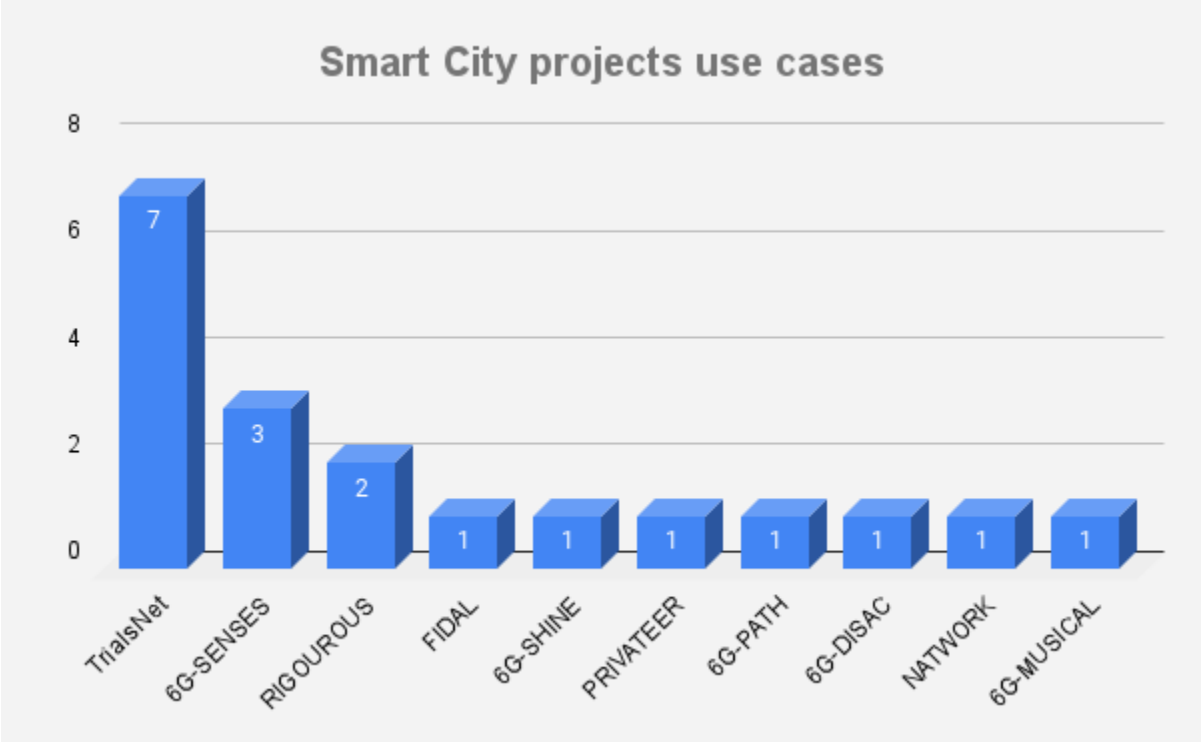

Figure 12. SNS JU Call 1 and 2 projects use cases targeting the Smart City vertical sector

In terms of use case distributions across streams, Smart City-related vertical use cases are equally distributed across two streams (Figure 13). Stream B accounts for 10 use cases, slightly ahead of Stream D, which has 9. The near-even distribution mirrors the overall large number of Stream B projects and the large number of use cases developed by Stream D.

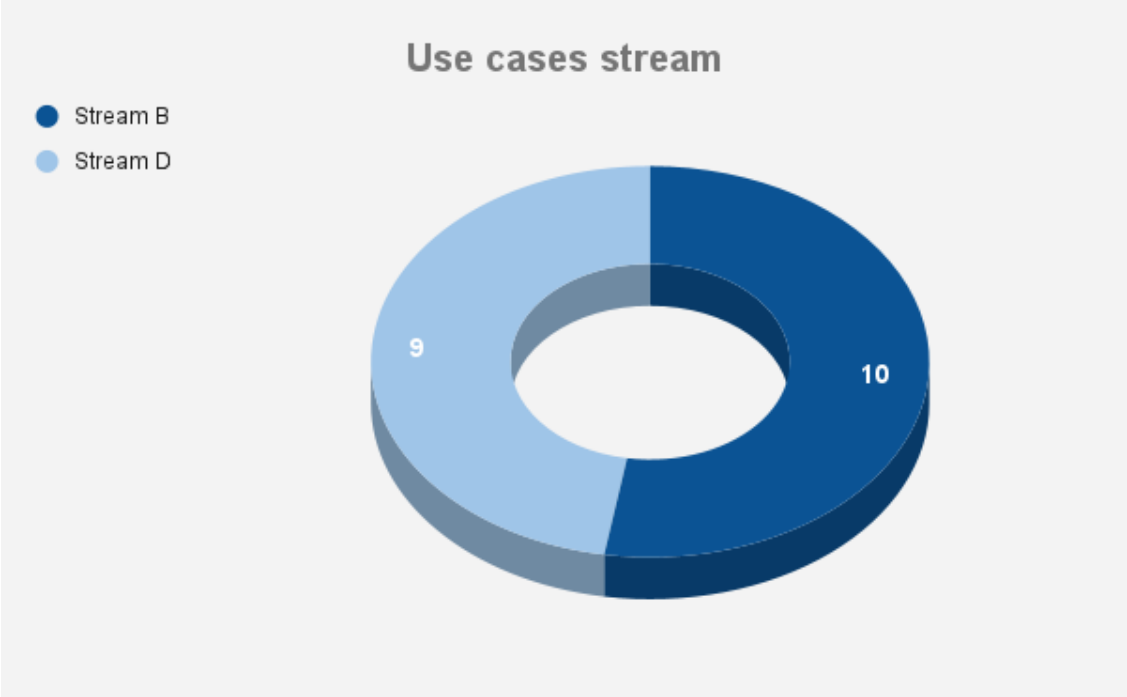

Figure 13. SNS JU Call 1 and 2 projects use cases targeting the Smart City vertical sector per stream

Similarly to the Smart Health vertical sector, mature use cases take the lead, with 8 trials and 2 pilots and only 8 among Simulation/Emulation (5) and Proof of Concept (3) experiments (Figure 14).

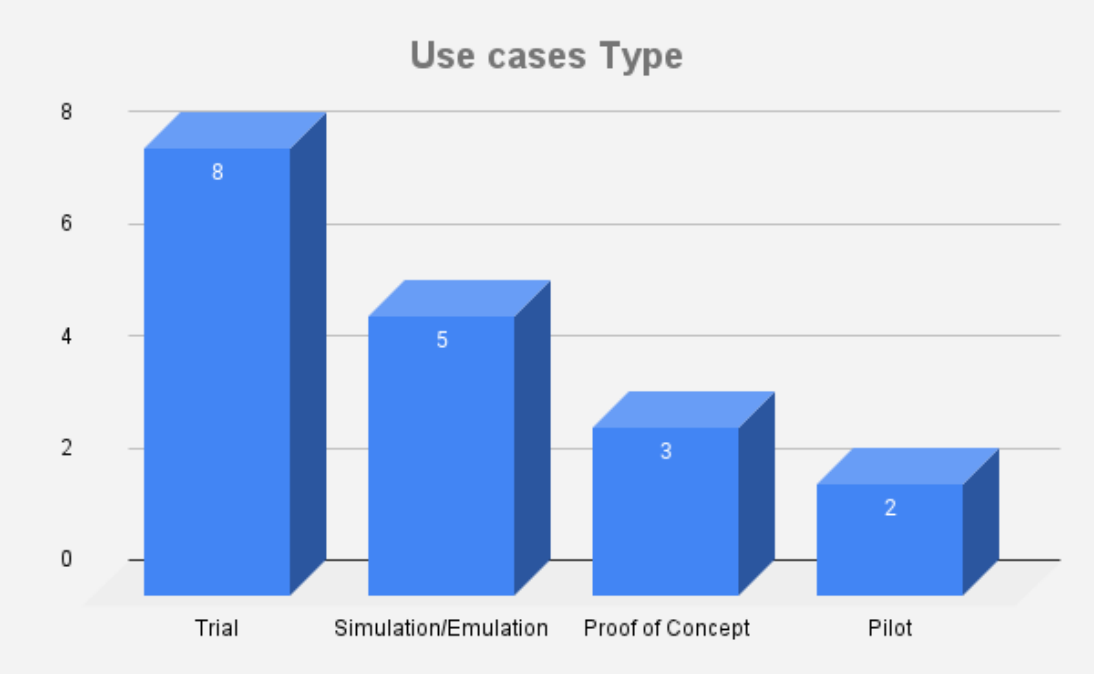

Figure 14. SNS JU Call 1 and 2 projects use cases targeting the Smart City vertical sector per type

In terms of geographical distribution, Spain leads with 5 use cases, while Romania and Greece follow with 3 each. Italy and Belgium each account for 2 use cases. Finland, Norway, France, Poland, and the UK contribute 1 use case each, as does the N/A category, which reflects unspecified locations (Figure 15).

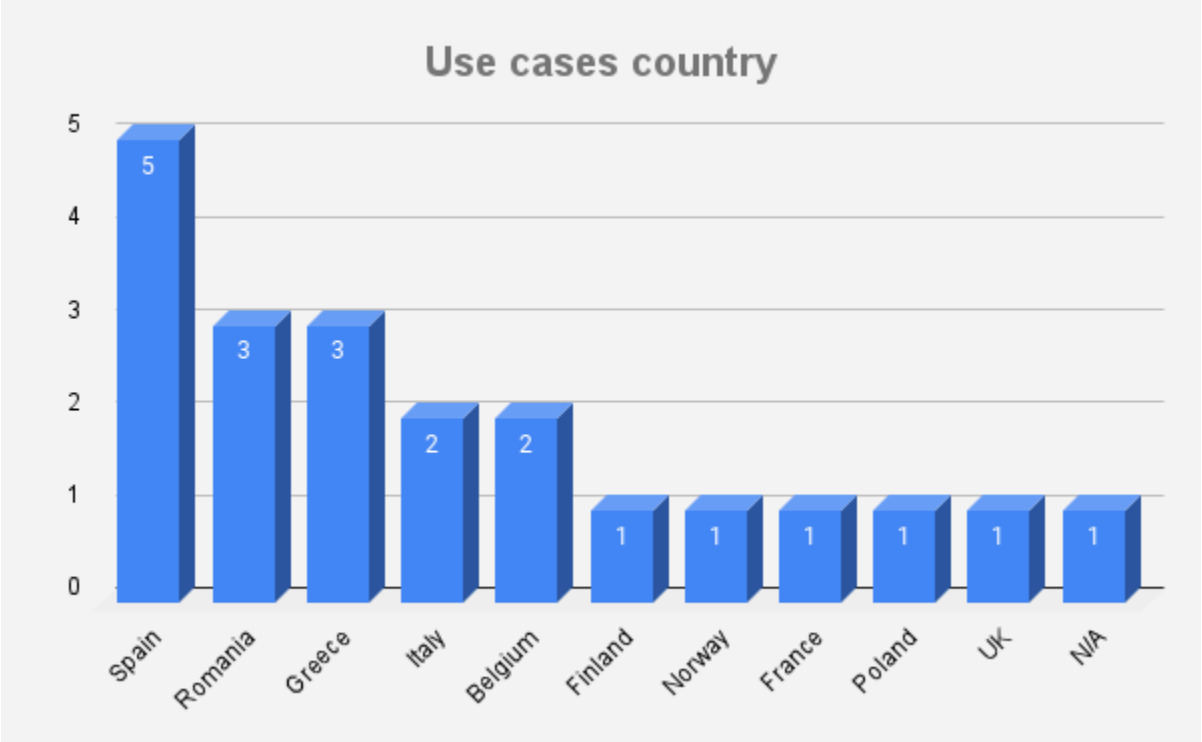

Figure 15. SNS JU Call 1 and 2 projects use cases targeting the Smart City vertical sector per location

3.3.3 Industry 4.0/Manufacturing

A much larger number of use cases (46 overall) target the Industry 4.0/Manufacturing vertical sector, as showcased by the graphic below (Figure 16). The Hexa-X-II, TIMES, and 6G-SANDBOX projects lead with 6 use cases each, followed by TARGET-X with 5. ADROIT6G has 3 use cases, while 6G-SHINE, IMAGINE-B5G, and other projects, including DETERMINE-5G, CONFIDENTIAL6G, and TERRA-META, each account for 2 use cases. The remaining projects, such as DESIRE6G, OPTI-6G, and TrialsNet, contribute 1 use case each.

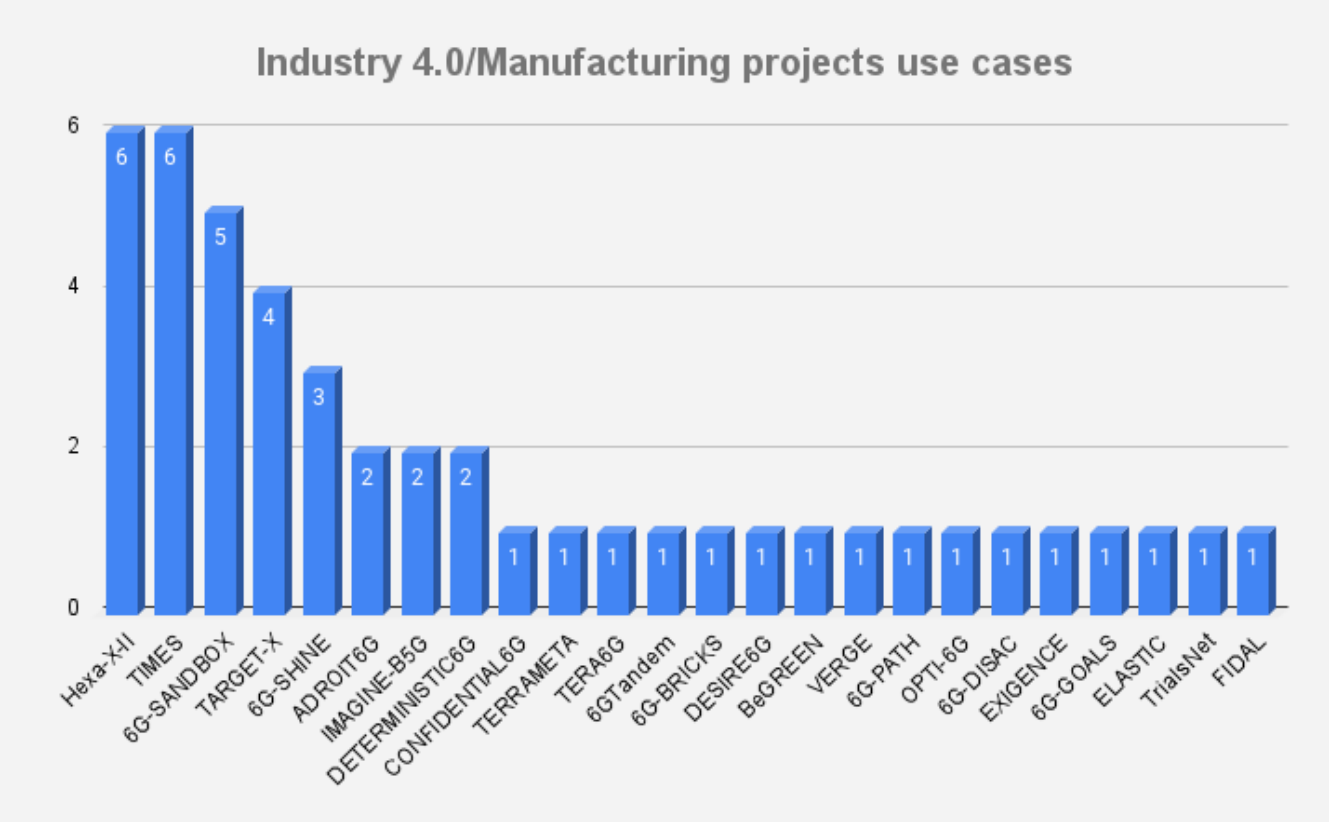

Figure 16. SNS JU Call 1 and 2 projects use cases targeting the Industry 4.0/Manufacturing vertical sector

In terms of corresponding streams, once again, Stream B and D dominate the chart with 29 and 9 use cases, respectively. Stream C accounts for 6 use cases, while Stream A represents the smallest share with only 2 use cases (Figure 17).

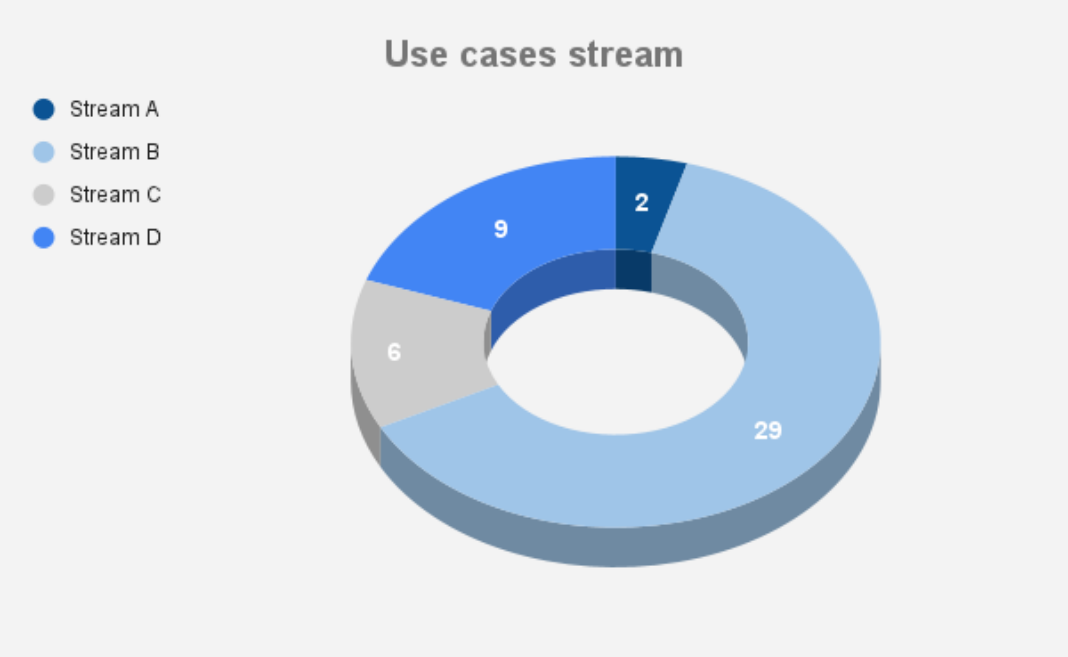

Figure 17. SNS JU Call 1 and 2 projects use cases targeting the Industry 4.0/Manufacturing vertical sector per stream

In terms of use case maturity, this vertical sector better reflects the overall use case trends showcased in Figure 7. Unlike Smart City and Smart Health verticals, less mature use cases dominate the Industry 4.0/Manufacturing vertical. Demonstrations and Proof of Concept lead with 20 and 8 cases, followed by Simulation/Emulation with 7. Conversely, more mature use cases only account for 9 use cases, with 7 Trials and 2 Pilots (Figure 18).

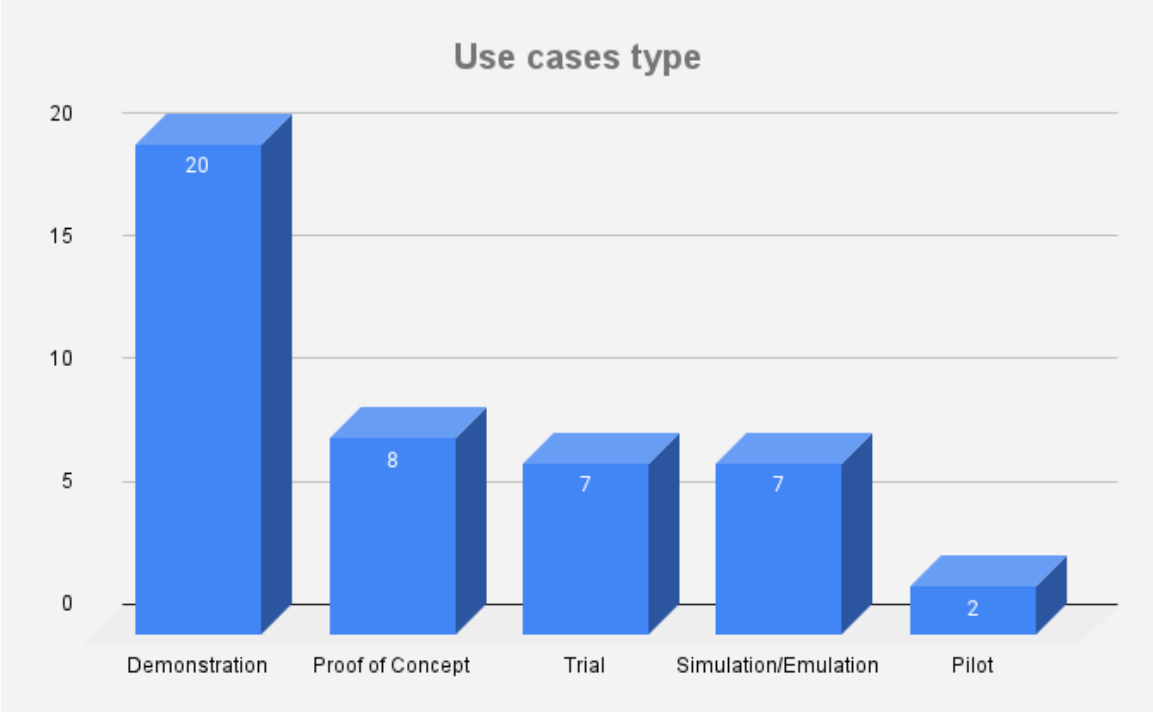

Figure 18. SNS JU Call 1 and 2 projects use cases targeting the Industry 4.0/Manufacturing vertical sector per type

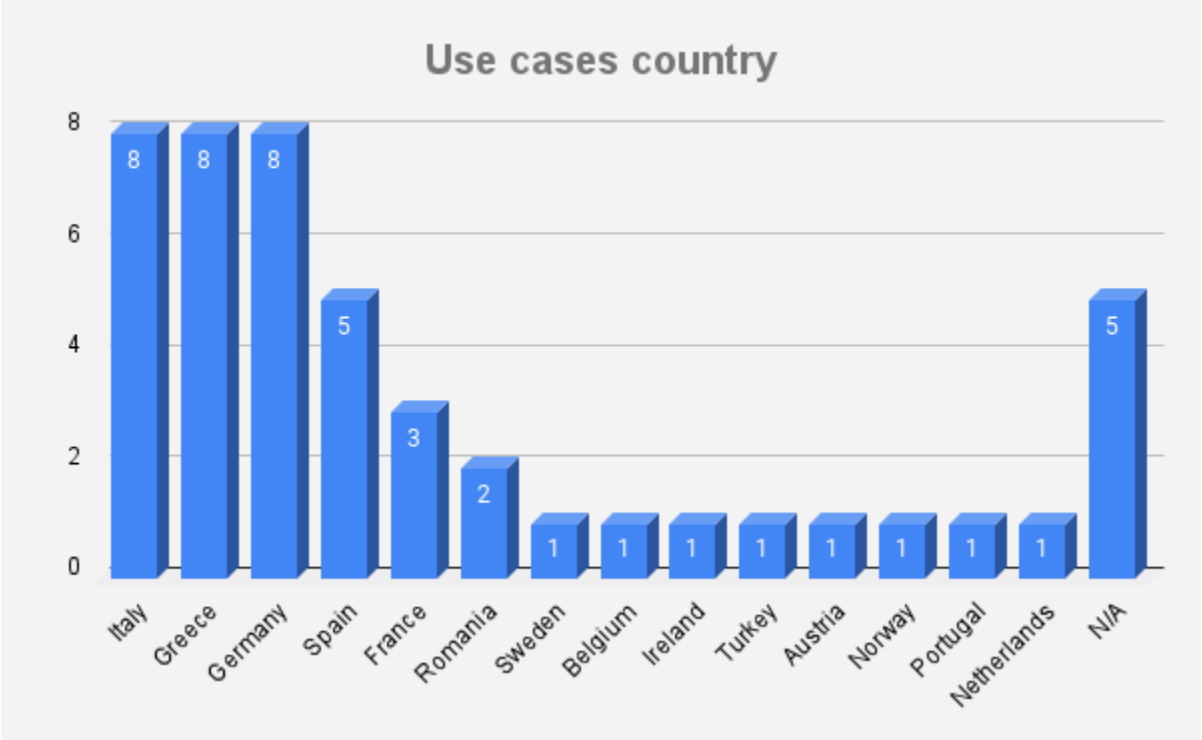

Figure 19. SNS JU Call 1 and 2 projects use cases targeting the Industry 4.0/Manufacturing vertical sector per location

In terms of geographical distribution, Italy, Greece, and Germany lead with 8 use cases. Spain follows with 5, while France reports 3 and Romania 2. Several other countries, including Sweden, Belgium, Ireland, Turkey, Austria, Norway, Portugal, and the Netherlands, contribute 1 use case each. Additionally, 5 cases are marked as N/A, representing unspecified locations (Figure 19).

3.3.4 Automotive/Transport/Logistics

In terms of use case distribution in the Automotive/Transport/Logistics sector, a total of 31 use cases are available. Among these ENVELOPE leads with 6 use cases, while TrialsNet follows with 4. TARGET-X has 3 use cases, and projects like NANCY and 5G-STARDUST each report 2 use cases. Several other projects, including Hexa-X-II, PREDICT-6G, CONFIDENTIAL6G, HORSE, VERGE, NATWORK, and SUNRISE-6G, each contribute 1 use case, showing a wide distribution across smaller projects (Figure 20).

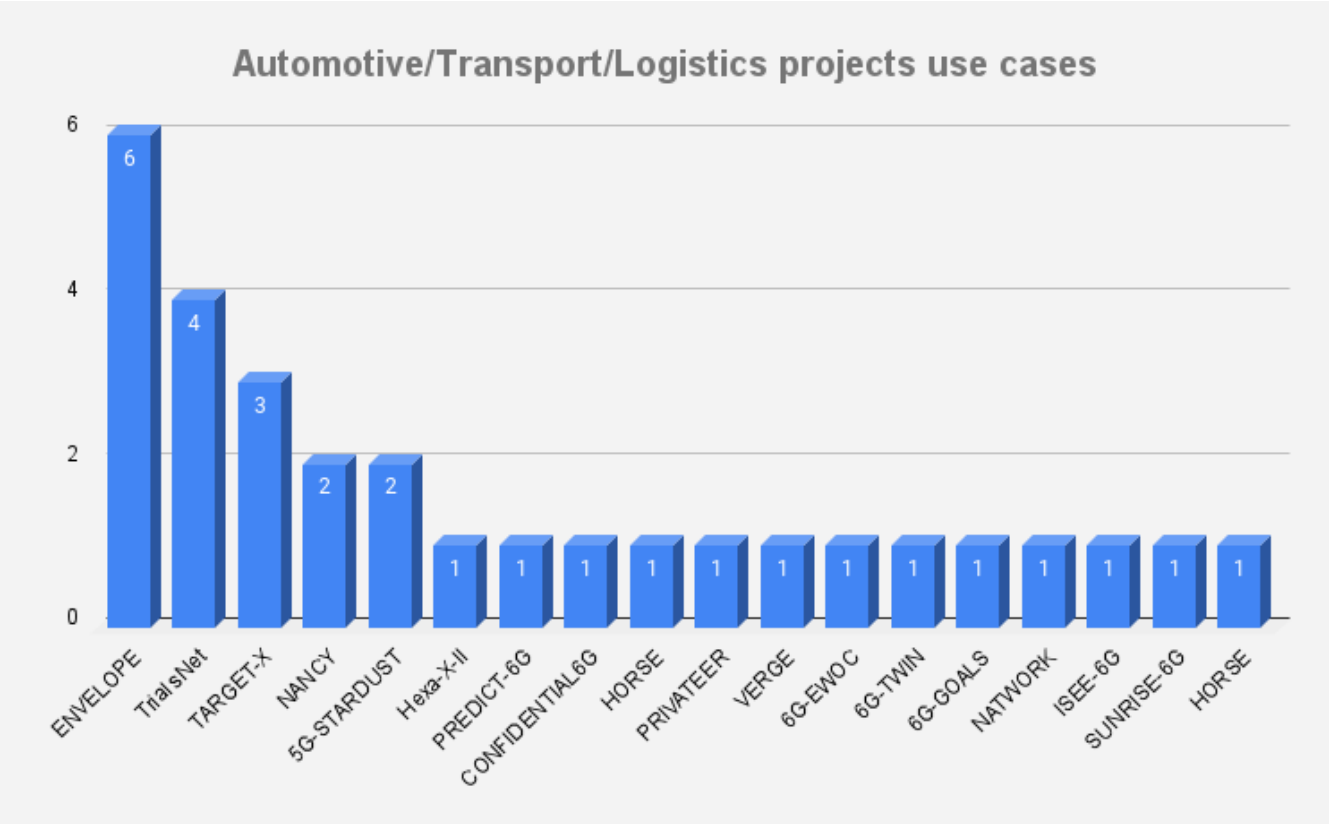

Figure 20. SNS JU Call 1 and 2 projects use cases targeting the Automotive/Transport/Logistics vertical sector

Unlike previous verticals, the Automotive/Transport/Logistics presents a majority of use cases linked to Stream D large-scale trials (15 total use cases), followed by Stream B with 10. Moreover, while Stream A contributes 5 use cases, Stream C adds just 1 (Figure 21).

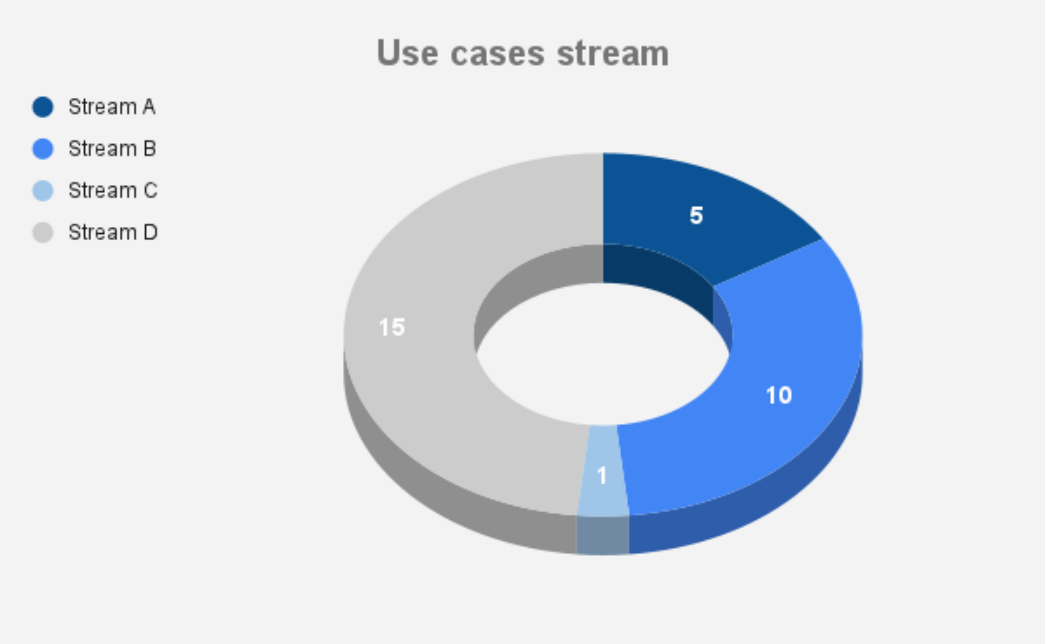

Figure 21. SNS JU Call 1 and 2 projects use cases targeting the Automotive/Transport/Logistics vertical sector per stream

In terms of use case maturity, the Automotive/Transport/Logistics vertical presents more mature use cases, reflecting the continuity of this sector with previous R&D efforts in 5G PPP (Figure 22). Trials are by far the most utilised vertical sector, with 14 instances, far ahead of other categories. Demonstrations and Proof of Concepts each account for 6 use cases, while Simulation/Emulation contributes 3 cases. Pilots are the least common, with only 2 instances, although some trials could turn into pilots later on as the technologies developed by such projects mature.

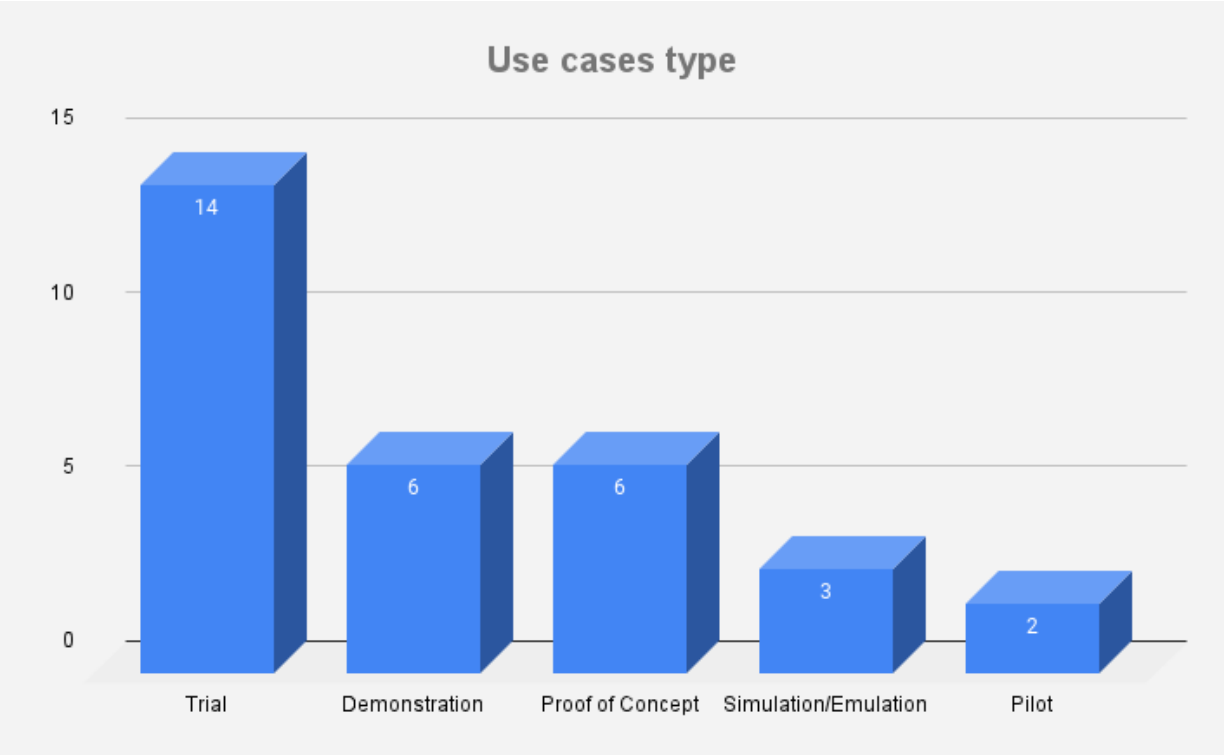

Figure 22.. SNS JU Call 1 and 2 projects use cases targeting the Automotive/Transport/Logistics vertical sector per type

In terms of geographical distribution, the general trends are also reflected by the Automotive/Transport/Logistics vertical sector. Top-tier countries lead the chart, with Spain accounting for 8 use cases, followed by Greece with 6 and Italy with 5. The Netherlands contributes 4 use cases, while France and Sweden each report 2. Countries such as Portugal, Luxembourg, the UK, Belgium, and Poland each have 1 use case (Figure 23).

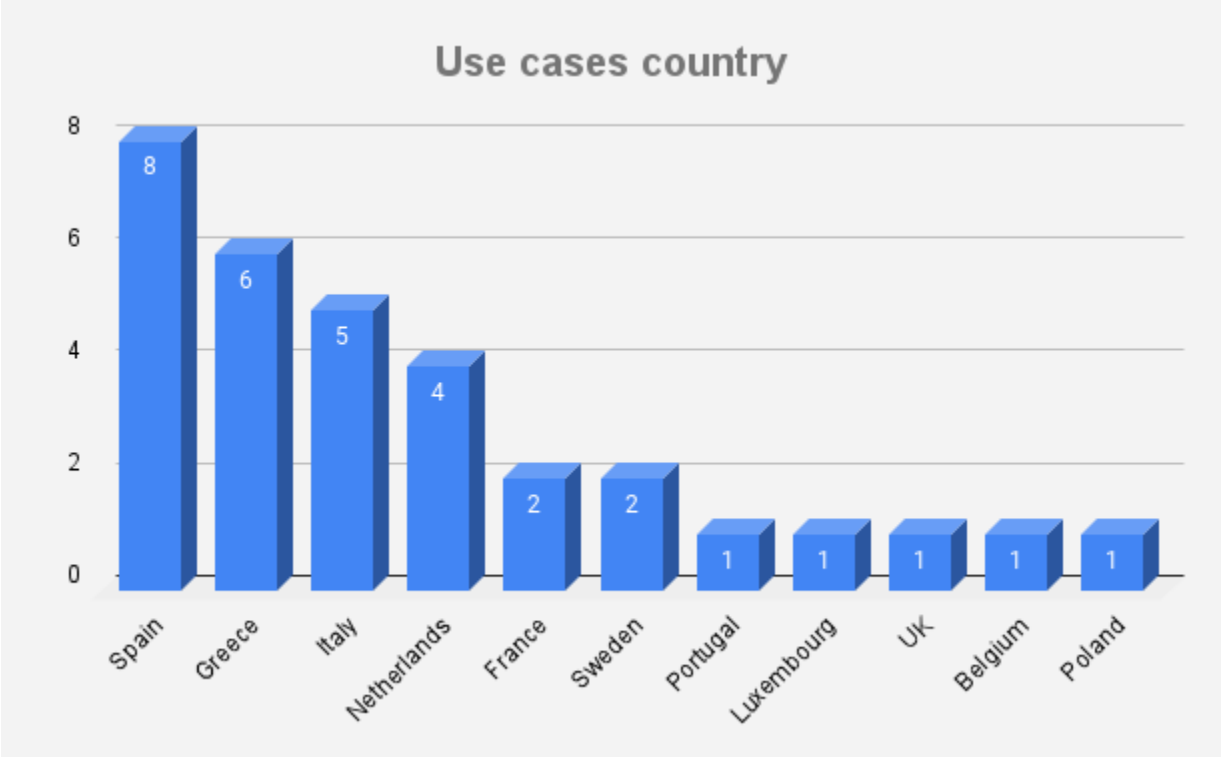

Figure 23. SNS JU Call 1 and 2 projects use cases targeting the Automotive/Transport/Logistics vertical sector per country

3.3.5 Media/xR

The Media/xR vertical presents 40 use cases, as displayed in the graphic below (Figure 24). The data shows a significant concentration of use cases in the top three projects. 6G-XR leads with 9 use cases, followed by FIDAL with 7 and Hexa-X with 4. Projects like TrialsNet, 6G-SHINE, 6G-SANDBOX, and 5G-STARDUST each contribute 2 use cases. The remaining projects, such as DESIRE6G, NANCY, SEASON, and SUNRISE-6G, each account for 1 use case (Figure 24).

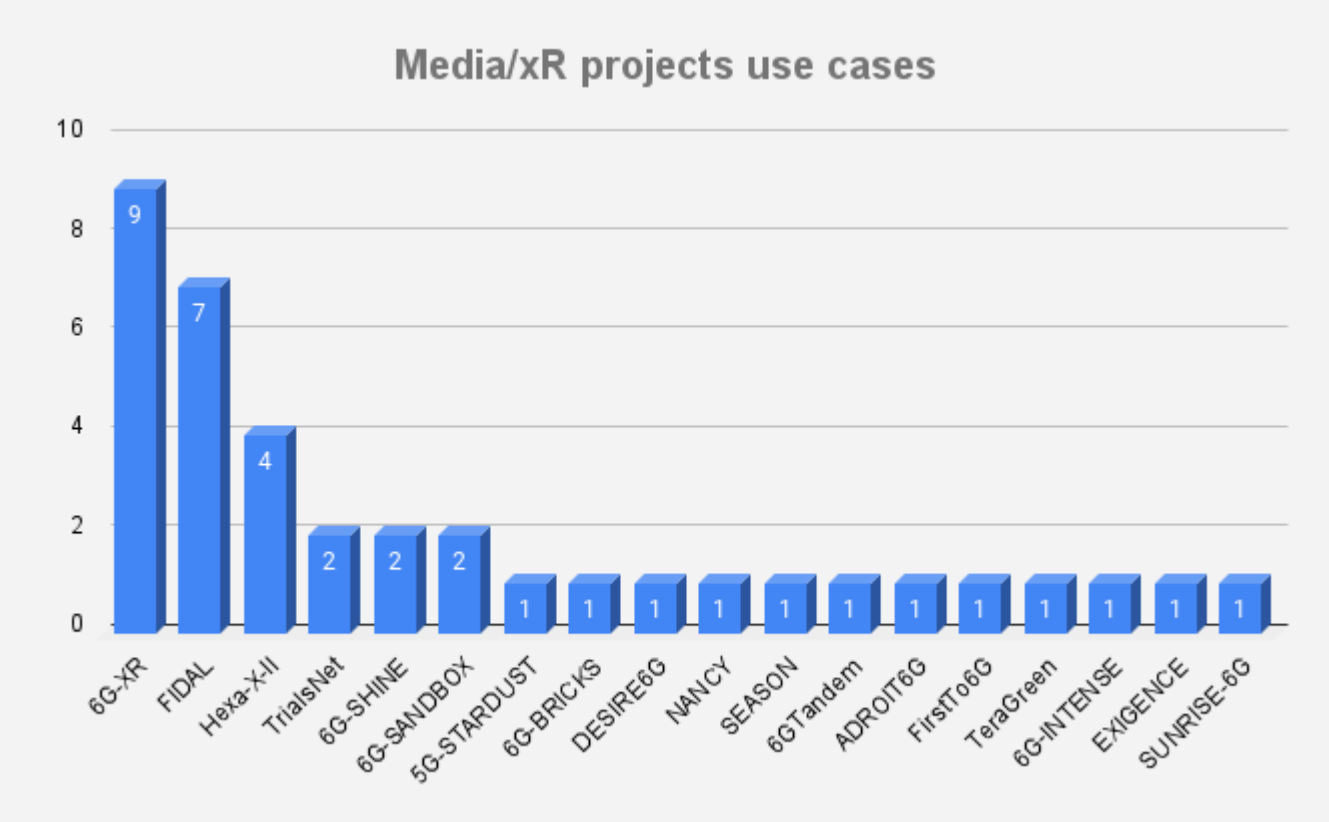

Figure 24. SNS JU Call 1 and 2 projects use cases targeting the Media/xR vertical sector

Such concentration is also reflected in the Stream chart below (Figure 25). While Stream B leads with 15 use cases from multiple projects, the 13 use cases belonging to Stream C are mainly the result of the 9 entries from the 6G-XR project. Stream D contributes 9 cases, 7 of which are from the FIDAL projects, while Stream A accounts for the smallest share with 3 use cases.

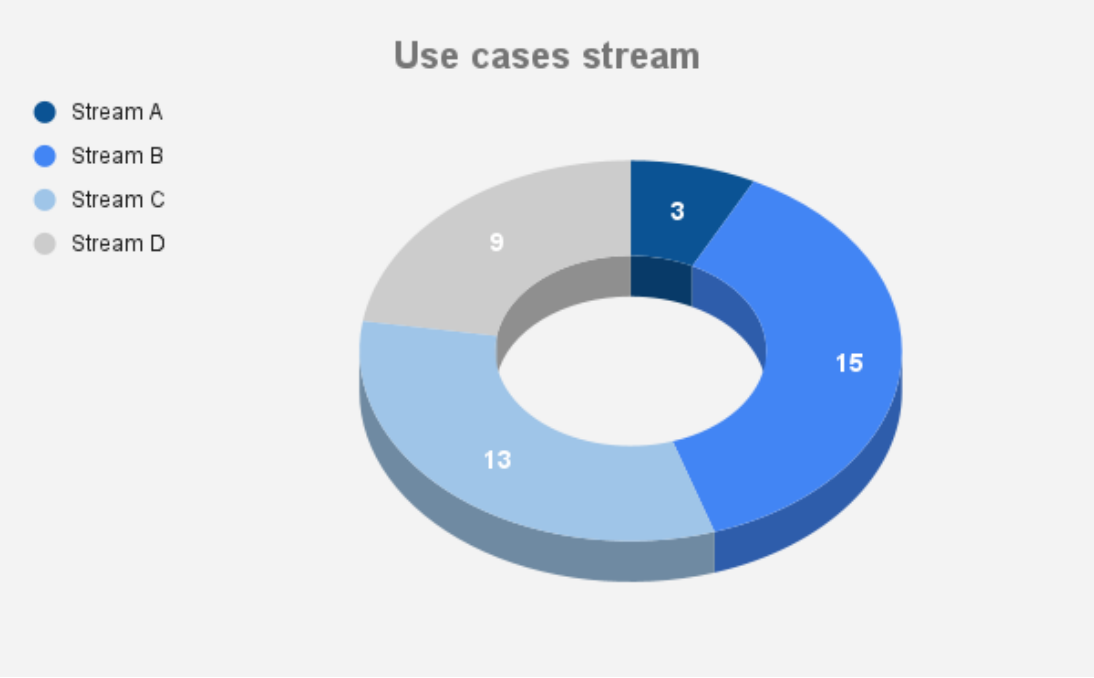

Figure 25. SNS JU Call 1 and 2 projects use cases targeting the Media/xR vertical sector per stream

In terms of use case maturity, the Figure 26 Media/xR project presents similar trends to the Industry 4.0/Manufacturing vertical, reflecting an emerging trend across vertical sectors with a larger number of use cases (Figure 26). Demonstrations are the most prominent, with 15 instances, followed by Proof of Concept with 8 and 3 Simulation/Emulation. Conversely, among more mature use cases, Prototypes lead with 7, followed by Trials & Pilots contributing with 5 and 2 use cases, respectively.

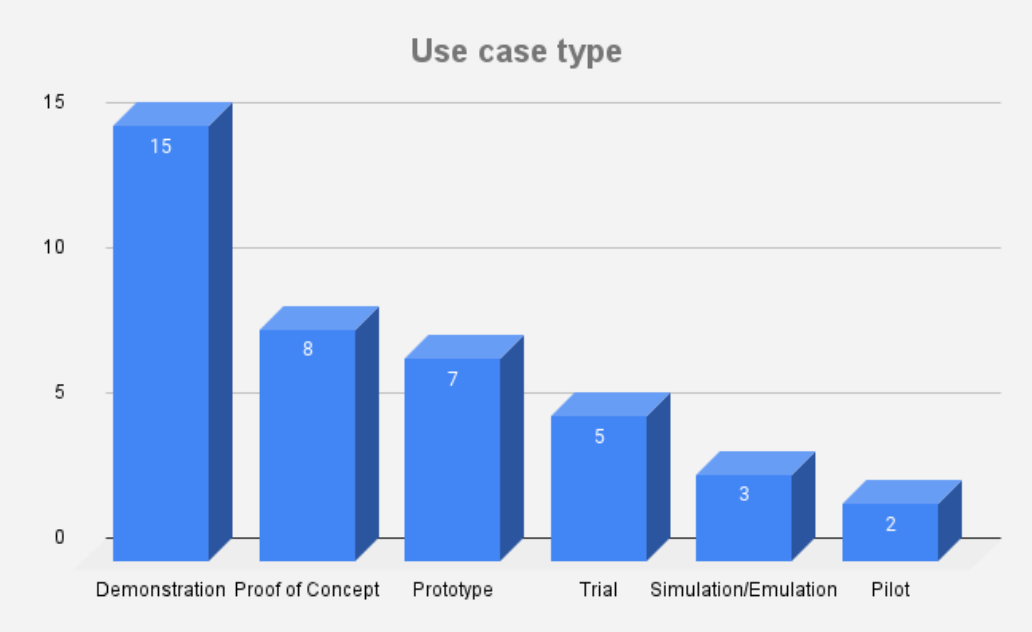

Figure 26. SNS JU Call 1 and 2 projects use cases targeting the Media/xR vertical sector per type

Similarly, in terms of geographical distribution, the general trends are also reflected for Media/xR use cases (Figure 27), with the exception of Italy. Spain leads with 11 cases, followed by Greece with 9. Sweden, France, and Germany each report 3 use cases, while Norway, Italy, and Belgium contribute 2 each. Poland has 1 use case, and 5 cases are categorised as N/A, representing unspecified locations.

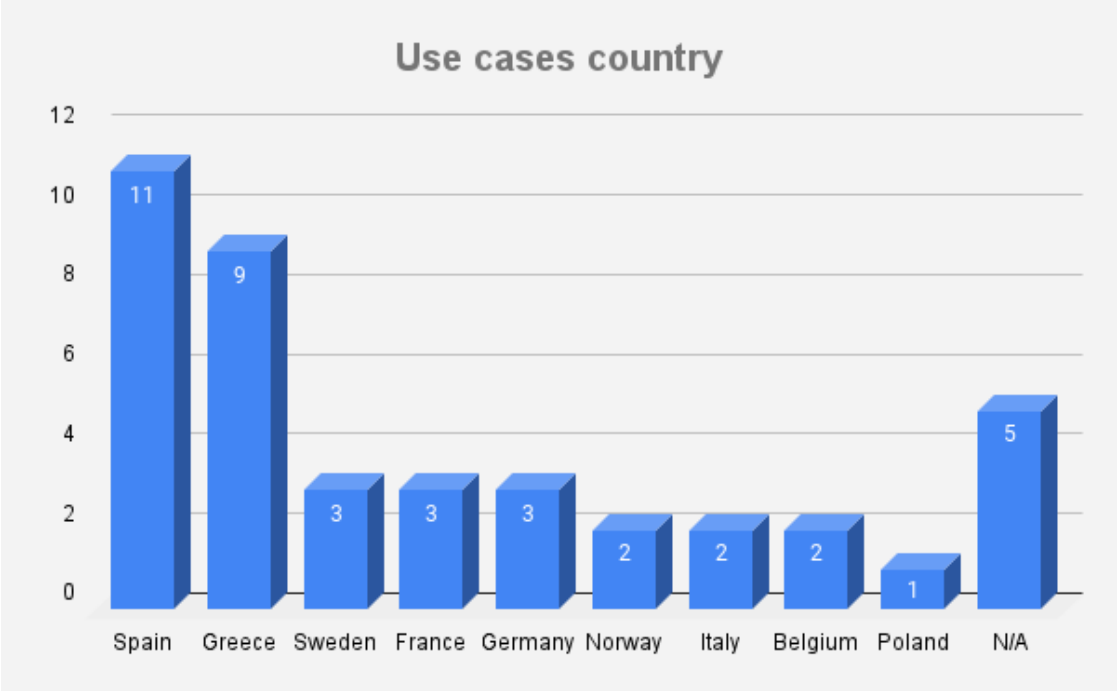

Figure 27. SNS JU Call 1 and 2 projects use cases targeting the Media/xR vertical sector per country

3.3.6 Security/PPDR

Figure 28 below displays the 27 use cases targeting the Security/PPDR vertical sector . Almost half of use cases are concentrated in one project (FIDAL), standing out significantly with 11 use cases. Conversely, IMAGINE-B5G, 6G-NTN, and NATWORK each account for 2 use cases. Projects like ISEE-6G, 5G-STARDUST, CONFIDENTIAL6G, RIGOUROUS, 6G-PATH, ROBUST-6G, Trust6G, and 6G-SANDBOX each contribute 1 use case, reflecting a more distributed representation across the smaller projects.

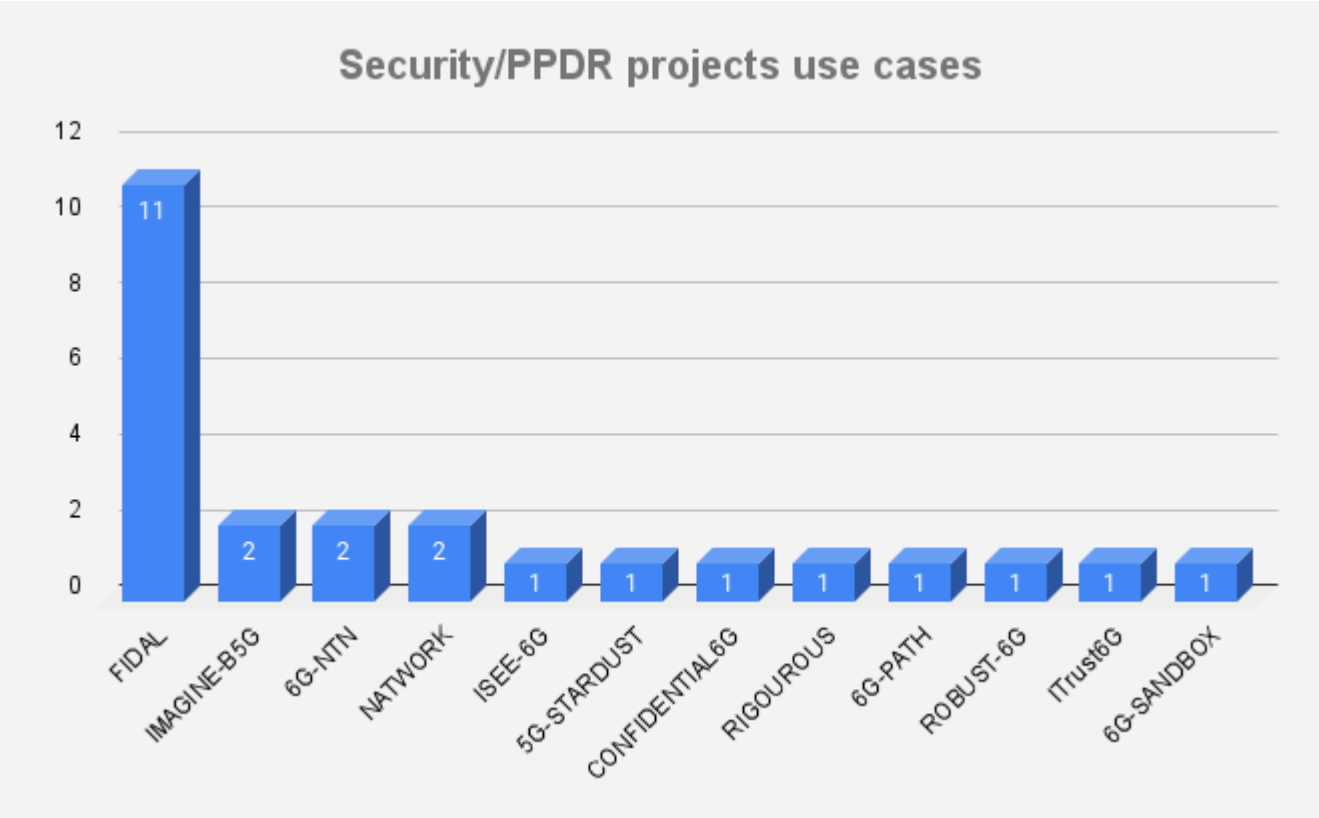

Figure 28. SNS JU Call 1 and 2 projects use cases targeting the Security/PPDR vertical sector

Such a tendency is also reflected in the Streams chart depicted in Figure 29, with Stream D dominating with 17 use cases, followed by Stream B with 9. While inverting the first and second positions, this trend reinforces and extends the dominance pattern across streams B and D. The sole submission from a different stream is a very small share from Stream A, with only 1 use case.

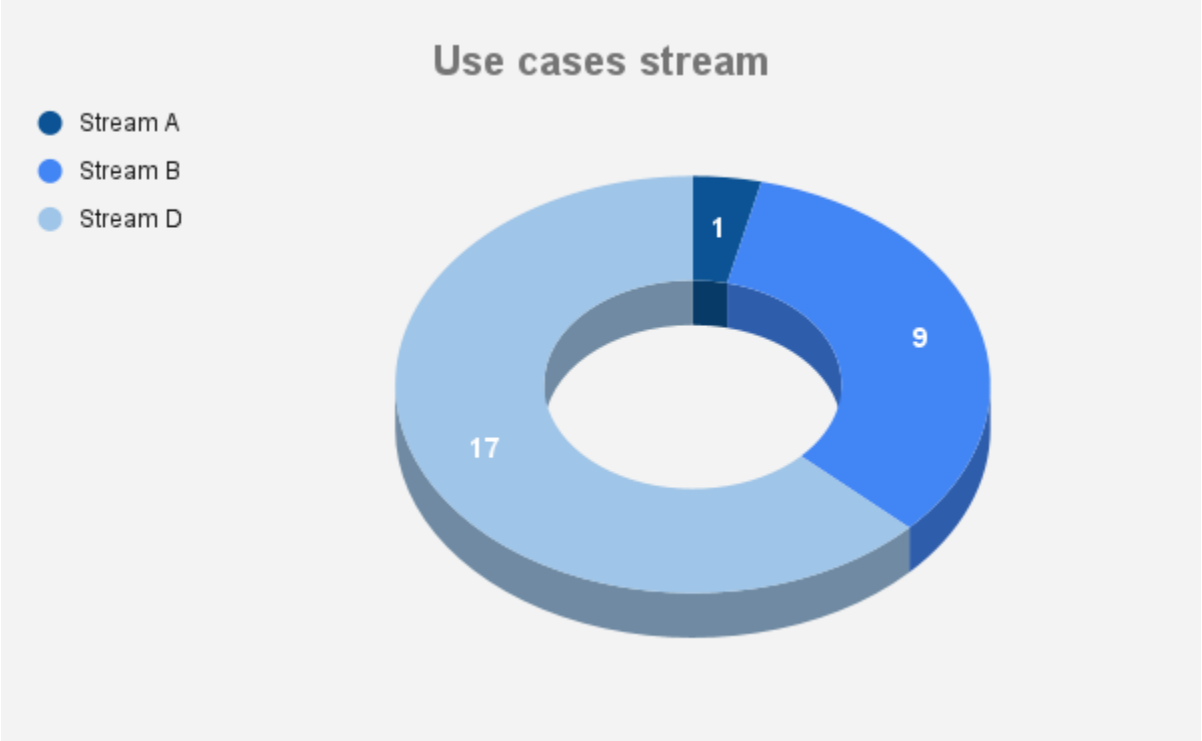

Figure 29. SNS JU Call 1 and 2 projects use cases targeting the Security/PPDR vertical sector per stream

In terms of use case type, the Media/xR sector presents a perfect balance, with 14 use cases presenting less mature results — 8 Demonstrations and 6 Proofs of Concept — and 14 more mature ones — 7 Trials, 5 Prototypes 2 Pilots (Figure 30).

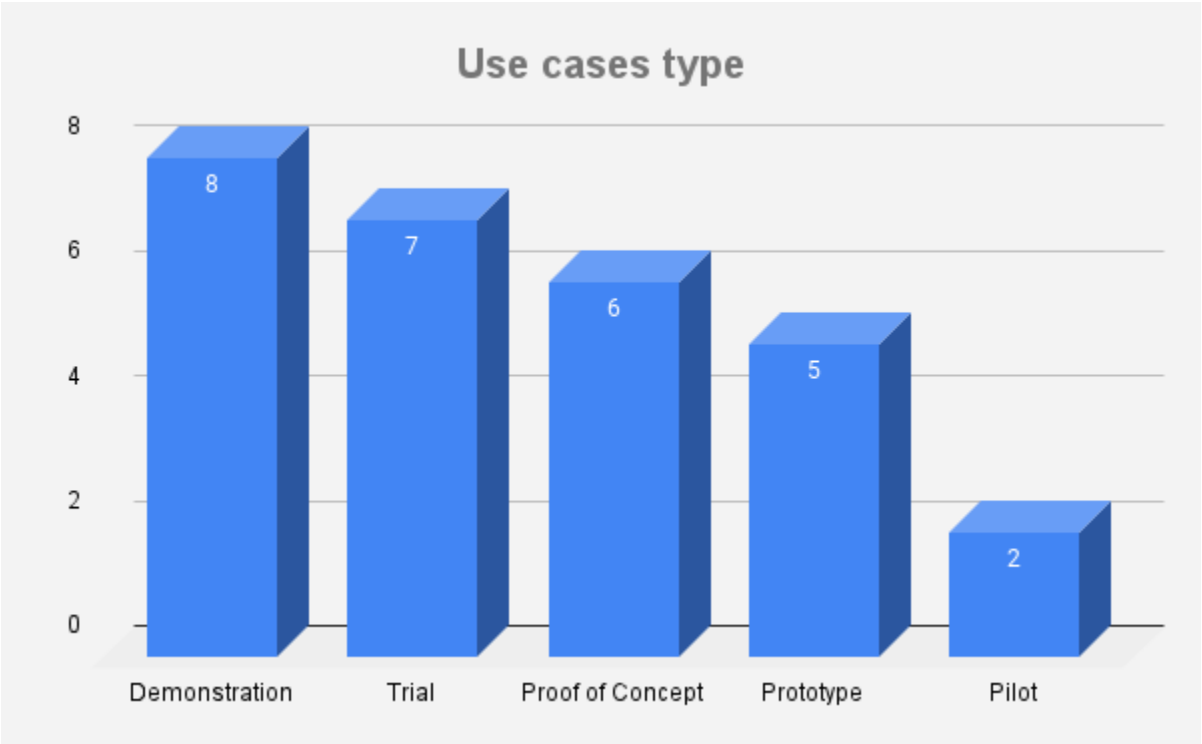

Figure 30. SNS JU Call 1 and 2 projects use cases targeting the Security/PPDR vertical sector per type

Just like for the Media/xR vertical sector, geographical distribution trends for the Security/PPDR vertical reflect general trends with the exception of Italy (Figure 31). Spain leads with 10 cases, followed by Greece with 6 and France with 4. Norway accounts for 3 use cases, while Portugal and Hungary each contribute 2. Other countries, including Romania, Belgium, Switzerland, Italy, Poland, and Serbia, each report 1 use case. Additionally, 2 cases are categorised as N/A, representing unspecified locations.

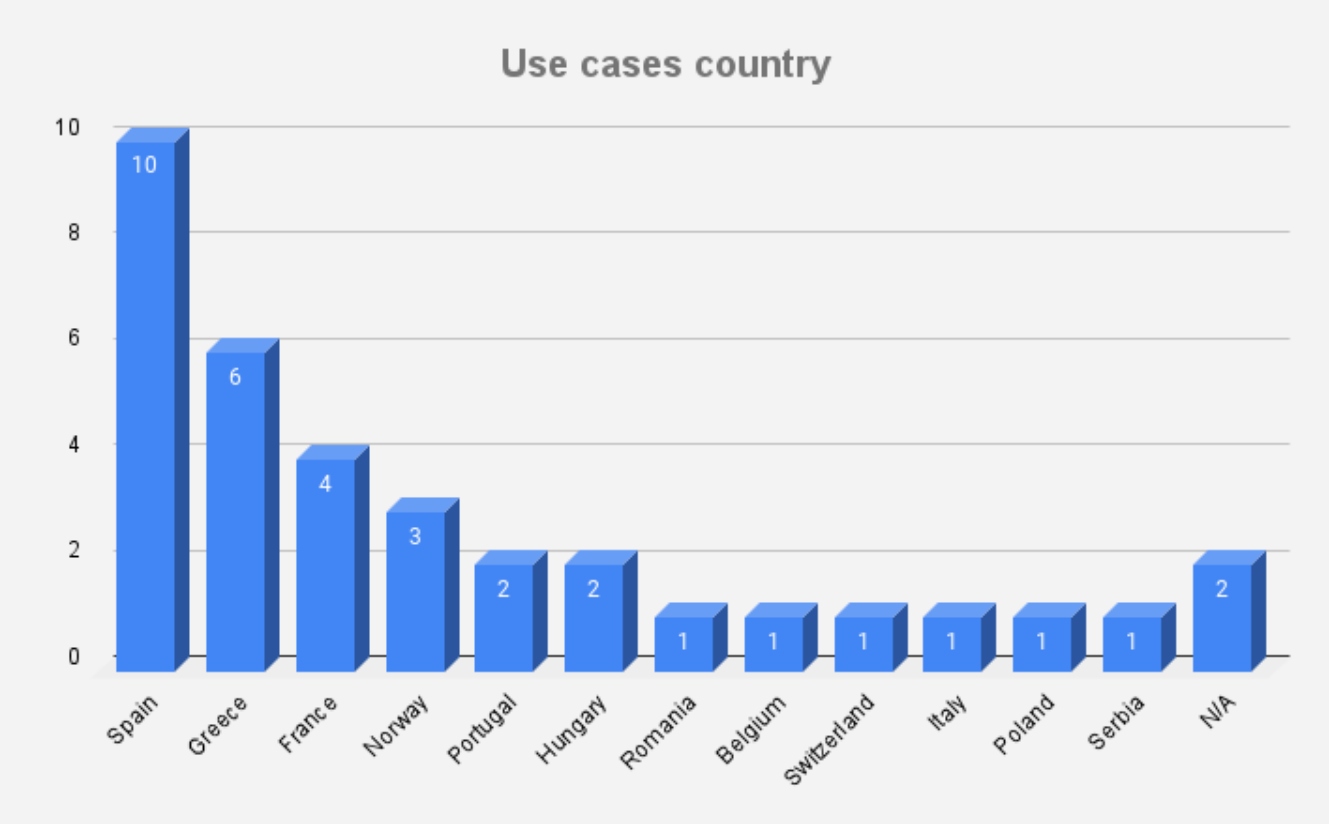

Figure 31. SNS JU Call 1 and 2 projects use cases targeting the Security/PPDR vertical sector per location

3.4 Third-party funding use cases

A handful of SNS JU projects, mostly originating from Call 1, are offering additional experimentation opportunities to 3xternal (3rd party) experimenters to use their facilities (platforms, tools, 5G connectivity, end devices, etc.) and to experiment, validating their proprietary solutions with the use of B5G connectivity[12]. Figure 30 shows the distribution of open-call use cases across projects, presenting the use cases developed through open-call-sponsored use cases (Figure 32). These are 63 total use cases sponsored by 5 SNS projects, all from Call 1 except for one instance from 6G-PATH[13]. Among the investigated projects, TrialsNet leads with 19 use cases, followed by FIDAL with 17 and 6G-XR with 14. 6G-SANDBOX contributes 12 use cases, while 6G-PATH has only 1, showing a significant concentration of use cases among the top four projects.

[12] https://smart-networks.europa.eu/open-calls-from-sns-projects/

[13] The vast majority of open call experimenters come from Call 1 projects, as they had a clear mandate to host open calls for the attraction of external experimenters, while the focus of Call 2 was different (although not precluding open calls).

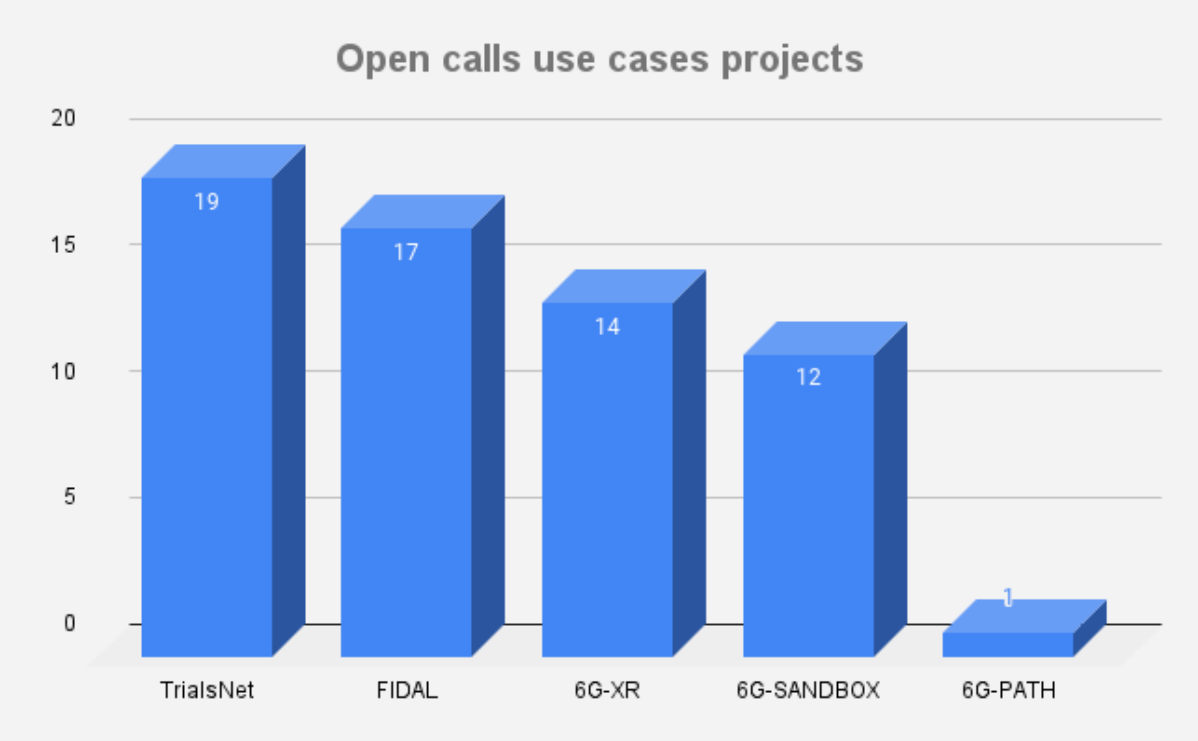

Figure 32. SNS JU Call 1 and 2 third-party funded vertical use cases per project

Given the dominance of large-scale trial projects such as TrialNet and FIDAL, Stream D accounts for the majority with 37 use cases, while Stream C contributes 26, distributed across 6G-XR and 6G-SANDBOX. This is a direct outcome of the Stream C and D call conditions, which requested the execution of open calls to attract external experimenters by Stream C and D projects (Figure 33).

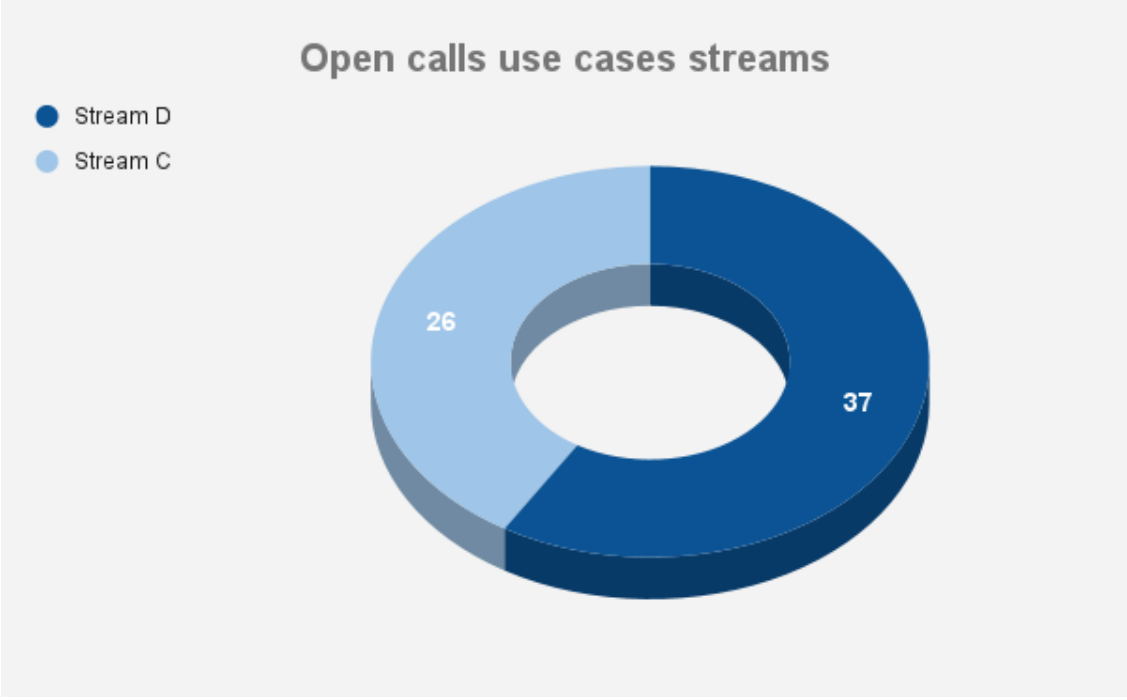

Figure 33.SNS JU Call 1 and 2 third-party funded vertical use cases per stream

Figure 34In terms of verticals, the main vertical sectors addressed by the use of externally funded use cases are only partly aligned with the overall trend. The Media/xR sector leads with 14 use cases out of the overall 41 (second place). This is followed closely by Security/PPDR with 12 use cases out of 28 (4th overall). Interestingly, Tourism & Culture is ranked in second position with 7 use cases out of 10 in the overall trend. Conversely, the Industry 4.0/Manufacturing sector which was leading in the SNS JU use cases, contributes with only 6 use cases, not reflecting the 44 general entries of the total inputs (1st overall, see Figure 4). Similarly, the Automotive/Transport/Logistics sector and Smart City sectors have only 4 and 3 use cases, respectively, in contrast with the 31 and 19 figures of the general trends (3rd and 5th overall). Smart Health and Smart Energy also account for 3 each. Non-Terrestrial Networks have 2 use cases, while those classified as "Other" include 8 (Figure 34).

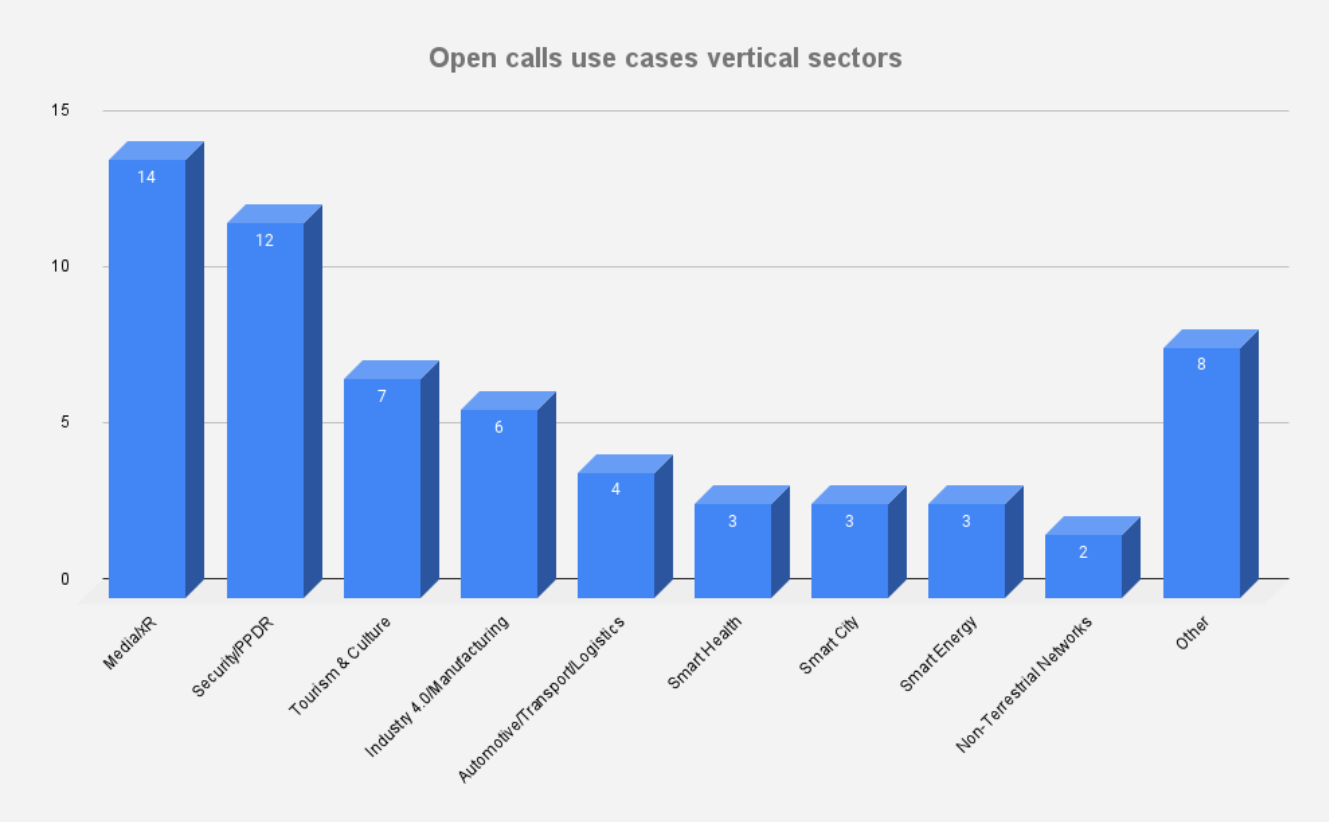

Figure 34. SNS JU Call 1 and 2 third-party funded projects addressed verticals

In terms of use case type, the degree of maturity is higher than the overall trend (Figure 35). 35 out of 63 use cases are indeed either Trials, Pilots and Prototypes with 26, 7 and 2 instances respectively, showcasing a significant mid-maturity level with few use cases peaking maturity. Conversely, less mature use cases present 13 Proofs of Concept, 11 Demonstrations and 4 Simulation/Emulation.

In terms of geographical distribution trends, these reflect general trends with countries such as Spain, Greece and Italy, leading with 23, 12 and 9 use cases each. Finland contributes 7 cases, while Norway, Romania, and Germany each have 3. The Netherlands and Israel report 2 use cases each, and 1 case is still unspecified (Figure 36).

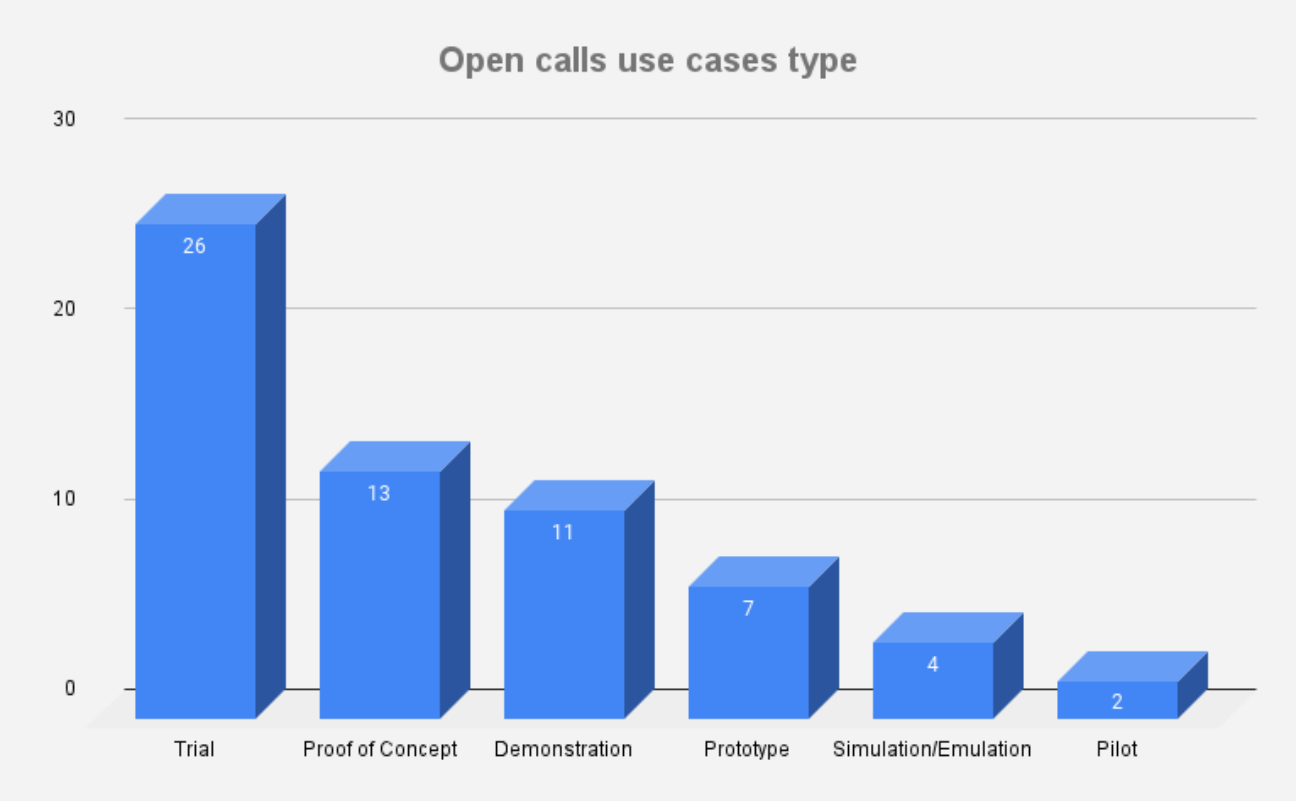

Figure 35. SNS JU Call 1 and 2 third-party funded vertical use cases per type

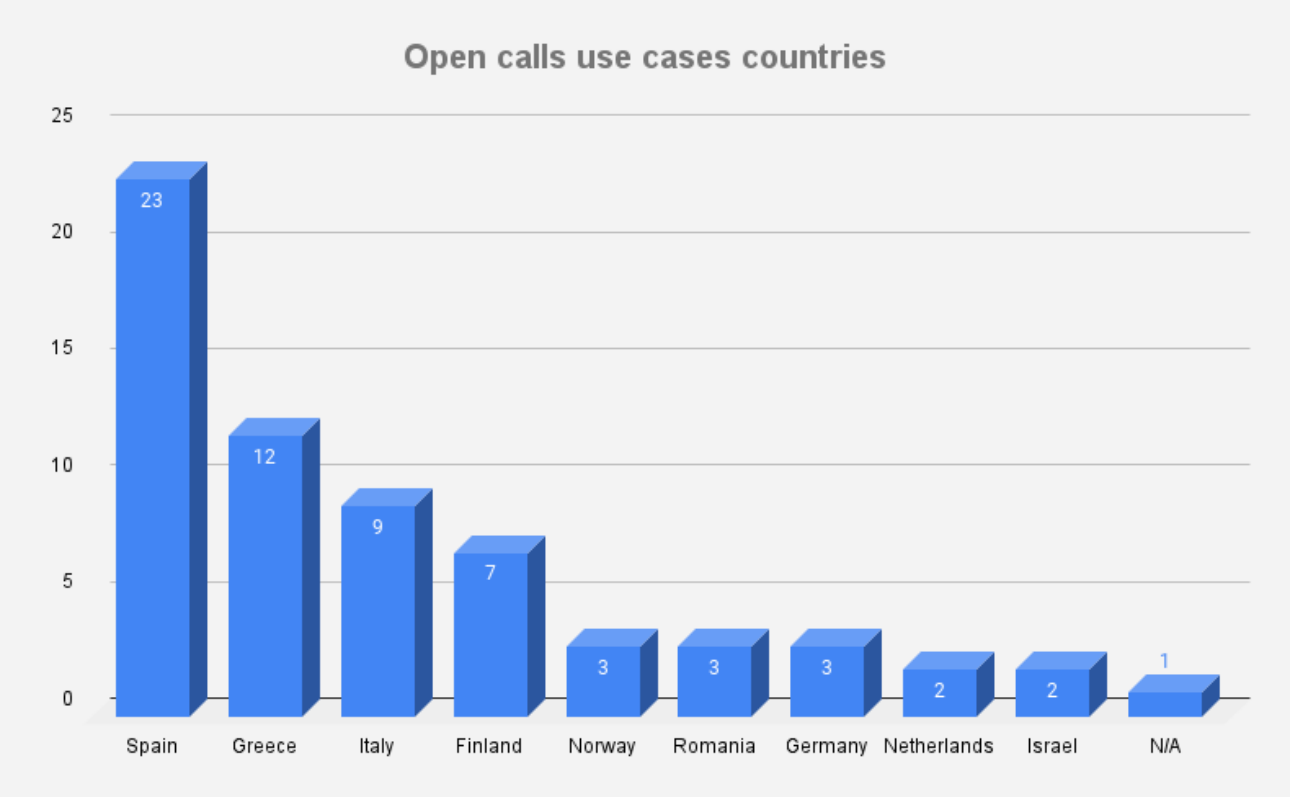

Figure 36. SNS JU Call 1 and 2 third-party funded vertical use cases per location

3.5 Trends and challenges analysis

Based on the datasets analysed below and the use case descriptions provided in each use case submission, preliminary trend and gap analyses can be elaborated.

3.5.1 Key trends

The analysis of use cases highlights a clear emphasis on transformative technologies such as **XR** (Extended Reality), **AI** (Artificial Intelligence), **IoT** (Internet of Things), and **Digital Twin** implementations, which are reshaping industries through their innovative applications. These technologies are primarily deployed to enhance operational efficiency, foster immersive user experiences, and address critical public safety needs. XR, particularly its subset AR (Augmented Reality), is at the forefront, with extensive applications in media, education, and manufacturing. In media, XR transforms live event experiences by enabling users to interact with virtual environments, whether as sports fans immersed in a 360-degree view of a match or concertgoers enjoying enhanced visual overlays. In education, AR creates engaging learning environments where students can interact with holographic representations, fostering deeper understanding and retention. In manufacturing, XR facilitates virtual prototyping and immersive training sessions, allowing workers to simulate operations and improve production efficiency while reducing risks.

AI and IoT, meanwhile, are central to advancing automation, improving decision-making processes, and enabling real-time monitoring. These technologies are deeply integrated into industries such as smart health, automotive, and manufacturing. In healthcare, AI-driven diagnostics, supported by IoT-enabled devices, allow for continuous patient monitoring, predictive analytics, and enhanced prosthetic control. The automotive sector leverages IoT sensors and AI algorithms to enable connected vehicles, predictive maintenance, and autonomous driving. Similarly, manufacturing utilises IoT devices for data collection and AI-powered systems to optimise production lines, enhance quality control, and reduce operational downtime. Together, AI and IoT exemplify how connectivity and intelligence converge to address complex challenges.

Technologies like 5G/6G and edge computing also play a pivotal role by providing these advanced applications with low-latency, high-reliability communication infrastructure. 5G/6G networks underpin XR environments by enabling real-time data processing and high-bandwidth transmission, ensuring seamless virtual experiences. Edge computing further enhances performance by bringing computational resources closer to the data source, reducing delays and ensuring responsiveness for mission-critical applications such as autonomous systems, smart cities, and public safety.

However, technologies such as Blockchain and Digital Twins, though promising, are less commonly referenced across use cases, suggesting their application is still emerging or confined to niche areas. Blockchain, with its inherent capability for secure data exchange and privacy-preserving mechanisms, shows potential in sectors like automotive and telecommunications, where secure and transparent transactions are critical. For instance, Blockchain can ensure the integrity of over-the-air updates for connected vehicles or provide tamper-proof records in collaborative telecommunication networks. Digital Twin technology, on the other hand, is predominantly associated with Industry 4.0 settings, where it is employed to simulate physical systems, enabling predictive maintenance and optimising resource utilisation. By creating virtual replicas of machinery or production lines, Digital Twins allow for real-time monitoring and proactive issue resolution, ensuring smoother operations and cost savings.

Overall, while XR, AI, and IoT dominate the technological landscape, the evolving presence of Blockchain and Digital Twins points to significant opportunities for growth and broader adoption in the coming years. The interplay between these technologies and advanced telco infrastructure is crucial for unlocking their full potential, driving innovation, and creating value across diverse verticals.

3.5.2 Key trends across verticals

3.5.2.1 Main Cross-vertical Technology Trends

The analysis of use cases across vertical sectors highlights the critical role of XR (Extended Reality), AI (Artificial Intelligence), IoT (Internet of Things), and 5G/6G connectivity in driving innovation across industries. These technologies are not just widely adopted but are also integral to their respective applications, leveraging telecommunications infrastructure to deliver seamless, efficient, and scalable solutions. Below is a detailed examination of these technologies, their applications, and their integration with telco systems.

XR Technologies (AR/VR)

XR technologies, encompassing Augmented Reality (AR) and Virtual Reality (VR), have become central to creating immersive environments that engage users in ways previously unimaginable. XR applications rely heavily on telecommunications infrastructure, particularly 5G/6G networks, which provide the low latency, high bandwidth, and edge computing capabilities necessary to process and stream high-quality content in real-time. For instance:

- In the Media/XR sector, XR allows fans to experience sports events or concerts from unique perspectives, regardless of location. VR headsets provide interactive, real-time views enhanced by the high-speed connectivity of telco networks.
- In Manufacturing, XR supports real-time virtual prototyping and collaborative design by leveraging edge computing to process complex 3D models near the source, reducing lag and improving collaboration among geographically distributed teams.
- In Education, XR applications such as holographic teaching rely on ultra-low-latency networks to stream high-resolution holograms, enabling interactive learning experiences that mimic real-world classrooms.
- XR's dependence on telco systems highlights its transformative potential across industries, turning traditional operations into dynamic, user-centric experiences.

AI (Artificial Intelligence)

Artificial Intelligence (AI) serves as the backbone of automation, data-driven decision-making, and predictive analytics. Its applications are diverse, spanning healthcare, automotive, smart cities, and beyond. AI's success in these domains is deeply tied to telecommunication systems, which provide the computational power and connectivity required for real-time data processing. Telco technologies such as edge computing enable AI models to process data locally, reducing latency and improving the responsiveness of AI-driven applications. For example:

- In Healthcare, AI powers advanced prosthetic devices, allowing them to adapt in real-time to the user's movements by analysing data streamed through reliable 5G networks.
- In Automotive, AI analyses data from IoT sensors in connected vehicles, enabling features like predictive maintenance and autonomous driving. The high-speed data transfer enabled by 5G/6G ensures that these systems operate without delay.
- In Smart Cities, AI optimises traffic flow by analysing real-time data from IoT-enabled cameras and sensors, predicting congestion patterns, and adjusting signals to improve efficiency.
- AI's integration with telecommunications creates intelligent systems capable of real-time insights and decisions, making it indispensable for industries aiming for innovation and efficiency.

IoT (Internet of Things)

IoT forms the backbone of connected ecosystems, enabling real-time monitoring, data collection, and communication between devices. Telecommunication systems play a vital role in supporting IoT by providing the

massive device connectivity, low-latency communication, and high reliability necessary for IoT deployments. For instance:

- In Transportation, IoT sensors embedded in vehicles transmit real-time data to central systems via 5G networks, enabling autonomous driving, predictive maintenance, and improved fleet management.
- In Healthcare, IoT devices such as wearables and remote patient monitoring systems rely on continuous connectivity to transmit vital data to healthcare providers, improving patient outcomes and enabling real-time interventions.
- In Smart Cities, IoT enables efficient utility management and public safety applications. Sensors monitor infrastructure, such as water systems and power grids, while IoT-enabled surveillance systems help manage crowd safety and detect anomalies.
- The ability of IoT to seamlessly integrate with telco infrastructure allows industries to create smarter, more responsive systems that enhance operational efficiency and user experience.

5G/6G Connectivity

5G and 6G are the foundational technologies enabling many modern applications. Their ability to deliver ultra-low latency, massive bandwidth, and high reliability makes them indispensable for advanced use cases across all verticals. These networks provide the connectivity needed for real-time data exchange, edge computing, and secure communication. Examples include:

- In Media/xR, 5G/6G enables real-time streaming of immersive VR and holographic content, enhancing user experiences in live events and interactive entertainment.
- In Manufacturing, the ultra-reliable low-latency communication (URLLC) capabilities of 5G support wireless control of robots and IoT devices, replacing traditional wired systems and enabling greater flexibility.
- In Public Safety, 5G/6G networks power real-time situational awareness systems, enabling first responders to access critical data and collaborate effectively during emergencies.
- In Education, 6G-powered holographic classrooms allow real-time 3D rendering and interaction, providing an immersive learning experience.

3.5.3 Key challenges

The overall technology landscape reveals a range of notable challenges in the adoption and integration of transformative technologies despite their evident potential across industries. While Blockchain and Digital Twin technologies are prominent examples of underutilised innovations, challenges include a broader set of technologies that remain inconsistently applied or entirely absent in certain verticals. They underscore both missed opportunities and areas for strategic development to ensure that industries fully leverage the technological possibilities available to them.

A key challenge lies in the limited deployment of Augmented Reality (AR) and Virtual Reality (VR) technologies beyond their stronghold in media and manufacturing sectors. While AR and VR are widely acknowledged for their ability to create immersive and interactive environments, their applications in public safety, healthcare, and education remain underexplored. In public safety, AR could provide real-time overlays of critical information, such as evacuation routes or hazard locations, enhancing the efficiency of first responders during emergencies. Similarly, in healthcare, VR could revolutionise medical training through lifelike simulations and support patient rehabilitation with immersive therapies. In education, AR could transform traditional learning environments by introducing interactive visual tools to make complex concepts more accessible. The absence of AR and VR in these sectors limits their ability to harness the full potential of immersive technologies.

Another critical challenge is the inconsistent adoption of IoT (Internet of Things) technologies in sectors where connectivity and real-time data analysis could yield substantial benefits. For instance, while IoT is widely used in manufacturing and transportation to monitor operations and optimise logistics, it remains underutilised in areas like urban planning and utility management. In smart cities, IoT sensors could provide real-time insights into infrastructure health, energy consumption, or traffic patterns, helping urban planners make informed decisions. In utilities, IoT could enhance resource efficiency and enable predictive maintenance of critical infrastructure, such as water pipelines and power grids. The lack of IoT integration in these domains represents a missed opportunity to improve operational efficiency and sustainability.

Similarly, AI (Artificial Intelligence), while heavily used in healthcare and automotive applications, is less prevalent in other sectors that could greatly benefit from its capabilities. For example, tourism and cultural heritage sectors could leverage AI to personalise visitor experiences or predict and manage crowd flow in popular destinations. AI could also play a more significant role in disaster management, where predictive analytics and automated decision-making could enhance preparedness and response times during crises. The underrepresentation of AI in these areas highlights an uneven distribution of its benefits, leaving certain industries underserved.

A final emerging challenge is the infrequent mention of edge computing across use cases where low-latency data processing is crucial. While edge computing is integral to sectors like automotive and manufacturing, where real-time decision-making is vital, its applications in other areas, such as public safety, education, and smart agriculture, are limited. For instance, edge computing could enable faster response times in emergency management, enhance personalised learning experiences in remote education, and optimise resource use in precision farming. The limited implementation of edge computing in these domains signals a need for greater investment and exploration.

These challenges in adopting technologies like AR/VR, IoT, AI, and edge computing across specific sectors illustrate the uneven pace of innovation and integration. Addressing these challenges requires a holistic approach that includes fostering cross-sector collaborations, investing in infrastructure, and prioritising the deployment of underutilised technologies in areas where their potential remains untapped. By bridging these challenges, industries can unlock new opportunities for efficiency, innovation, and societal impact.

3.5.4 Key challenges across verticals

The analysis of key challenges across verticals reveals uneven adoption of transformative technologies such as AR (Augmented Reality), VR (Virtual Reality), IoT (Internet of Things), AI (Artificial Intelligence), and edge computing. While widely applied in some sectors, these technologies are often overlooked in areas where their adoption could drive significant improvements in efficiency, innovation, and responsiveness. Below, key challenges are identified with illustrative examples for each vertical.

3.5.4.1 AR and VR Technologies

AR (Augmented Reality) and VR (Virtual Reality) have demonstrated their transformative potential in creating immersive and interactive environments. However, their application remains concentrated in a few sectors, with significant underutilisation in areas where they could address critical challenges or provide innovative solutions.

- Security/ PPDR: AR and VR are underutilised in scenarios such as enhancing firefighter visibility during smoke-filled rescues, providing first responders with real-time hazard overlays, or offering immersive training for crowd control scenarios in densely populated urban areas.
- Smart Health: VR is insufficiently used for surgical planning and rehearsal, where it could simulate complex operations, or in pain management therapy, where VR environments can provide distraction and relaxation for patients undergoing treatment.

- Education: AR adoption is sparse in STEM education, where interactive visualisations of concepts like molecular structures or physics experiments could revolutionise traditional teaching methods.

3.5.4.2 IoT Integration

IoT (Internet of Things) is central to enabling real-time data collection and monitoring, yet its adoption remains inconsistent across sectors. In domains like urban planning, utilities, and tourism, IoT could provide actionable insights to optimise operations, but its potential remains largely untapped.

- Urban Planning: IoT sensors are underused for monitoring real-time air quality and noise pollution in cities or for managing adaptive street lighting that could improve energy efficiency and enhance public safety.
- Automotive/ Transport/ Logistics: IoT is not widely implemented for predictive maintenance of sewage systems or for optimising renewable energy sources like solar panels and wind turbines in large-scale utility grids.
- Tourism and Culture: IoT-enabled solutions, such as personalised audio guides for museum tours or dynamic crowd control systems in historical sites like the Acropolis or Machu Picchu, remain largely absent.

3.5.4.3 AI Underrepresentation

AI (Artificial Intelligence) has revolutionised sectors like healthcare and manufacturing but remains underutilised in other domains. By enabling data-driven decision-making, predictive analytics, and automation, AI could address key inefficiencies and improve operational outcomes in several industries.

- Tourism and Culture: AI has untapped potential in analysing visitor data to create personalised itineraries or using machine learning to predict visitor flow patterns during peak seasons to reduce congestion.
- Security/ PPDR: AI's role in predicting natural disasters like landslides or hurricanes remains limited, even though it could assist authorities in pre-emptive evacuations or resource deployment.
- Education: AI-driven systems for assessing student progress and recommending tailored learning paths are not widely implemented despite their ability to address individual educational needs effectively.

3.5.4.4 Edge Computing Limitations

Edge computing brings computational resources closer to data sources, enabling faster processing and reduced latency. Despite its importance in real-time applications, edge computing remains underutilised in areas where immediate decision-making and low-latency communication are critical.

- Security/ PPDR: Edge computing is underutilised for processing data from drones during search-and-rescue missions in remote or disaster-affected areas, where low-latency analysis could save lives.
- Education: In remote education environments, edge computing could support high-resolution video conferencing or AR-based collaborative projects, but its adoption remains minimal.
- Smart Agriculture: Edge computing is not leveraged enough for managing autonomous tractors or for real-time soil health analysis, which could optimise resource use and boost yields.

A comparative analysis of key gaps and trends is provided in Table 5.

Table 5. Key trends and challenges in SNS JU vertical use cases

Vertical sector	Key trends	Key challenges
Media/xr	XR (AR/VR) for immersive user experiences in live events with 360-degree views	Limited adoption of AR/VR in enhancing accessibility for differently-abled users
	5G/6G to enable low-latency, high-bandwidth connectivity for real-time VR streaming	Scalability issues for high-quality XR experiences in large-scale live events
	AI to personalise content delivery based on user preferences	Inconsistent integration of AI for dynamic user engagement during live events
Education	XR (AR/VR) to create interactive learning environments (e.g., holographic teaching)	Sparse adoption of AR for STEM education to visualise complex concepts
	AI-driven systems to assess student progress and recommend tailored learning paths	Limited AI applications for personalised learning in remote education settings
	5G/6G to support real-time, high-resolution video and interactive collaboration	Edge computing underutilised for enabling real-time collaboration in low-connectivity areas
Manufacturing	XR facilitating virtual prototyping and immersive worker training	Edge computing inconsistently implemented for latency-sensitive processes in manufacturing o
	IoT enabling real-time monitoring and optimisation of production lines	IoT devices face cybersecurity concerns
	Digital Twins simulating machinery for predictive maintenance and resource efficiency	Digital Twin technology adoption limited to large enterprises, with smaller businesses lacking resources
Smart Health	AI-driven diagnostics for decision-making in patient care	Insufficient use of VR in rehabilitation therapies and surgical planning.

This project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101095841

	IoT-enabled wearables support real-time patient monitoring.	IoT adoption in rural healthcare facilities remains low
	5G/6G ensures connectivity for remote surgeries and advanced prosthetics.	Limited edge computing integration for real-time analysis, leading to delays in decision-making
Automotive/Transport/Logistics	IoT sensors enable predictive maintenance and fleet optimisation	Inconsistent IoT deployment for predictive maintenance in public transportation
	AI algorithms power autonomous driving and real-time traffic management	Limited edge computing use for immediate decision-making in autonomous vehicle systems.
	Blockchain secures over-the-air updates for connected vehicles	Low adoption of Blockchain for secure transaction records in fleet operations
Public Safety (PPDR)	IoT sensors enable predictive maintenance and fleet optimisation.	Inconsistent IoT deployment for predictive maintenance in public transportation.
	AI algorithms power autonomous driving and real-time traffic management.	Low adoption of Blockchain for secure transaction records in fleet operations.
	Blockchain secures over-the-air updates for connected vehicles.	Limited edge computing use for immediate decision-making in autonomous vehicle systems.
Smart Cities	IoT sensors monitor infrastructure health (e.g., water systems, power grids)	Limited IoT integration for adaptive lighting and air quality monitoring
	AI analyses real-time data for traffic flow optimisation and energy efficiency	AI adoption remains inconsistent for crowd management and urban planning
	Edge computing reduces latency in smart utility management	Edge computing underutilised for real-time insights into managing urban infrastructure
Tourism & Culture	AI personalises visitor experiences and predicts crowd flow in popular destinations	Limited integration of AI for real-time recommendations and dynamic itinerary planning for visitors

	IoT-enabled guides provide dynamic tours of historical sites	Sparse IoT adoption for crowd control and infrastructure monitoring in heritage sites
	XR technologies create virtual museum exhibits and cultural experiences	VR applications for virtual tourism are underexplored
Agriculture	IoT-enabled sensors provide real-time soil and crop health data	Inconsistent IoT deployment for water and nutrient monitoring in developing regions
	AI optimises resource use and pest management	AI-driven analytics for weather predictions and yield forecasting remain underutilised
	Edge computing supports precision farming by enabling low-latency decision-making	Minimal adoption of edge computing for real-time farm equipment management

4 Conclusions and next steps

The findings presented in this deliverable offer a detailed analysis of the current state and outlook of 5G and emerging 6G technologies across diverse vertical sectors. The data collected from the SNS ICE survey and the Vertical Engagement Tracker highlights significant progress in 5G adoption and promising experiments leading to 6G functionalities. Perhaps more importantly, current applications developed in the SNS telco ecosystem seem increasingly tailored to meet the specific needs of industries such as Automotive/Transport/Logistics, Industry 4.0, Media/xR, and Security/PPDR. These sectors demonstrate strong engagement, driven by the transformative potential of enhanced connectivity, low latency, and reliability, which enable disruptive use cases with game-changing functionalities.

Despite this progress, many use cases remain in their early stages, particularly in sectors with nascent infrastructure or limited market readiness. Demonstrations and proofs of concept dominate the landscape, but the transition to trials and prototypes in several industry domains seems to reflect growing maturity and an evolving readiness to scale. The data also underscores that addressing key challenges, including high implementation costs, regulatory barriers, and standardisation delays, is essential to ensuring broader adoption and integration of advanced connectivity solutions.

Through firsthand information collected from various vertical industry associations and member organisations the document's analysis also identifies emerging trends that are shaping the evolution of 5G and paving the way for 6G technologies. These include increased focus on the integration of non-terrestrial networks, and the adoption of enabling technologies like AI, edge computing, and cybersecurity.

To treasure the main learnings of this document and provide actionable insights for relevant stakeholders, the main learnings of this document will be summarised in a position paper (D3.4 Position Paper on 6G for Verticals, forthcoming in March 2025) outlining a clear pathway for aligning strategies with sector-specific needs and technological advancements.

This project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101095841

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Appendix 1 Industry verticals

This section presents a sector-by-sector summary of the use cases linked to the projects that replied to the survey, categorised by call and ordered alphabetically. Given the large number of use cases, a summary bird's eye view is provided, mentioning all submitted UCs per vertical sector,

Automotive/ Transport/ Logistics

Call1

- 5G-STARDUST – Maritime, Railways, Airways neutral-host cell
- 5G-STARDUST – Vehicle Connected
- CONFIDENTIAL6G – Intelligent connected vehicle, mission-critical services, OTA updates, FL/ML and vehicle-to-infrastructure communication
- FIDAL – CORAL - Robot remote control
- FIDAL – FIDAL-VLC: 5G Robot Race
- Hexa-X-II – 6G-based sensing algorithms and concepts with real-time performance: Network-Assisted Mobility
- HORSE – Secure smart LRT (Light Rail Transit) systems
- NANCY – Spanish outdoor demonstrator
- NANCY – Italian massive IoT demonstrator
- PREDICT-6G – Smart Factory
- PRIVATEER – Securing Intelligent Transport Systems
- TARGET-X – Cooperative Perception (Automotive Vertical)
- TARGET-X – Digital Twin (Automotive Vertical)
- TARGET-X – Predictive Quality of Service for Tele-operated Vehicles (Automotive Vertical)
- TrialsNet – Public Infrastructure Assets Management
- TrialsNet – Autonomous Apron
- TrialsNet – Automated Tele-Operated Sustainable (ATOS) driving
- TrialsNet – 5GS3
- VERGE – Edge-assisted Autonomous Tram

Call2

- 6G-EWOC – Smart Urban Mobility
- 6G-GOALS – Collaborative Robots (Cobots)
- 6G-TWIN – Teleoperated driving supported by network digital twins
- ENVELOPE – Advanced In-Service Reporting for Automated Driving Vehicles
- ENVELOPE – Dynamic Collaborative Mapping for Automated Driving
- ENVELOPE – Data sharing for real-time situation awareness
- ENVELOPE – Periodic vehicle data collection for improving digital twin (DT)
- ENVELOPE – Vehicle testing with mixed reality
- ENVELOPE – Tele-operated driving aided by DT
- ISEE-6G – Connected and cooperative autonomous mobility
- NATWORK – Anti-jamming technologies for AVs
- SUNRISE-6G – Collaborative Robotic exploration of mining environments

Education

Call1

- 6G-SHINE – Immersive education

- 6G-XR – MST

Call2

- 6G-PATH – XR in Rural Schools
- 6G-PATH – Classroom of the Future

Industry 4.0/ Manufacturing

Call1

- 6G-BRICKS – 6G applications for Industry 4.0
- 6G-SANDBOX – 6G-VIZ
- 6G-SANDBOX – 6G-MOBKPI
- 6G-SANDBOX – Prosperancy
- 6G-SHINE – Subnetwork Co-existence in Factory Hall
- 6G-SHINE – Visual Inspection Cell
- 6G-SHINE – Robot control
- 6GTandem – Digital Twin in Industrial Enviroments
- ADROIT6G – 6G IIoT
- ADROIT6G – Collaborative robots (cobots) in construction
- BeGREEN – Physical and environmental awareness
- CONFIDENTIAL6G – Predictive maintenance for airline consortium using blockchain-based data sharing platform and federated AI/ML orchestration
- DESIRE6G – Digital Twin
- DETERMINISTIC6G – Exoskeleton in industrial context
- DETERMINISTIC6G – Factory Automation: Adaptive Manufacturing
- FIDAL – TiFi: Tactile Internet Fidelity over FIDAL for Bilateral Teleoperation
- Hexa-X-II – Management & Orchestration: Cooperating Mobile Robots
- Hexa-X-II – Pervasive Technologies and Network Functions: Cooperating Mobile Robots
- Hexa-X-II – Evolved Management & Orchestration, Evolved Network Functions(Trustworthy flexible topologies, Network beyond communications), 6G Device Components, 6G Radio Aspects: Cooperating Mobile Robots
- Hexa-X-II – Sustainability and trustworthy-oriented orchestration in 6G: Cooperating Mobile Robots
- Hexa-X-II – AI-assisted E2E lifecycle management of a 6G latency-sensitive service across the compute continuum: Cooperating Mobile Robots
- Hexa-X-II – Trustworthy flexible topologies in 6G, leveraging on “beyond communication” aspects: Cooperating Mobile Robots
- IMAGINE-B5G – ALMA
- IMAGINE-B5G – ULTRA-FAB5G
- TARGET-X – Inline Quality Assurance for Machining (Manufacturing Vertical)
- TARGET-X – Environmental Condition Monitoring (Manufacturing Vertical)
- TARGET-X – Trace and Tracking of Workpieces (Manufacturing Vertical)
- TARGET-X – Edge-controlled Automation with Mobile Manipulation (Robotics Vertical)
- TERA6G – Point to multipoint THz connectivity in high throughput industrial scenarios
- TERRAMETA – THz RIS Enabled Smart Factory
- TIMES – Mobile Robot Management
- TIMES – Predictive maintenance, monitoring of machine / Production line with Hi data Flow, substitute Field Bus in NON RTI Applications
- TIMES – AR/VR - Digital Twin - Virtual Commissioning - Hi Level Maintenance

- TIMES – High Dynamic Control, Substitute Field Bus in RTI for Motion and Robotics
- TIMES – Ensuring Seamless and Secure Field Bus Substitution Process
- TIMES – Flexible Factory
- TrialsNet – Intelligent control of interconnected manufacturing infrastructures (i-CNC)
- VERGE – B5G edge computing for XR-driven collaborative design and real-time virtual prototyping

Call2

- 6G-DISAC – DISAC for smart factory shop floors
- 6G-GOALS – Semantic State Representation Function
- 6G-PATH – Automated logistics
- ELASTIC – Smart Connected Factory of the Future
- EXIGENCE – Physical security in industry
- OPTI-6G – Industry 4.0

Media/xR

Call1

- 5G-STARDUST – Residential Broadband
- 6G-BRICKS – Metaverse as an enabler of a Modern Workplace
- 6G-SANDBOX – Internet of Sense
- 6G-SANDBOX – Testing the integration of an open-source 5G FR2 gNB with the 6G-SANDBOX Reconfigurable Intelligent Surface
- 6G-SHINE – Indoor interactive games
- 6G-SHINE – Virtual live production
- 6GTandem – AR enriched events
- 6G-XR – Control plane optimisations
- 6G-XR – ExCalibAR
- 6G-XR – TrustNet
- 6G-XR – REQUIEM
- 6G-XR – 5G/6G FWA with optical RAN
- 6G-XR – 5G-SlAIce
- 6G-XR – 6G-SLICE: Enabling end-to-end O-RAN slicing in 6G-XR
- 6G-XR – METAPHOR - Volumetric Capture and Transmission in Broadcast Environments
- 6G-XR – FALADIN
- 6G-XR – 6G-REMIX
- ADROITG – Holographic Teaching
- DESIRE6G – Intelligent and resilient VR/AR applications with perceived zero latency
- FIDAL – Virtual Reality Networked Music Performance
- FIDAL – Advanced sports area media services
- FIDAL – Internet of Senses / Haptic sensing
- FIDAL – B5GVideoNet (B5GVN)
- FIDAL – AI-HOLOCOM
- FIDAL – VideoGee
- FIDAL – Music live streaming over 5G network
- Hexa-X-II – Training and inference of collaborative distributed machine learning model on a dynamically changing heterogeneous 6G architecture environment: Cooperating Mobile Robot
- Hexa-X-II – AI-Native Air Interface: Seamless Immersive Reality

- Hexa-X-II – ML-based channel state feedback compression in a multi-vendor scenario: Seamless Immersive Reality
- Hexa-X-II – End-to-End Extended Reality: Seamless Immersive Reality
- NANCY – Greek outdoor demonstrator
- SEASON – User-driven immersive experiences
- TrialsNet – Immersive Fan Engagement
- TrialsNet – Extended XR Museum Experience

Call2

- 6G-INTENSE – Metaverse
- EXIGENCE – Media streaming carbon footprint transparency
- FirstTo6G – Ultra-high data rate
- SAFE-6G – Industrial Metaverse of a production line
- SAFE-6G – Metaverse for Education & Formation
- SUNRISE-6G – Federated Metaverse
- TeraGreen – Live immersive XR in large-scale events

Non-Terrestrial Networks (NTN)

Call1

- 6G-SANDBOX – MAGDALENA (MeAsuring 5G anD sAteLlite nEtwork iNtegrAtion)
- 6G-SANDBOX – NTN
- ETHER – Service provisioning to delay-tolerant IoT applications from LEO satellites
- ETHER – Air-space safety critical operations

Call2

- ISEE-6G – Aerial Corridors
- SUNRISE-6G – Federated Non-Terrestrial Networks

Security/ PPDR

Call1

- 5G-STARDUST – PPDR
- 6G-NTN UC4 – Adaptation to PPDR or Temporary Events"
- 6G-NTN UC1 – Maritime Coverage For Search and Rescue Coast Guard Intervention"
- 6G-SANDBOX – Broadcast-Multicast Communications
- CONFIDENTIAL6G – Privacy-preserving confidential computing platform that enables mitigation of internal threats for telecom cloud providers
- FIDAL – XR-assisted services for public safety/ On-site XR-assisted emergency surgical operations
- FIDAL – XR-assisted services for public safety / AR for improving Law Enforcement Agents (LEA) situational awareness
- FIDAL – City security event / incident
- FIDAL – MC-SEAL (Mission Critical SEAL as an enabler of AI-based emergency coordination and decision-making)
- FIDAL – Enterprise 5G for Time Critical Applications
- FIDAL – City Security Event / Incident
- FIDAL – RescueSync - Beyond 5G Emergency Coordination

- FIDAL – Enhancing Public Safety by Leveraging the Mobitrust Situational Awareness Ecosystem for Policing Large-Scale Events
- FIDAL – AI ARMORS
- FIDAL – 5G
- FIDAL – SwarmCatcher
- FIDAL – Digital twin for First Responders
- IMAGINE-B5G – Mission-Critical services
- IMAGINE-B5G – SafeFlow
- RIGOUROUS – PPDR IoT Situational Awareness
- TrialsNet – Remote Coordination and Interworking of First-Responders in Emergency Situations
- TrialsNet – AI/ML-based Preventive and Reactive Emergency handling Toolset and Dataset for Mission Critical Services (AI-PREMSET-MCX)
- TrialsNet – SkyLink Vision

Call2

- 6G-PATH – Smart Cities- Security Coordination
- ISEE-6G – Safety Enhancement
- ITrust6G – Programmable security as a service
- NATWORK – IoT security
- NATWORK – Improving variability of the network with continuous security
- ROBUST-6G – Security Capabilities Exposure with Network-Security-as-a-Service (NetSecaaS)

Smart Agriculture

Call1

- DETERMINISTIC6G – Mobile Automation: Smart Farming
- IMAGINE-B5G – AI4FS

Call2

- 6G-PATH – FARM1-Water saving
- 6G-PATH – UC-FARM-2 – Smart Vineyards
- ISEE-6G – Agricultural industrial IoT
- ISEE-6G – Energy harvesting

Smart City

Call1

- 6G-SHINE – Intelligent Network Architecture
- FIDAL – Smart village engagement services
- PRIVATEER – Securing Smart City Applications
- RIGOUROUS – Utilities Management and security
- RIGOUROUS – IoT-based Smart City Platform
- TrialsNet – Smart Crowd Monitoring
- TrialsNet – Smart Crowd Monitoring
- TrialsNet – Smart Traffic Monitoring
- TrialsNet – Control Room in Metaverse
- TrialsNet – MILESTONE

- TrialsNet – AdaptoFlow
- TrialsNet – Cities without Barriers

Call2

- 6G-DISAC – VRU protection at a smart intersection
- 6G-MUSICAL – Cooperative communication and multi-static sensing based on OFDM waveform
- 6G-PATH – Connected and Sensing City
- 6G-SENSES – Exploiting sensing information to improve communication services
- 6G-SENSES – Ubiquitous Connectivity and Immersive Services
- 6G-SENSES – Network Digital Twin
- NATWORK – Sustainability and reliability of 6G Slices and services

Smart Energy

Call1

- 6G-SANDBOX – Power Storm
- 6G-XR – ENORMOUS
- FIDAL – DADOLTI
- TARGET-X – Energy Monitoring and Energy Consumption Awareness (Energy Vertical)

Call2

- 6G-TWIN – Energy savings in dense deployments supported by network digital twins

Smart Health

Call1

- IMAGINE-B5G – LEOSED
- IMAGINE-B5G – DCA
- SUPERIOT – Sustainable IoT network in medical environments
- TrialsNet – MCI and Emergency Rescue in Populated Area
- TrialsNet – Remote Proctoring
- TrialsNet – Smart Ambulance
- TrialsNet – Adaptive Control of Hannes Prosthetic Device
- TrialsNet – COMO5 - CONTINUOUS MONITORING OF PATIENTS WITH CHRONIC DISEASE VIA 5G
- TrialsNet – MediVision5G
- TrialsNet – 5GVIREH

Call2

- 6G-PATH – 3D Hydrogel patches
- 6G-PATH – Elderly monitoring

Tourism & Culture

Call1

- TrialsNet – Service Robots for Enhanced Passenger's Experience
- TrialsNet – City Parks in Metaverse
- TrialsNet – Extended XR museum experience

- TrialsNet – DreamPark
- TrialsNet – Cloud Gaming
- TrialsNet – B5G Football Stadium
- TrialsNet – 5G-NU-ART
- TrialsNet – Torino4U
- TrialsNet – Mobile Augmented Reality for Outdoor PoI Enrichment
- TrialsNet – B5G Football Stadium

Call2

No use cases for Call 2

Other

Call1

- 5G-STARDUST – Global private networks
- 6G-NTNUC2 – Autonomous Power Line Inspection using Drones"
- 6G-NTNUC3 – Urban Air Mobility"
- 6G-NTNUC5 – Consumer Handheld Connectivity and Positioning in Remote Areas"
- 6G-NTNUC7 – Direct Communication via Satellite (UE-to-satellite-to-UE)"
- 6G-NTNUC6 – Architecture for service versatility (terrestrial-NTN seamless mobility)"
- 6G-NTN – Ubiquitous and resilient connectivity
- 6Green – Critical operation maintenance during energy-constraint disaster scenarios
- 6G-SANDBOX – Next cell prediction using Graph Neural Networks (NEXT-CELL-GNN)
- 6G-SANDBOX – Integration between 5G/6G and LoRaWAN (6G-LoRaGRAN project)
- 6G-SANDBOX – Smart Contract-based Digital Twins for the IoT (SCDT)
- 6G-SANDBOX – NWDAF Stream Analyzer
- 6G-XR – TOP4 - AI/ML algorithm for efficient resource optimization in the 5G slicing techniques
- 6G-XR – Stream Analyzer For 5G Slicing
- 6G-XR – Dynamic Service Migration Optimization in Unified Network Continuum (DYNAMICON)
- 6G-XR – OpenCAMARA
- BeGREEN – BeGREEN Intelligent Plane
- FIDAL – Effect
- Hexa-X-II – Crowd-detectable zero-energy devices: Realtime Digital Twins
- Hexa-X-II – Flexible modulation and transceiver design: Cooperating Mobile Robots
- Hexa-X-II – Radio propagation measurements to collect data for radio channel modelling: Seamless Immersive Reality
- HORSE – Remote Rendering to Power XR Industrial (R22XRI)
- PREDICT-6G – Multi-domain deterministic communication
- RIGOUROUS – Protection of 6G-enabled Services against Cyber Threats
- TARGET-X – 5G for Automation of Deconstruction Processes (Construction Vertical)
- TARGET-X – 5G for Energy Analytics of Construction Processes (Construction Vertical)
- TARGET-X – Extended Reality for Deconstruction Processes (Construction Vertical)
- TERA6G – Point to multipoint THz x-Haul, supporting PNI-NPN implementations
- TERRAMETA – Telecom Outdoor & Outdoor-to-Indoor Use Case

Call2

- 6G-CLOUD – AI-driven multi-domain operations

- ELASTIC – Privacy-preserving confidential computing to migrate on-premise sensitive IT services to the cloud
- ISEE-6G – Joint Communications and Sensing in a 6G Cell-free environment
- ITrust6G – Operational security and trust re-evaluation
- ITrust6G – Dynamic security orchestration and trust establishment in multi-stakeholder and multi-domain environment
- PROTEUS-6G – Flexible dynamic RAN
- ROBUST-6G – Automatic threat detection and mitigation in 6G-enabled IoT environments
- ROBUST-6G – UMU CyberDataLab Decentralised Federated Learning for joint privacy-preserving AI/ML model training
- TeraGreen – Fronthaul in ultra-dense small cell networks
- TeraGreen – High throughput fixed wireless access (FWA)
- TeraGreen – Wireless data centers

Appendix 2 Vertical Trends survey

Your Full Name*

———————————-

Your Email

———————————-

Your Organisation

———————————-

Company or Association name

———————————-

Your Job Title

———————————-

Your Vertical Sector

----------MULTIPLE CHOICE----------

- Automotive/ Transport/ Logistics
- Education
- Industry 4.0/ Manufacturing
- Media/xR
- Space/Non-Terrestrial Networks (NTN)
- Smart Agriculture
- Smart City
- Smart Energy
- Smart Health
- Security/ PPDR
- Tourism & Culture
- Other

If "other", please specify:

———————————-

What is the size of your company? (EU criteria)

----------MULTIPLE CHOICE----------

- Association
- Large enterprise (over 250)
- Medium (up to 250)

- SME (up to 50)

PART 1 - Uptake of 5G and use cases covered (5 Questions)

According to a recent GSMA survey, the adoption of 5G mobile connections will continue at pace and will account for almost 60% of mobile connections in 2030 at a worldwide level.

Q1.1: What % of 5G connections do you foresee in your industry by 2030?*[14]

Your estimate of % of 5G connections...(Refer only to M2M/IoT lines

(max 300 characters)

———————————-

Q1.2:What 5G form factor will be more common?*

----------MULTIPLE CHOICE----------

- Drones
- Autonomous connected machines (e.g. cars)
- Robots/Cobots
- Sensors
- 5G modules
- Other
- Don't know

If "other", please specify:

———————————-

Q2: Do you have any use cases that were not feasible with 4G and that took advantage of 5G?*

5G use cases....

(max 300 characters)

———————————-

Q3.1: What are the most significant 5G use cases implemented in your vertical sector, and how is success measured?*

e.g. Customer satisfaction, product/service innovation, cost reduction. List in order of importance.

(max 300 characters)

———————————-

[14] * indicates mandatory fields

Q3.2: Which of the below 5G functionalities has been applied by each use cases in your vertical sector, and for what purpose?*

- Enhanced Broadband (from “eMBB”);
- Massive Communication (from “mMTC”);
- Low latency (Ultra-Reliable Low-Latency Communication) (from “URLLC”)
- e.g. Use Case 1: functionality eMBB, mMTC, UrLLC

————————————-

Q4: Are any of the design principles below already concretely applied in your vertical sector?*

----------SINGLE CHOICE----------

- 5G Slices
- Yes
- No

If "No" can you state the main reasons?

----------MULTIPLE CHOICE----------

- Do not know
- Not interested
- Not been offered by ICT provider
- Not fit for the purpose
- 5G Private Network is a better solutions
- Not considered mature
- Low usability (difficult to integrate/configure autonomously)
- Not economically viable

5G Private Networks

----------SINGLE CHOICE----------

- Yes
- No

If "Yes" would you consider to acquire you own spectrum?

----------MULTIPLE CHOICE----------

- Yes
- Do not know
- Not interested
- Not economically viable
- Other

If "other", please specify:

———————————-

If "No" can you state the main reasons? Choose top 3 reasons:

----------MULTIPLE CHOICE----------

- Do not know
- Not interested
- Not been offered by ICT provider
- Not fit for the purpose
- 5G slices are a better solutions
- Not considered mature
- Low usability (difficult to integrate/configure autonomously)
- Not economically viable
- Other

If "other", please specify:

———————————-

Please tick if you use only public 4G or 5G networks for machine connectivity (if not slices or private networks)

----------MULTIPLE CHOICE----------

- 4G/5G FWA
- Satellite connectivity
- Wifi for M2M connectivity
- Open RAN access
- Network APIs (eg. CAMARA/Open Gateway)
- Licenced LPWA technologies (3GPP family like LTE M or NB IoT)
- Unlicenced LPWA technologies (eg. LORA. Sigfox, others)
- Low range technologies (eg. bluetooth)

Q5.1: What are the most relevant trends that will shape your vertical sectors in the next 5 years?*

(max 300 characters)

———————————-

Q5.2:What will be the digital technologies that will mostly affect those trends?*

----------MULTIPLE CHOICE----------

- Advanced Connectivity (5G and Beyond 5G)
- 5G FWA
- FBB (FTTx)
- Wifi
- AI
- Gen AI
- Quantum Computing

- Cloud
- Edge Cloud
- IoT for Big Data/analytics
- xR (Augmented / Virtual / Mixed Realities
- Metaverse
- Cybersecurity technologies
- Digital Twins

Please list other technologies (digital or not) that will be relevant in your industry:

(max 300 characters)

———————————-

Are there any other significant matters concerning 5G this survey has overlooked that deserve attention?

(max 300 characters)

———————————-

PART 2 - Beyond 5G/6G (5 questions)

Q1: List use cases that were not feasible with 5G and will need 5G evolution/6G?*

(max 2000 characters)

———————————-

Q2: What are the challenges and barriers to market deployment and adoption beyond technology for these promising use cases?*

(max 2000 characters)

———————————-

Q3: Which of the new 6G features can impact your vertical sector and why?*

----------MULTIPLE CHOICE----------

- Integrated AI & Communication (AI network services)
- Integrated Sensing & Communication
- Integration with satellite connectivity
- Thz Communications
- Cloud native communications (“cloud networks”)
- Network APIs (network as a service)
- Low energy communications
- Quantum computing
- RIS (Reconfigurable Intelligent Surfaces)

Q4: What do you expect from Beyond 5G / 6G that 5G could not deliver?*

----------MULTIPLE CHOICE----------

- Sufficient bandwidth
- Global coverage
- Very low latency
- AI-powered services (delivered from within the 5G network)
- Security/resilience
- Simplicity & maintainability (e.g. slice setting)
- New device form factors
- Economic sustainability
- Environmental sustainability
- Others
- Don’t know

If you selected "other" please list:

(max 300 characters)

——————————-

Q5: Which other digital technologies do you evaluate as most valuable for your sector to be provided with beyond 5G / 6G connectivity?*

Please prioritise (7 most valuable, 1 less valuable, 0 no value)

----------SCORE BARS----------

- Smart connectivity (ATAWAD)
- Cloud/Edge computing
- AI/ML
- GenAI
- Quantum computing
- Blockchain
- Digital Twins
- Immersive communications
- Metaverse
- Cybersecurity technologies
- Others
- Don't know

If you selected Others, please list any other relevant digital technologies:

(max 300 characters)

——————————-

Are there any other significant matters concerning concerning 5G advanced, or 6G this survey has overlooked that deserve attention?

(max 300 characters)

———————————-

Appendix 3 Vertical Engagement Tracker survey

Project Name*[15]

----------DROPDOWN LIST----------

- 5G-STARDUST
- 6G REFERENCE
- 6G-BRICKS
- 6G-CLOUD
- 6G-DISAC
- 6G-EWOC
- 6G-GOALS
- 6G-INTENSE
- 6G-MUSICAL
- 6G-NTN
- 6G-PATH
- 6G-SANDBOX
- 6G-SENSES
- 6G-SHINE
- 6G-TWIN
- 6G-XCEL
- 6G-XR
- 6GTandem
- 6Green
- ACROSS
- ADROIT6G
- BeGREEN
- CENTRIC
- CONFIDENTIAL6G
- DESIRE6G
- DETERMINISTIC6G
- ECO-ENET
- ELASTIC
- ENVELOPE
- ETHER
- EXIGENCE
- FIDAL
- FirstTo6G
- FLEX-SCALE
- Hexa-X-II
- HORSE
- ISEE-6G
- IMAGINE-B5G
- INSTINCT
- ITrust6G
- NATWORK
- NANCY

[15] * indicates mandatory fields

- OPTI-6G
- ORIGAMI
- PREDICT-6G
- PRIVATEER
- PROTEUS-6G
- RIGOUROUS
- ROBUST-6G
- SAFE-6G
- SEASON
- SUNRISE-6G
- SUPERIOT
- TARGET-X
- TERA6G
- TeraGreen
- TERRAMETA
- TIMES
- TrialsNet
- VERGE

SNS JU Call*

----------SINGLE CHOICE----------

- Call 1
- Call 2
- Call 3

SNS JU Stream*

----------SINGLE CHOICE----------

- Stream A
- Stream B
- Stream C
- Stream D

Is your use case from a project's open call (3rd party funding)?*

----------SINGLE CHOICE----------

- Yes
- No

Use Case Name*

———————————-

Use Case Contact Name*

———————————-

Use Case Contact email*

———————————-

Vertical Sector*

----------MULTIPLE CHOICE----------

- Automotive/ Transport/ Logistics
- Education
- Industry 4.0/ Manufacturing
- Media/xR
- Non-Terrestrial Networks (NTN)
- Smart Agriculture
- Smart City
- Smart Energy
- Smart Health
- Security/ PPDR
- Tourism & Culture
- Other

If “Other” please specify:

———————————-

Type of Experiment*

----------SINGLE CHOICE----------

- Simulation/Emulation
- Demonstration
- Pilot
- Proof of Concept
- Prototype
- Trial

Maturity*

----------SINGLE CHOICE----------

- TRL 1-2 (Technology concept formulated)
- TRL 3-5 (Technology Development)
- TRL 5-6 (Technology Demonstration)
- TRL 6-8 (System/subsystem development)
- TRL 8-9 (System test, launch and operation)

Functionality*

----------MULTIPLE CHOICE----------

- Cloud-Native Architecture
- Enhanced Mobile Broadband (eMBB)
- Holographic Communications
- Hyper-connectivity
- Intelligent Network Architecture
- Massive Machine-Type Communications (mMTC)
- Multi-Access Edge Computing (MEC)
- Network Slicing
- Quantum Communication and Computing
- Terahertz (THz) Communication
- Ultra-Reliable and Low Latency Communications (URLLC)
- Other

If “Other” please specify:

——————————-

Use Case Location (lab Location)*

----------MULTIPLE CHOICE----------

- Austria
- Belgium
- Bulgaria
- Denmark
- Finland
- France
- Germany
- Greece
- Hungary
- Ireland
- Israel
- Italy
- Luxembourg
- Netherlands
- Norway
- Poland
- Portugal
- Romania
- Serbia
- Slovenia
- Spain
- Sweden
- Switzerland
- To be defined

- Turkey
- UK
- Various

Use Case Summary*

———————————-