Smart Networks and Services International and European Cooperation Ecosystem

D3.2 Initial Trends Analysis in Vertical Sectors – Rel.1

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Contributors and Peer Reviewers

Contributors		
Contributor Name	**Contributor email**	**Affiliation**
Claudio de Majo	c.demajo@trust-itservices.com	Trust-IT Services
Pierre-Yves Danet	pierreyves.cdanet@6g-ia.eu	6G-IA
Raffaele de Peppe	raffaele.depeppe@telecomitalia.it	TIM
Jos Beriere	jos.beriere@tno.nl	TNO
Carles Antón-Haro	carles.anton@cttc.es	CTTC
Kostas Trichias	Kostas.trichias@6g-ia.eu	6G-IA
Alex Kaloxylos	alexandros.kaloxylos@6g-ia.eu	6G-IA
Peer Reviewers		
Reviewer Name	**Reviewer email**	**Reviewer Affiliation**
Katrina Petersen	k.petersen@psc-europe.eu	PSCE
Nikolaos Tsampieris	n.tsampieris@mail.ertico.com	ERTICO
Angelika Avila	angelica.avila@6ghi.net	6GHI
Maria Guta	maria.guta@esa.int	ESA
Andreas Mueller	andreas.mueller21@de.bosch.com	5G ACIA

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Abbreviations List

Abbreviation / Term	Description
3GPP	3rd Generation Partnership Project
5G4SC	5G for Smart Communities
5GAA	5G Automotive Association
5G-ACIA	5G Alliance for Connected Industries and Automation
5G-MAG	5G Media Action Group
5G PPP	5G Public Private Partnership
6G-IA	6G Smart Networks and Services – Industry Association
6GHI	6G Health Institute
AI	Artificial Intelligence
AIOTI	Alliance for IoT and Edge Computing Innovation
AR	Augmented Reality
CCAM	Cooperative Connected and Automated Mobility
CEF	Connecting European Facility
COTS	Commercial Off The Shell
DaaS	Delivery as a Service
DG CNECT	Directorate General for Communications Networks, Content and Technology
DG HOME	European Commission's department of migration and home affairs
DIHs	Digital Innovation Hubs
EBU	European Broadcasting Union
ECSO	European Cyber Security Organisation
EHDS	European Health Data Space
eID	European Digital Identity
eMBB	Enhanced Mobile Broadband
ERTICO	European Road Transport Telematics Implementation Co-ordination Organisation
ESA	European Space Agency
ETCS	European Train Control System
ETSI	European Telecommunications Standards Institute
EUCCS	EU Critical Communication System
EuCNC	European Conference on Networks and Communications
EUTC	European Utilities Telecom Council
EV	Electric Vehicle
FHIR	Fast Healthcare Interoperability Resource
FRMCS	Future Rail Mobile Communication System
GEO	Geostationary Earth Orbit
HAP	High Altitude Platform
HDE	Health Data Space

HL-7	Health Level 7
ICT	Information and Communication Technologies
IoT	Internet of Things
ITS	Intelligent Transport System
ITU	International Telecommunications Union
JU	Joint Undertaking
LaaS	Logistics as a Service
LEO	Low Earth Orbit
LMR	Land Mobile Radio
MaaS	Mobility as a Service
MCC	Mission Critical Communications
MCCG	Mission Critical Communications Group
MCPPT	Mission Critical Push to Talk
MEC	Multi-Access Edge Computing
MEO	Medium Earth Orbit
mMTC	Massive Machine-Type Communications
ML	Machine Learning
MoU	Memorandum of Understandings
NEM	New European Media Initiative
NGMN Alliance	Next Generation Mobile Networks Alliance
NGSO	Non Geostationary Earth Orbit
NIST	National Institute of Standards and Technology, US Department of Commerce
NTN	Non Terrestrial Network
PSCE	Public Safety Communication Europe
PS	Public Safety
PSA	Public Safety Agents
PPDR	Public Protection and Disaster Relief
QoS	Quality of Service
RIA	Research and Innovation Action
Satcom	Satellite Communications
SCoDIHNet	Smart Connectivity Digital Innovation Hub Network
SDN	Software Defined Network
SLA	Service Level Agreement
SNS	Smart Networks and Services
THz	Terahertz
TTC	EU-US Trade and Technology Council
UE	User Equipment
UX	User Experience
VR	Virtual reality
URLLC	Ultra-Reliable and Low Latency Communications

WG	Working Group
WP	Work Program
xR	Extended reality

Executive Summary

Launched in January 2023, the SNS ICE project aims to establish a collaborative environment for European and global stakeholders involved in developing 6G smart networks and services. It serves as a platform to showcase, leverage, and position the achievements of SNS JU in major European and global forums. The project actively engages with regions where 6G activities are planned or ongoing, including vertical industries, through established associations to understand their requirements and promote SNS JU solutions, enabling the development of tailored 6G solutions for early adoption.

As a Coordination and Support Action (CSA) project, SNS ICE's practical actions include supporting and representing the SNS JU Research and Innovation Action (RIA) projects in their technological developments. In this context, SNS ICE particularly seeks to cooperate with Phase 1 projects, divided into four Streams (A, B, C and D).

Deliverable D3.2 of WP3 is a top down and "outside in" approach to gather inputs from vertical industries to shape 6G in the research phase and drive adoption from 2030 to create positive economic and societal impact in Europe. In a second release expected by end of year trends and use cases will be fine-tuned and prioritized to define real world business cases though some economic analysis. Based on the input of key vertical industry stakeholders this report has been compiled which will also constitute one of the inputs towards the Task Force that will prepare the next SNS JU Work Programme (WP 2025).

Special thanks to 6GIA partner vertical associations and members for providing the necessary information and/or performing peer review of their respective sections, ensuring the accuracy and validity of the presented information. SNS ICE seeks the continuous collaboration with vertical association as it results in a win-win situation, driving meaningful mobile technologies from day 1 that the mobile industry will exploit leveraging increased adoption rates from verticals. As the information presented in this report have been verified by the vertical industry representatives, it constitutes an accurate status overview of the main vertical industries, and the outlook of their representatives towards the use of current and future mobile networks.

1 Introduction

The mobile telecommunications industry is key for the growth of European economy. The Mobile Economy (including the mobile industry and effects on other sectors) contribution to the European GDP was 910 B€ in 2022 representing 4,3% of the total GDP, as shown in Figure 1.

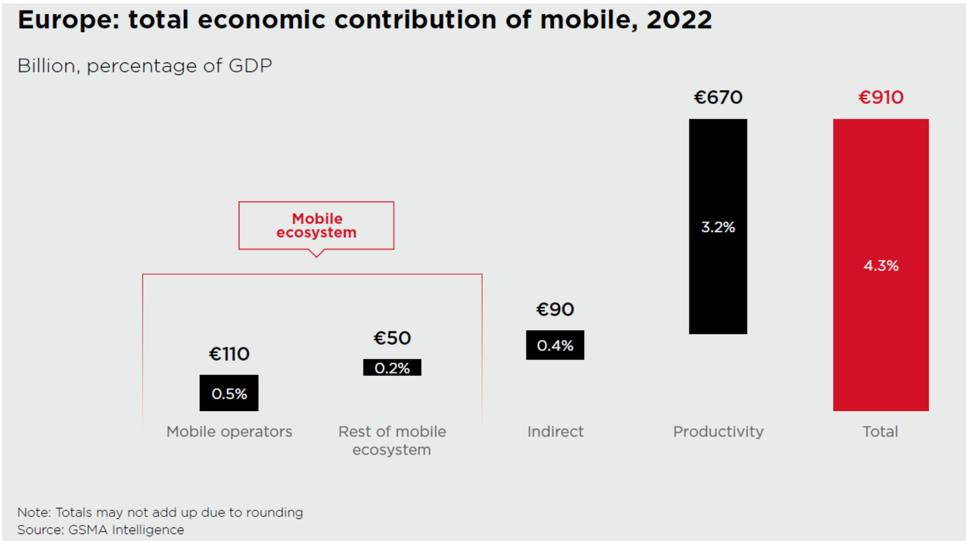

Figure 1: Mobile Economy Europe [1]

Mobile Economy will reach approximately €1 trillion in Europe by 2030 when 6G will be unfolding, 5G will count for 153 B€ thanks to productivity gains in verticals sectors, as depicted in Figure 2.

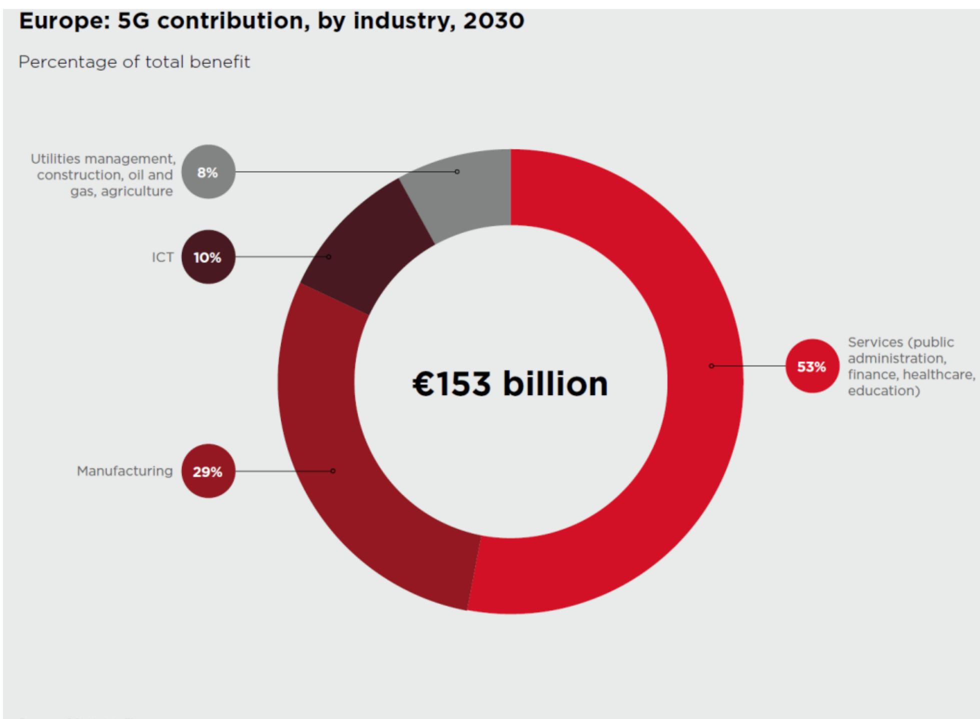

Figure 2: 5G Contribution by Industry [1]

Vertical Engagement activities have been established under 5GPPP by 5GIA Board several years ago to establish a collaboration framework with key European industrial sector. The key driver was to promote 5G technologies to future adopters while collecting their needs in terms of requirements and use cases. Key activities included participation to key vertical industries events, partnerships with key industry associations (MoUs), project vertical cartographies and industry focused whitepaper dissemination.

Continuing the trajectory established by 5GPPP, vertical engagement activities have been carried further enhanced within SNS JU and formalized by the SNS ICE project. This deliverable provides trends in vertical sectors that should ideally forge 6G services to create economic impact in the next decade (2030-2040). While it is difficult to predict future use cases from now to 2030, trends can be assessed and validated by 6GIA vertical partners and members to provide a direction to 6G research through an "outside in" top-down approach that can ideally complement the traditional bottom-up technology driven EU funded research. Trends and scenario analysis is a common best practice within corporate strategic planning to evaluate strategic options for the future.

This document is structured as follows.

Section 1 provides an outlook of the Mobile Economy in Europe with projections to 2030 when 6G will unfold. Section 2 provides key trends in European vertical sectors to provide strategic guidance to 6G research with an outside in approach.

Section 3 provides trends in non-terrestrial networks which will be complementary to 6G terrestrial networks with a stronger level of integration with respect to 5G.

Section 4 discusses the 5G Infrastructure Public Private Partnership's (5GPPP) significant impact through its research and innovation projects, highlighting Europe's advancements in large-scale trials and pilots for Beyond 5G and 6G technologies across various verticals.

Section 5 outlines the SNS JU Work Programs' commitment to involving a diverse range of vertical industries in its projects. This strategic inclusion of various industries ensures comprehensive coverage and guides future work programs to address key sectors effectively.

Section 6 retains fundamental shifts in trends that Evolution Beyond 5G must support from 2030.

2 Monitoring and Analysis of Vertical Trends

Assessing ongoing and future trends in vertical sectors is key to shape future mobile technologies such as 6G. Sections below provide a preliminary analysis of trends in key European sectors to provide strategic directions to SNS JU research work programmes from 2025 onwards. Trends assessments will support the definition of 6G technologies and services for key industrial sectors in Europe.

2.1 Public Safety

In today's digitally driven society, where rapid access to data is crucial across industries, Public Safety (PS) services require pathways to better leverage available technology in order to improve how they utilize essential information, such as video data, which can be critical in life-saving situations. While Land Mobile Radio (LMR) solutions are globally used for efficient voice communication in **Mission Critical Communications** (MCC), their voice-centric design restricts data transfer, and thus necessary risk and situational awareness capabilities.

To overcome these limitations, Public Safety entities can turn to 3GPP (LTE and 5G) technologies, which significantly expand the capabilities of LMR solutions by introducing data-driven technologies and supporting use cases that reflect increasingly complex operations. These can provide MCC needs that go above and beyond the criteria of everyday commercial networks.

Enhanced connectivity will act as a catalyst in this evolution, offering new levels of connectivity and capabilities previously unattainable. This transformation will mark a significant departure from traditional public safety operations, moving towards more interconnected, intelligent, and responsive systems [2].

2.1.1 Trends and Challenges in the Public Safety Sector

Mission-Critical Communications: mission-critical push-to-talk (MCPTT) standards are being implemented, enhancing communication for public safety users. As citizen safety is a top priority for national governments, making highly reliable and available communication networks for Public Safety Agents (PSAs) a necessity. In addition, with the increasing occurrence of natural disasters and terrorist attacks, having a robust communication system is essential for enhancing PSAs' ability to communicate with each other, sharing situational awareness, and facilitating emergency responses in uncertain environments. Mission Critical Communications (MCC) networks, characterized by high availability and reliability through network redundancies, are vital for saving lives.

These networks are designed to ensure that communication packets are handled with the highest priority, reducing latency and to avoid congestion issues through priority for PSAs. Moreover, MCC networks are increasingly secure against cyberterrorism, offering additional protection against modern threats.

Challenges:

- **Ensuring Network Robustness and Resilience**: despite their high availability, reliability, resilience, and efficiency in high-demand scenarios, narrowband technologies cannot handle high traffic volumes, limiting their ability to support new use cases brought about by recent technological advancements or recent large-scale disasters. Thus, the main technical challenge lies in creating a network infrastructure that is robust enough to handle mission-critical communications without failure, even under extreme conditions such as natural disasters or high network traffic scenarios. This involves implementing advanced network management and routing protocols that prioritize public safety communications.
- **Interoperability with Legacy and Diverse Systems**: integrating MCPTT and other advanced communication standards with existing land mobile radio (LMR) systems presents a significant technical hurdle. This hurdle is raised further when the systems have to talk between agencies or responders from different countries. This requires the development of interoperable solutions that can seamlessly bridge the gap between new 5G/6G capabilities and older communication technologies, ensuring uninterrupted

service during the transition phase. Specifically, implementing LTE or 5G as Mission Critical Communication (MCC) networks necessitates adherence to specific standards, such as high availability, reliability, efficiency in demanding scenarios, resilience, and top-tier security, to reduce failure risks during catastrophic events. Network hardening is often essential to meet these requirements. While technical standards facilitate interoperability, practical situations may demand proprietary solutions due to ongoing standardization issues and the reluctance of some LMR vendors to implement the Interworking Function (IWF) [3].

Advanced Location Services: the implementation of vertical (z-axis) location technology for emergency calls and public safety personnel is advancing. This technology allows for accurate location tracking within a range of plus or minus three meters of the handset.

Challenges:

- **Achieving High Accuracy in Diverse Environments**: implementing location technology that maintains high accuracy in varied environments, including dense urban areas, rural regions, and indoor settings, is a complex technical task. It requires advanced signal processing algorithms and the integration of multiple location-determining technologies to ensure reliable and precise location tracking. Overall, the availability of spectrum and efficient licensing are vital in stimulating the necessary investment to broaden mobile access, cater to the growing demand for data services, and improve the quality and diversity of services provided. Both low and high-frequency bands are crucial in delivering substantial benefits and are essential for offering the most innovative services to all users, whether they are located in industrial settings or rural areas.
- **Universal Implementation Across Varied Networks**: ensuring that advanced location services are uniformly implemented across different network carriers and in all regions, including those with less infrastructure, poses a significant challenge. This requires standardization of technologies and protocols, as well as collaboration between network operators, public safety agencies, and technology providers [3].

Customized Devices and Interfaces: there is an expectation of more purpose-built devices and interfaces specifically designed for public safety use. These would be tailored for challenging environments that first responders often face.

Challenges:

- **Ruggedized and Adaptive Design**: understanding the requirements for wireline connections between devices and accessories is essential in public protection and disaster relief (PPDR) scenarios, where they need to be ruggedized for optimal performance. Standard commercial connectors like USB or 3.5mm jacks may not be durable enough for heavy usage and could damage the device. Moreover, devices used in PPDR must be developed specifically to withstand harsh and unpredictable conditions. These devices should be rugged, equipped with dedicated push-to-talk (PTT) buttons, offer superior voice and image quality, and have long battery life. This involves using durable materials, ensuring waterproof and dustproof capabilities, and designing for shock resistance. Additionally, these devices must be adaptive to various environmental conditions, such as extreme temperatures and variable light conditions.
- **Intuitive and Accessible User Interfaces**: creating user interfaces that are easily accessible and intuitive for first responders in stressful and time-sensitive situations is a complex task. This includes designing interfaces that can be operated while wearing different types of gloves or in low-visibility situations and ensuring that the interfaces are responsive and easy to navigate under pressure [3][3].

2.1.2 Relevant Use Cases in the Public Safety Sector

Real-Time Emergency Response Coordination: the integration of smart networks will enable real-time coordination during emergency responses as well as shared situational awareness. This includes instantaneous data sharing, live video streaming from the scene, and enhanced communication between different emergency services. It also requires systems that can manage different data gathering and sharing practices as well as multi-directional communication capabilities. Unlike restricted voice-centric technologies, video-based applications could significantly enhance decision-making processes in critical situations, potentially impacting life-or-death outcomes.

Smart Surveillance and Public Safety Monitoring: this includes both continuous monitoring of the situation as it unfolds as well as of the responder's safety in the field. 5G/6G technologies can be used to create advanced surveillance systems with real-time monitoring capabilities. Applications such as network slicing facilitate the creation of specialized slices with prioritized access, enabling Network-as-a-Service (NaaS) offerings or dedicated slices with tailored Quality of Service (QoS), suitable for specific applications like video surveillance.

Enhanced Disaster Management and Recovery: high bandwidth and low latency will be crucial in disaster management, guaranteeing robust networks for emergency communications and enabling quick deployment of communication networks in disaster-hit areas, support drone operations for search and rescue, and facilitate efficient resource allocation and management. It also supports rapid deployment and connection of teams from wherever they are needed. The ability to incorporate a range of data streams, such as from sensors, drones, communication devices, location services, etc. make it possible to get a rich understanding of the risks faced and public safety needs.

Supporting Response from a Distance: experts not at the scene can get a detailed view or information to provide virtual expert training or support faster than were they to travel, such as remote surgeries or guiding connected vehicles. It also supports improved planning before arrival at the scene.

6G technologies must provide capabilities on the fly that can be prioritized with no resource constriction in critical situation. The evolution towards 6G will further support Situational Awareness features in disaster scenarios based on MC-data and MC-video.

EU research has been key to trigger a shift from Public Safety legacy technologies to 3GPP standard based technologies. Following conclusion of the successful **BroadWay**[1] EU funded project (11 countries at Ministry/Agency level), European Commission (DG Home) is preparing legislative proposals to establish the **EU Critical Communication System** (EUCCS). An **expert group** for MCC at EU level (MCCG[2]) was formed that includes experts from all EU and Schengen Member States.

A new EU funded research program, BroadEU.Net[3] coordinated by PSCE, builds upon the leanings of BroadWay to implement a network of national **MC testbeds** (16 countries at Ministry/Agency level).

Policy based developments for PPDR communications sets a new milestone for future developments in Public Safety that 6G will need to underpin.

2.2 Automotive

Over the past decade and since the advent of 4G and 5G networks, there has been enhanced interest from the automotive sector regarding the capabilities of mobile networks and how they can enhance, the safety, security and efficiency of transportation. The notion of **Cooperative Connected and Automated Mobility** (CCAM) has been a prominent research topic (and still is), as it stands to change the landscape of mobility as we know it, especially when enabled by cellular networks though **Cellular Vehicle to Everything** (C-V2X) communications. As such, an association of automotive and telecoms experts and researchers has been established to investigate

[1] https://www.broadway-info.eu/overview-on-broadway-solutions/
[2] https://ec.europa.eu/transparency/expert-groups-register/screen/expert-groups/consult?lang=en&groupID=3908
[3] https://broadeu.net/

and promote the services enabled by 5G (and beyond) networks for the automotive sector, called 5**G Automotive Association** (5GAA).

5GAA has released an updated roadmap on November 2022 [4], summarizing the current status of 5G enabled vehicle deployments and describing the next steps towards fully connected and automated mobility. A growing deployment of connected safety services targeting traffic efficiency and safety has been observed in recent years. Vehicles enabled with both Cellular-V2X (C-V2X) network and direct communications technologies have been released on the Chinese market. The first cars with 5G new radio technology connected to the rapidly growing 5G networks relying on the 3GPP Release 15 standard are available in China, Europe and US. Many Original Equipment Manufacturers (OEMs) have extended the list of hazard warnings distributed over the network within their products. A growing number of cities provide pre-emptive green lights to emergency responders and time-to-green information to vehicles over the network.

As new capabilities give rise to new use cases, and help redesign the approach, the above positive market changes along with the anticipated novel features are reflected in the new roadmap of 5GAA. The envisioned evolution of C-V2X use cases according to 5GAA is depicted in Figure 3.

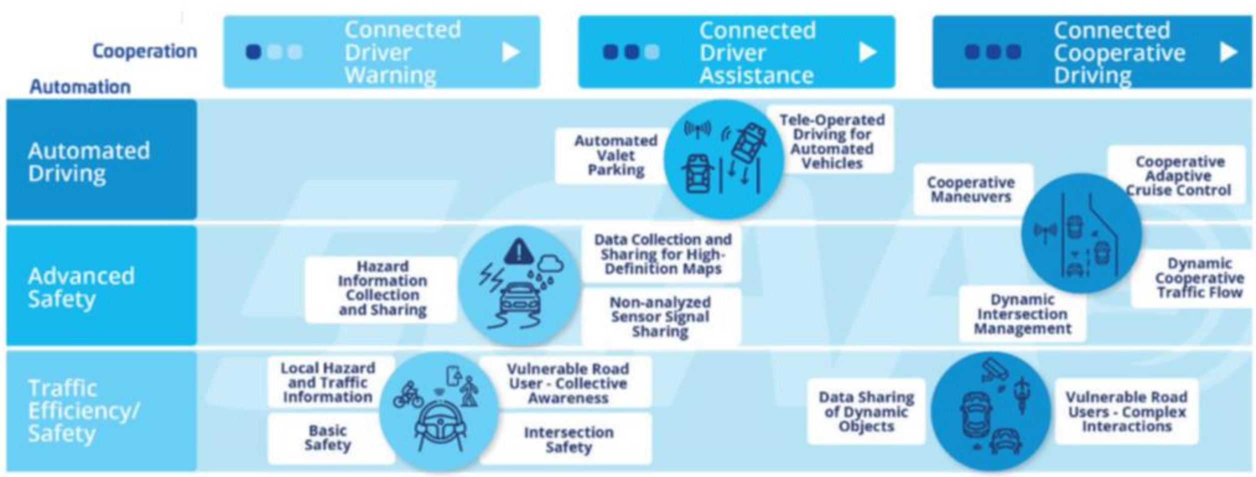

Figure 3: Evolution of C-V2X use cases towards connected cooperative driving [4].

The 5GAA roadmap focuses mostly on Europe, North America and China, as these regions showcase the most significant interest and investment in V2X and CAM services. The first 5G-enabled vehicles have hit the roads globally, supporting multiple use cases listed in the 5GAA roadmap: Local Hazard and Traffic Information (BMW, Audi, Ford), Hazard Information Collection and Sharing, and Basic Safety Applications. Wireless connectivity has been recognized as a supporting technology to address key crash scenarios, while other regional developments have had a positive impact on the deployment of V2X globally. In China, several Chinese OEMs launched C-V2X vehicles, while in the US, V2X Direct-enabled vehicles are planned to be deployed soon, following authorization from the FCC. The German initiative on Automated Driving (AD) L4 law and regulation has been finalized. This legislation allows the deployment of AD L4 vehicles on predefined routes that include reliable connectivity.

Although 5GAA's roadmap focuses on the above-mentioned regions, 5GAA is in close contact with other regions (e.g. South Korea, Japan, Australia, and India), which helps it keep on top of global market trends. The roll-out of use cases and services in the different regions depends heavily on ongoing security, spectrum and privacy regulations, and may change in the future. Figure 4depicts the updated 5GAA roadmap and the expected timelines for mass deployment of C-V2C use cases.

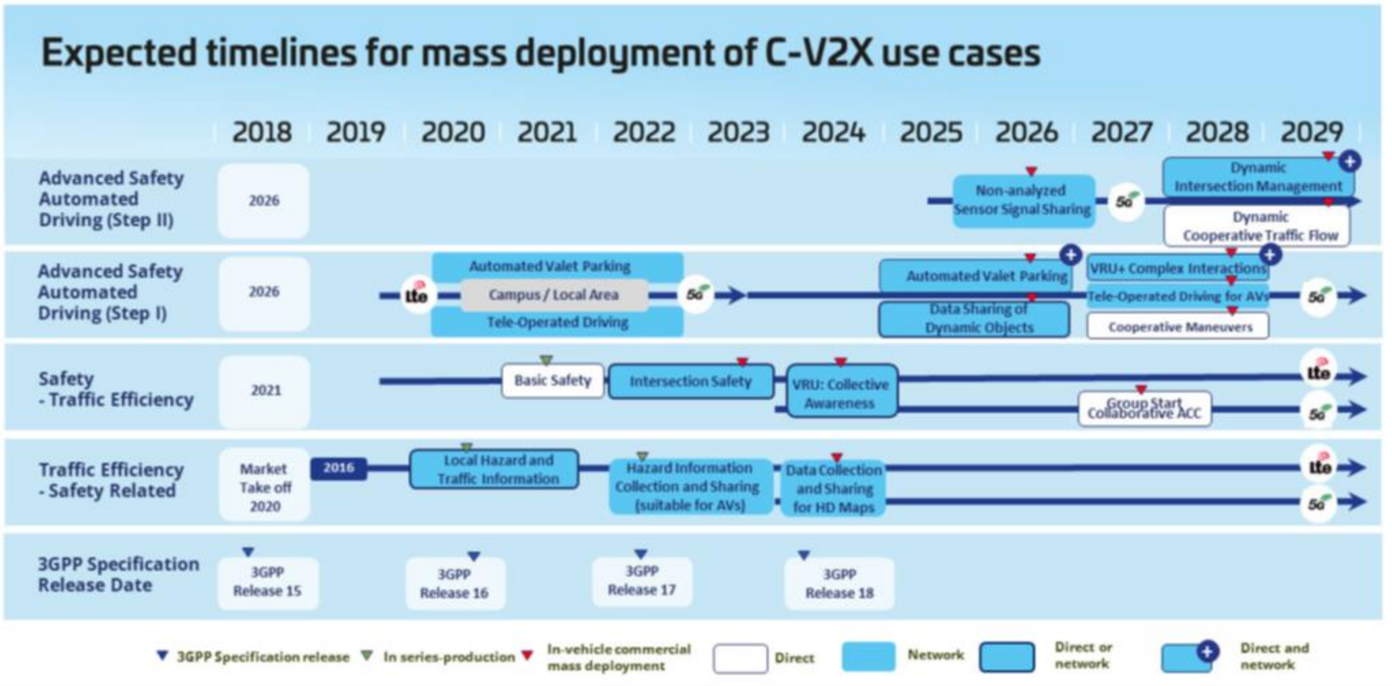

Figure 4: 5GAA Roadmap - Expected timelines for mass deployment of C-V2X use cases [4].

The 5GAA has further analyzed the status of the necessary spectrum dedicated to C-V2X communications, as well as the future spectrum needs according to the expected CAM service class. 5GAA estimates that with regards to spectrum for C-V2X network-based (V2N) communications:

- At least 50 MHz of additional service-agnostic low-band (<1 GHz) spectrum would be required for mobile operators to provide advanced automotive V2N services in rural environments with affordable deployment costs.
- At least 500 MHz of additional service-agnostic mid-band (1 to 7 GHz) spectrum would be required for mobile operators to provide high-capacity, citywide advanced automotive V2N services.

With regards to spectrum needs for C-V2X direct communications (V2V/I/P):

- The delivery of day-1 use cases via LTE-V2X for the support of basic safety ITS services requires up to 20 MHz of spectrum at 5.9 GHz for V2V/I/P communications24.
- The delivery of advanced use cases via 5G-V2X (NR-V2X in addition to LTE-V2X) for the support of advanced driving services will require an additional 40 MHz or more of spectrum at 5.9 GHz for V2V/I/P communications.

Besides the above roadmap, 5GAA has also recently published a detailed technical report, analyzing the evolution of vehicular communications system beyond 5G and the impact that this is expected to have on V2X services [5]. In this report the 5GAA experts analyze five main trends in the automotive sector that will likely play a key role in the evolution of connected vehicular services. These trends are:

- *Higher levels of vehicular automation*: Higher number of active users at any point in time, increasing demand on infotainment services, use of sensing information to improve performance, sharing of vehicular 'compute capability'.
- *Availability of relevant travel and traffic information*: Wireless connectivity to access and update traffic and travel information, increasing infrastructure-based sensing capability, availability of long-range wireless links.
- *Proliferation of connected devices and services*: Support of more diverse use cases and additional requirements, service continuity concerns (increasing number of connected devices working on different

generations of communication technologies), higher connection density of devices, energy efficiency concerns, accurate positioning.

- *Digital roads*: Coordination between different entities, monitoring and reporting issues along the way by vehicles (reliable uplink required), mixed vehicle traffic with different automation levels, ow-latency link between certain vehicles, infrastructure, and the central network entity, Storage and processing capability closer to the roadways.
- *Diverse mobility services*: Wireless access to vehicles in indoor/underground parking lots, support emergency call services at all times, wireless link availability that can enable remote driving of vehicles whenever requested.

The 5GAA experts also highlight the essential features for ubiquitous connected and automated mobility systems of the future which include, *extreme networks availability and reliability, predictability of performance, harmonized Quality of Service (QoS) and policy framework, enhanced network exposure, device capability, enhanced privacy and security, matched spectrum demands and alignment of regulations, policies and standards*.

Moreover, a list of the most promising technological enablers from the viewpoint of the automotive community is provided, including technologies such as *Integrated sensing and communication, Integrated terrestrial and non-terrestrial networks, distributed on-broad communication systems, refractive meta-surfaces, data-driven networks and distributed computing and novel privacy* and *security mechanisms*.

2.3 Transportation

ERTICO, representing the European transportation sector, has produced a roadmap extended to 2035 with key milestones that show which and when new features will arrive in the different focus areas.

2.3.1 Urban Mobility

Future transport systems will support demographic changes in Europe like population aging and urbanization. Transportation infrastructures will be seamlessly integrated for people and goods. This will involve all modes of transport, such as cycling, walking, public transport and urban air mobility. Mobility as a Service (MaaS) will be the norm, offering multiple travel/mode choices, including public transport and user services, supported by interoperable transport payment and ticketing systems. The concept of Mobility as a Service (MaaS) creates new ways to use and pay for mobility, it shifts the decision power to the individual user through tailored solutions. This means that new organizational and business models will be developed to integrate mobility modes, provide information and have secure payment options.

Traffic management will be more predictive and interactive leveraging AI applied to mobility data and the principle of co-opetition between private and public bodies. Multimodality will be integrated into services offered by private and public operators, including vehicle manufacturers.

In cities and urban areas, vehicle technologies, traffic and transport systems and internet applications are converging in a fast-growing ecosystem of new “connected mobility” services for travelers and transport users. City governments seek mobility solutions able to significantly reduce traffic congestion while increasing the use of collective and low-carbon means of transport. Exploiting newest internet and mobile communication technologies is leading to innovative ways in order to re-think the road transport services and improve mobility

Vision 2035: widespread deployment of a new generation of cooperative, connected and personalized mobility services. The goal for 2035, as depicted in Figure 5 is to achieve full integration of all mobility solutions - this will reduce traffic congestion and increase the use of low-carbon and low-emission solutions, leading to high-quality travel for all citizens and businesses.

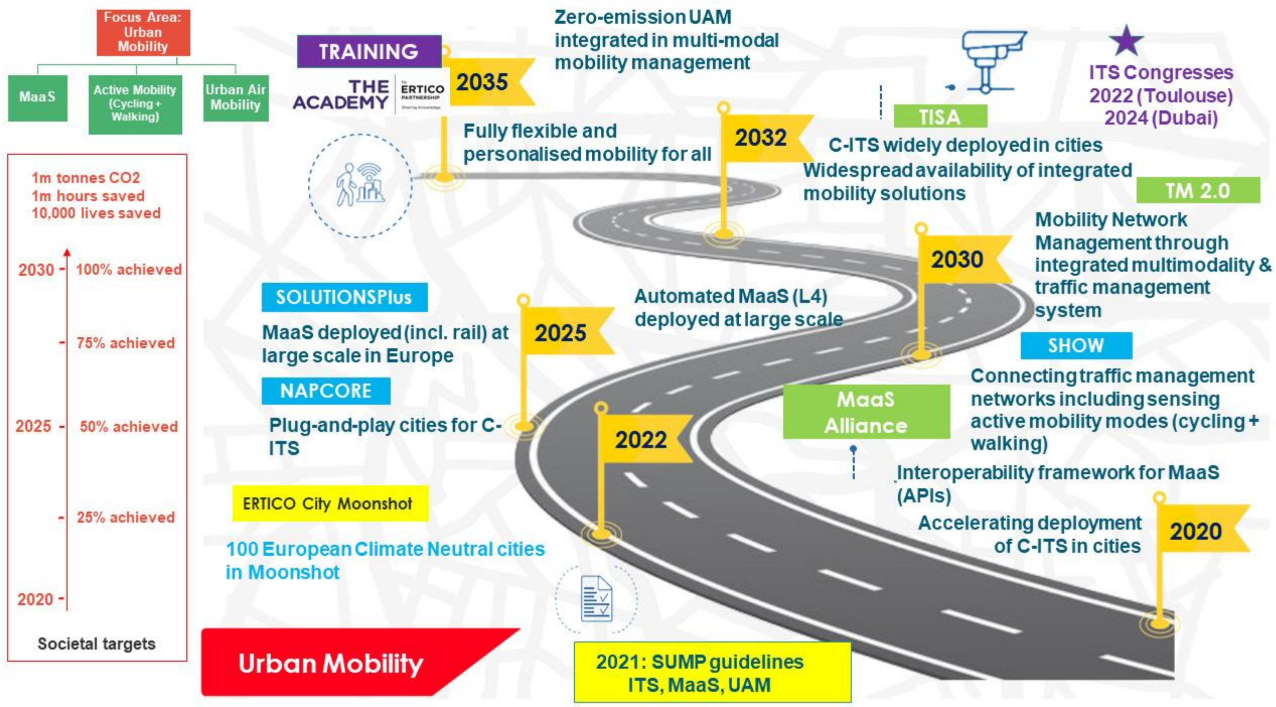

Figure 5: ERTICO Urban Mobility Roadmap[4].

2.3.2 Connected, Cooperative & Automated Mobility (CCAM)

Highly automated vehicles are operating on European roads and fast evolving. Every new generation of vehicles increases by an order of magnitude onboard computing power and the number of sensor data. They increasingly collect large amounts of real-life data to be used to train deeper machine learning algorithms for mission critical AI applications. Building an infrastructure that will allow the generation and handling of this data is a strategic step. The convergence of C-ITS, cellular connectivity and automated vehicles along with the evolution of the road infrastructure will be key for CCAM.

Vision 2035: CCAM will benefit from the expanding deployment of 5G and the emergence of 6G. Technologies and services will converge towards a hybrid approach in which short-range and long-range communications offer further developments for CCAM and higher levels of automation. Such automation will enable the realization of CCAM services for shared multimodal transportation of people and goods. Data privacy and security are important enablers to support the transition from individual legacy vehicles toward CCAM services. These will consolidate into multiple trusted and interoperable data platforms, offering services to individuals, logistics service providers and public authorities. To facilitate deployment, an EU-wide regulatory regime will establish interoperability for integration in, for example, the broader traffic system and cross-border operations. Figure 6 depicts the CCAM Roadmap according to ERTICO.

[4] Available at https://ertico.com/focus-areas/urban-mobility/.

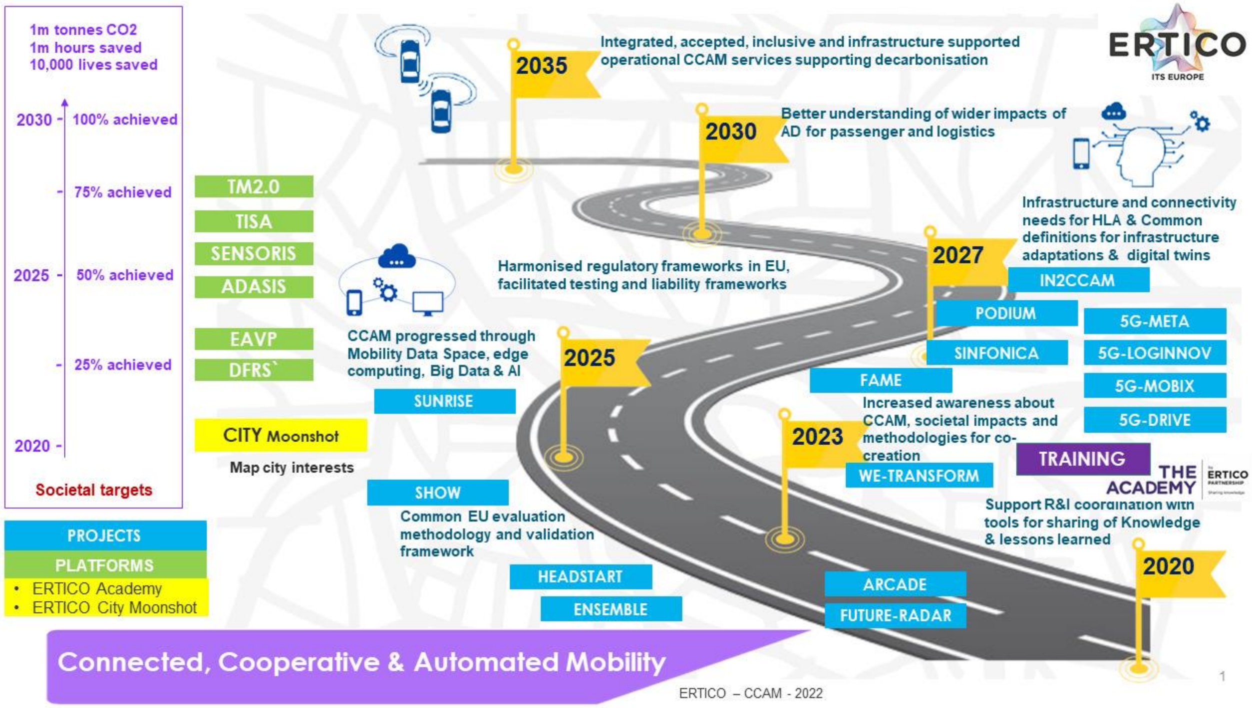

Figure 6: CCAM ERTICO Roadmap[5].

2.3.3 Sustainable Mobility

Smart mobility innovations make a major contribution towards reducing the impact of transport on the environment, particularly in terms of reducing fuel consumption and emissions. Transport currently accounts for almost a quarter of greenhouse gas emissions worldwide and making mobility more sustainable is a key policy objective of governments, EU and international organizations. Deployment of intelligent transport solutions (ITS) can help reduce the carbon footprint and emissions by helping transport users and providers make smarter decisions. To achieve this, systems and services need to be made more efficient and attractive through greater interoperability and better information.

Deployment of intelligent transport solutions help reduce the carbon footprint and emissions by helping transport users and providers make smarter decisions. To achieve this, systems and services need to be made more efficient and attractive through greater interoperability and better information.

Vision 2035: A major transport objective of the UN Climate Change Conference (COP26) in Glasgow 2021 was to show that the transition to zero-emission road transport technology has reached a tipping point. This step-change towards mass-market clean mobility will focus on electric vehicles (EV), necessary infrastructures, and the greater multimodality and shared mobility ecosystem. It will significantly contribute to the European Green Deal, making Europe climate neutral by 2050. In the shorter term, clean air policies in cities will change travel patterns and impose the 'polluter pays' principle. Evidence-based guidelines describe ways to relieve transport pollution for a healthier population, a better quality of life, and reduce CO_2 emissions significantly. Pricing, taxation, education and awareness will contribute to adopting greener behaviors. How transport is managed today will change accordingly as transport decision-makers increasingly set environmental targets. Figure 7 depicts ERTICO's clean mobility roadmap.

[5] Available at https://ertico.com/focus-areas/connected-cooperative-automated-mobility/.

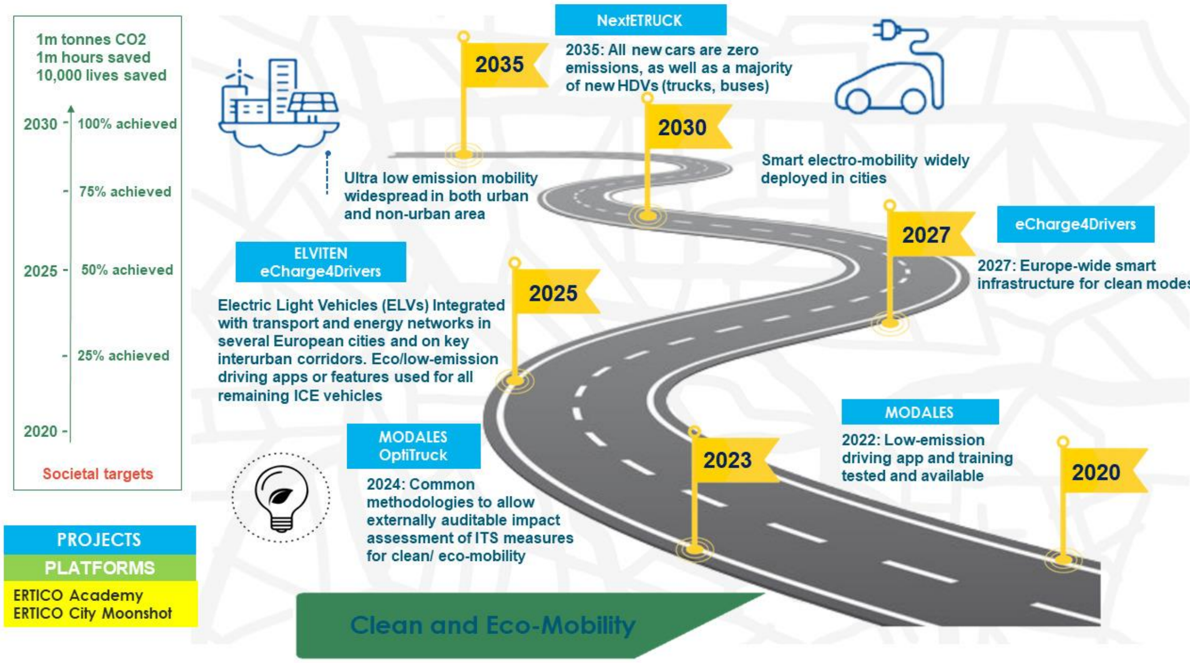

Figure 7: ERTICO Clean Mobility Roadmap[6].

2.3.4 Transport & Logistics (T&L)

Congestion, especially on the road, is one of the biggest transport challenges. It costs Europe about 1% of its GDP every year and is the cause of considerable carbon emissions. To reduce emissions, logistics actors are implementing environmentally concerned collaborative strategies addressing supply chain integration, multimodal transport, consolidation of deliveries and reverse logistics. CMR is the most common paper document in freight transport. Adopting eCMR, the electronic version of consignment notes, is now a reality and a huge step towards digitizing European supply chains. We will continue to see the integration of ports and cities, focusing on the management of goods and data exchange.

Vision 2035: A challenge for Transport & Logistics is the digitizing process of transport networks and infrastructure. If fully implemented, this process could better integrate road, rail, air and waterborne travel into a seamless logistics supply chain across Europe. Many solutions for logistics were developed by individual companies based on their legacy information systems but the many different digital platforms, applications and products, that currently exist, cause a high degree of fragmentation. Freight and Logistics benefits from an interconnected world and can draw from ICT technological trends (i.e. Artificial Intelligence, Big Data, Internet of Things, Automation) and smart solutions for Transport & Logistics. 5G/6G enablers and automation deployment will play an important role in modernizing freight and logistics. Implementation of smart logistics services will be supported by a trusted and interoperable EU wide data platform while secure and seamless shared multimodal solutions will become available. Delivery as a Service (DaaS) for last-mile operations and Logistics as a Service (LaaS) is becoming a reality. Developing clean electromobility will be the primary building lock for urban logistics. Figure 8 depicts ERTICOS's T&L roadmap.

[6] Available at https://ertico.com/focus-areas/clean-mobility/.

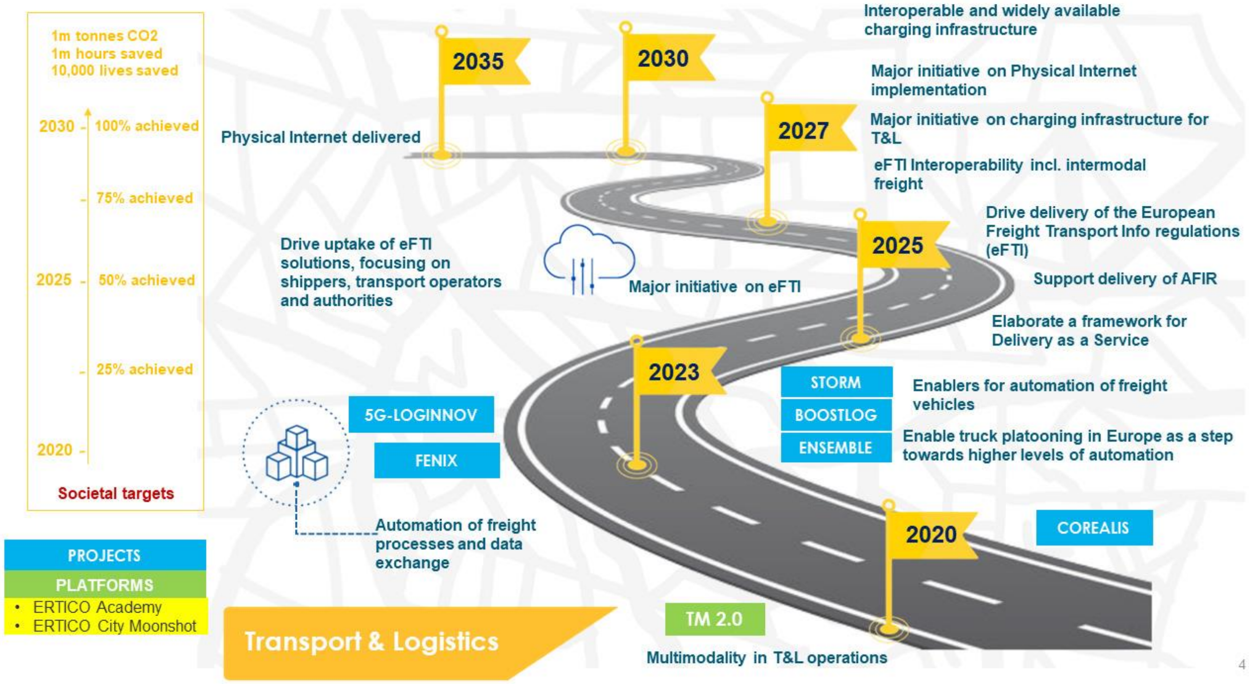

Figure 8: T&L ERTICO Roadmap[7].

2.4 Smart Manufacturing

The smart manufacturing sector in the European Union and around the World is poised for a significant transformation, which is supported and accelerated by 5G and in future 6G technology. This new phase, often termed the 'Fourth Industrial Revolution' or 'Industry 4.0', is characterized by the integration of digital and smart technologies in manufacturing processes. The implementation of 6G is expected to accelerate this transformation further, introducing new services and technological capabilities. The technological infrastructure of Industry 4.0 extends comprehensively from devices to the cloud, and the landscape of vendors is evolving. This evolution is characterized by increasingly blurred distinctions between traditional operational technology (OT), information technology (IT), original equipment manufacturers (OEMs), cloud services, and communication service providers [6].

2.4.1 Trends and Challenges in the Smart Manufacturing Sector

Integration of Servitization and Advanced Manufacturing Models: a growing trend in the industry is the shift towards 'servitisation', where manufacturing companies increasingly technology-based offer more services and Industry 4.0 solutions in conjunction with products. This could range from maintenance services to performance-based contracts [7][8].

Selected Challenges

- **Development of Integrated IT Systems**: implementing servitisation models requires sophisticated IT systems that integrate services with traditional manufacturing processes. These systems must handle complex tasks such as service tracking, billing, and customer relationship management while seamlessly integrating with production workflows. Moreover, ensuring rigorous oversight, control, and surveillance are crucial operational factors, making private 5G networks an ideal solution for industrial settings. These networks inherently provide secure and widespread connectivity with authenticated devices, gateways, and comprehensive management and monitoring capabilities. Additionally, they offer flexibility, allowing

[7] https://ertico.com/focus-areas/transport-logistics/.

not only the easy tailoring and configuration of the network according to one's needs, but also enabling customers to determine the extent and level of access to all data produced within the network.

- **Data Management and Analytics**: servitisation relies heavily on data collection and analysis to tailor services to customer needs. The challenge lies in managing vast amounts of data, analysing it for actionable insights, and ensuring data security and privacy, especially under regulations like GDPR [6].

Embracing Disruptive Technologies: integrating various disruptive technologies such as AI, IoT, and robotics is becoming increasingly prevalent in manufacturing. The adoption of disruptive technologies captures the essence of Industry 4.0 (I4.0), which stands distinct from its predecessor, Industry 3.0 (I3.0). While I3.0 utilised computers and industrial networks like EtherCAT and Modbus TCP for enhanced automation and digital process control, I4.0 comes along with the creation of digital twins of physical entities and processes for data-driven decision-making in near-real-time. At the core of I4.0 are cyber-physical systems and the Internet of Systems (IoS), a network interconnecting machines, devices, and sensors to facilitate efficient coordination and data exchange, enabling seamless system integration.

Selected Challenges:

- **Ensuring Interoperability and System Integration**: integrating AI, IoT, and robotics into existing manufacturing systems poses significant challenges in ensuring interoperability between diverse systems and technologies. The prevalence of disparate, non-standardised systems leads to data and operational silos. This lack of integration hampers end-to-end operation visibility and optimisation. These systems require diverse skill sets for maintenance, often resulting in prolonged troubleshooting or dependency on vendors for proprietary system issues. Consequently, this focus on reactive problem-solving can impact various aspects of the business, including efficiency, safety, and costs, while limiting opportunities for innovation and data-driven improvements. Manufacturers need to establish standardised protocols, interfaces and corresponding ecosystems to enable seamless communication and data exchange across different platforms and devices.
- **Lack of Skills and Balancing Automation with Human Workforce**: the adoption of disruptive technologies raises the challenge of finding the right balance between automated processes and the human workforce. This created an anticipated shortage of skilled workforce, a gap already increased by 36% compared to 2018. Automation technologies such as automation, collaborative robots and digital twins as well as novel assistance systems such as AR / VR / XR can help to address some of the workforce gaps and provide opportunities for upskilling existing employees.
- **Device commercialization delays**: limited commercial availability of essential network components and especially chipsets and devices supporting the right feature set have delayed large-scale, production-grade deployments. Chipset manufacturers, modem producers, and makers of user equipment (UE) and other connectivity devices are hesitant to incorporate advanced features such as Ultra-Reliable Low Latency Communications (URLLC) and Time-Sensitive Networking (TSN). This reluctance stems from a wait-and-see approach, where industry players are observing their peers for initial adoption before committing themselves. This situation creates a classic chicken-and-egg problem, where the availability of these advanced capabilities is stalled by a lack of early adopters.

Customer Involvement and Customization: a growing trend of involving customers directly in manufacturing, leading to more customized and personalized products. Indeed, intelligent, software-driven services supported by smart, connected products are set to provide hyper-personalized experiences, shifting the key to differentiation in the market from the physical product to the experiences these products offer. Such experiences have the potential to secure customer loyalty and generate higher margins than the products themselves. The data and insights gathered from these connected products create a beneficial cycle, fostering continuous enhancement of features, new product developments, and progressively improved user experiences. This shift is essential for competitiveness in the digital economy, requiring a collaborative effort across the entire ecosystem, encompassing cultural changes, process reengineering, and strategic upgrades of diverse networks and systems. It's a gradual transformation that spans people, processes, and technology, underscoring that the shift to I4.0 is not just a technological challenge but also an organizational one.

Selected Challenges:

- **Adapting Manufacturing Processes for Customization**: shifting to a customer-centric manufacturing model requires significant alterations in production processes. Manufacturers need to develop flexible and modular production systems that can quickly adapt to custom specifications while maintaining efficiency and quality control. Accelerating time-to-market through ready-made designs is therefore a must for industry 4.0. As a result, industry 4.0 necessitates the capability to gather data almost instantaneously, enabling swift, data-informed decisions and actions. The widespread deployment of sensors, or 'mass sensorization', results in the production of vast quantities of real-time data that needs to be constantly analyzed to respond promptly to emerging issues and perpetually enhance various aspects of their operations, including production and supply chain management.
- **Real-Time Supply Chain Management**: customization demands more dynamic and responsive supply chain management. Manufacturers face the technical challenge of developing systems that can efficiently handle variable demand, manage just-in-time inventory, and respond rapidly to custom orders, all while minimizing waste and maintaining supply chain agility. Such a task necessitates the capability to gather data almost instantaneously, enabling swift, data-informed decisions and actions, through 'mass sensorisation' processes [6].

2.4.2 Relevant Use Cases in the Smart Manufacturing Sector

Integrated Sensing and Communication (ISAC) as the basis for digital twinning and another steps towards convergence of different technologies into a single system

Evolving 6G in a **sophisticated application enablement platform** (rather than yet a better connectivity infrastructure), offering integrated platform services such as digital twinning, AI-aaS, etc.

Non-Terrestrial Networks (NTN) for outdoor applications, industrial processes including oil & gas.

Novel network structures, such as 6G subnetworks, for supporting easy system integration in diverse multi-vendor production systems and partial sub-system autonomy.

2.5 Media

The media sector in the European Union is on the brink of a significant transformation, primarily driven by the advent of 6G technology. This next generation of wireless communication promises to revolutionize how media is produced, distributed, and consumed. The integration of 6G into the media landscape is expected to bring about unprecedented levels of speed, connectivity, and efficiency, enabling new forms of content creation and consumption.

2.5.1 Trends and Challenges in the Media Sector

Enhanced Connectivity and Real-Time Content Delivery: The introduction of 6G technology is poised to bring a paradigm shift in media content delivery. With its ultra-high-speed data transmission capabilities, 6G will enable real-time streaming of media content, including high-definition videos and interactive applications, with virtually no latency. This enhanced connectivity will allow for more dynamic and responsive media experiences, making live events, sports broadcasts, and other time-sensitive content more immersive and engaging.

Challenges:

Infrastructure Investment: The deployment of 6G technology need significant investment in network infrastructure. This includes installing new hardware and upgrading existing systems and ongoing maintenance along with technology updates to ensure optimal performance.

Network Coverage and Quality: Achieving consistent and high-quality network coverage is a major hurdle. This is particularly challenging in ensuring that rural and remote areas have the same level of access and experience as urban centers, thereby avoiding digital divides in media accessibility.

AI-Driven Content Creation and Personalization: AI is transforming content creation and personalization in the media sector. By analyzing vast amounts of user data, AI algorithms can create and recommend content tailored to individual preferences, enhancing user engagement and providing a more personalized media experience. This trend is reshaping how audiences interact with media platforms, moving towards a more user-centric approach.

Challenges:

- **Data Privacy and Ethical Concerns**: The increasing reliance on AI for content personalization raises significant data privacy issues. There are concerns about how media companies collect, store, and use personal data. Additionally, ethical considerations around AI, including biases in algorithmic decision-making and the potential for manipulation, are key concerns that need addressing.
- **Algorithmic Transparency**: Ensuring transparency in AI algorithms is critical to maintaining user trust and compliance with regulatory standards. Users and regulators demand clarity on how personal data influences content recommendations and decision-making processes within AI systems.

Immersive and Interactive Media Experiences: 6G's capabilities are set to unlock new potentials in immersive and interactive media experiences. Technologies like VR and AR will enable more engaging content, offering audiences novel ways to interact with media. This includes immersive storytelling, interactive advertising, and enhanced educational content, providing a richer and more engaging user experience.

Challenges:

- **Technological Expertise and Resource Allocation**: Creating high-quality immersive content demands significant technological expertise and investment. This includes advanced software development, content creation tools, and specialized skill sets, which might be challenging for smaller media companies to acquire or develop.
- **Hardware Accessibility**: The wider adoption of VR and AR experiences hinges on the accessibility of required hardware. Ensuring that these immersive technologies are affordable and accessible to a broad audience is crucial for their mainstream adoption. This involves overcoming barriers related to cost, availability, and user-friendliness of VR and AR devices.

2.5.2 Relevant use cases in the Media Sector

Real-Time High-Definition Broadcasting: Features such as high bandwidth and ultra-low latency, are pivotal in enabling real-time broadcasting of high-definition content. This technology can support extremely high-quality video content streaming, such as 4K and 8K resolutions, without any perceptible delay. The high bandwidth ensures that large amounts of data required for high-definition video can be transmitted quickly, while the low latency ensures that this transmission is almost instantaneous. The impact of this technology will be most pronounced in live events, sports broadcasting, and real-time news coverage. For live events and sports, the ability to broadcast in high definition and in real-time means that viewers can enjoy an immersive experience that closely replicates being present at the event. In the case of news broadcasting, the immediacy provided by 6G will allow for more dynamic and responsive coverage, bringing viewers closer to the events as they unfold.

Interactive and Personalized Streaming Services: streaming services stand to benefit significantly from 6G capabilities. The technology will enable these platforms to offer their viewers highly interactive and personalized experiences. The key here is the ability of 6G to handle large amounts of data at high speeds, which can be used to tailor content in real-time according to viewer preferences. One of the most exciting prospects is the ability for viewers to interact with the content they are watching. This could involve choosing different narrative storylines or camera angles in a live broadcast. Such features make the viewing experience more engaging and give viewers a sense of control over how they consume media, leading to a more customized and immersive experience.

Enhanced Remote Production Capabilities: the integration of 5G and 6G applications are likely to significantly diminish the geographical barriers that currently exist in media production. The technology will enable media teams to collaborate and produce content seamlessly from different locations around the world. The low latency and high-speed data transfer capabilities of 6G are critical in this regard, as they allow for real-time collaboration and communication among team members, regardless of their physical location. Moreover, a more diverse range of content can be created. By enabling teams across different countries and cultural backgrounds to work together effectively, 6G will facilitate the creation of content more representative of a global perspective. This could lead to media that is more varied in its storytelling and more inclusive in terms of the narratives and cultures it represents.

2.6 Agriculture

Agriculture is ongoing a deep digital and green transition which will be reinforced in the coming years. 6G will need to reinforce ongoing and upcoming trends in this European key economic area, mitigating climate changes effects.

2.6.1 Smart Agriculture trends and challenges

The recent EU Agricultural report 2022-2032 [9] is showing that in recent decades, the EU was able to steadily increase agricultural productivity, and thereby production. A significant role in this was played by Member States that joined the EU after 2004 where structural investment, thanks to EU funding, has boosted crop and milk yields. This may be seen as a transition following decades of underinvestment in these countries. Looking at the next decade in this report, key productivity parameters seem to enter a new phase:

- **crop yield** growth is now due to slow down and production level to stagnate, for a series of reasons including climate change and weather-related events, lower use of plant protection products and synthetic fertilizers, limited access to gene-editing and a slowdown of possible genetic improvements.
- **milk production** growth that has been robust since the end of the milk production quotas may significantly slow down and turn even slightly negative, as the herd number reduction may not be compensated anymore by the milk yield increase.
- on the consumption side, **meat consumption** is expected to decline. This is another reversing trend, which is supported by a continuing decline in beef and pig meat consumption, and a sign of diet change in the EU. However, in the rest of the world meat demand continues expanding, driven by population and income growth.

Smart agriculture is a way to optimize the food production and delivery, the Demeter project[8] is giving a good definition: By Smart Agriculture we mean the use of digital techniques to reinvent, govern and optimize agricultural production processes. Digital Transformation boosts human intervention in agriculture and helps to reduce the workload, to carry out specific measures, to calibrate the use of chemical products on the soil and crops, in addition to guaranteeing and increasing the harvest. It also helps to manage all those processes that enable or support agricultural production, including economic-administrative processes. So far, the benefits expected from the introduction and integration of technological processes in agriculture have been attributed to greater production and quality efficiency, the reduction of company costs, optimization of inputs and minimization of environmental impacts, and the creation of job opportunities for specialized personnel. However, thanks to the support of agricultural policies and the growing awareness of the economic and

[8] https://h2020-demeter.eu/

ecological benefits they can produce, new technologies in agriculture really have the potential to spark off a process of radical transformation in the sector. According to analysts*, the global Smart Agriculture market, which was worth almost $10 billion in 2017, will exceed $23 billion in 2022.

The digitization of the European agricultural sector has the potential to revolutionize the industry, promoting efficiency, sustainability, and competitiveness [10]. From artificial intelligence (AI) and robotics to the Internet of Things (IoT) and 5G, the latest technologies can offer invaluable support for farmers and agribusinesses. Through digitization, stakeholders can benefit from a more streamlined value chain, with closer collaboration and improved communication between producers, processors, distributors, and retailers. Meanwhile, innovative SMEs can emerge and thrive, bolstering the industry with new ideas and fresh perspectives.

Artificial intelligence, robotics, IoT and 5G connectivity have been transforming the agricultural sector by providing farmers with access to real-time data on environmental and machine conditions. These data help farmers make better decisions and improve every aspect of their work, including crop farming and livestock monitoring. By combining IoT real-time data with accurate geospatial data, farmers can practice precision farming, resulting in higher yields, reduced waste, and more sustainable practices. Additionally, IoT technology enables farmers to remotely monitor crops and livestock, reducing labor costs and ensuring the health and safety of their animals.

A way to identify the key digital technologies needed by the Smart Farming sector has been proposed by the research paper “Smart Farming Technology Trends: Economic and Environmental Effects, Labor Impact, and Adoption Readiness”. The Key challenges and relevant technologies are depicted in Table 1.

Table 1: Technological Challenges in the Smart Farming Sector.

Challenges	Relevant technologies
Challenge 1: Resource efficiency (e.g., water, nutrients, pesticides, labor)	• Sensors and Networks • Big data analytic tools • DSS (Decision support system) • FMIS (Farm management information system) • Intelligent water application systems • VRA (Variable rate application) fertilization/pesticides systems • RFID tags
Challenge 2: Management/prevention of diseases, weeds, etc.	• Early warning sensors and networks • Specific farm machines • FMIS • DSS for infestation management • VRA spraying system
Challenge 3: Risk management (e.g., food safety, pesticide residue elimination and emission of agro-chemicals, etc.)	• Sensors (e.g., weather station, multispectral • Cameras, thermal cameras, etc.) • Traceability technology • Barcodes, QR codes, RFID • Real-time recording systems
Challenge 4: Compliance with legislation and standards (greening of CAP; regulations on soil	• Recording technologies • Web-based, open, and interoperable standards for • end-to-end tracking systems

management, pesticide, fertilizer, and water use)	
Challenge 5: Collaboration across the supply chain (supply chain of companies and processors)	• Smart traceability system • Smart logistics system • Various analytical tools

2.6.2 Smart Agriculture use cases

There are a number of use cases already studied, developed and experimented by research projects among them we can list the most well-known:

Monitoring of climate conditions: Probably the most popular smart agriculture gadgets are weather stations, combining various smart farming sensors. Located across the field, they collect various data from the environment and send it to the cloud. The provided measurements can be used to map the climate conditions, choose the appropriate crops, and take the required measures to improve their capacity (i.e. precision farming)

Greenhouse automation: Typically, farmers use manual intervention to control the greenhouse environment. The use of IoT sensors enables them to get accurate real-time information on greenhouse conditions such as lighting, temperature, soil condition, and humidity.

Crop management: One more type of digital solution in agriculture and another element of precision farming are crop management devices. Just like weather stations, they should be placed in the field to collect data specific to crop farming; from temperature and precipitation to leaf water potential and overall crop health. Thus, you can monitor your crop growth and any anomalies to effectively prevent any diseases or infestations that can harm your yield.

Cattle monitoring and management: Just like crop monitoring, there are IoT agriculture sensors that can be attached to the animals on a farm to monitor their health and log performance. Livestock tracking and monitoring help collect data on stock health, well-being, and physical location. For example, such sensors can identify sick animals so that farmers can separate them from the herd and avoid contamination. Using drones for real-time cattle tracking also helps farmers reduce staffing expenses.

Precision farming: Also known as precision agriculture, precision farming is all about efficiency and making accurate data-driven decisions. It's also one of the most widespread and effective applications in agriculture. By using IoT sensors, farmers can collect a vast array of metrics on every facet of the field microclimate and ecosystem: lighting, temperature, soil condition, humidity, CO2 levels, and pest infections. This data enables farmers to estimate optimal amounts of water, fertilizers, and pesticides that their crops need, reduce expenses, and raise better and healthier crops.

Agricultural drones: Perhaps one of the most promising agritech advancements is the use of agricultural drones in smart farming. Also known as UAVs (unmanned aerial vehicles), drones are better equipped than airplanes and satellites to collect agricultural data. Apart from surveillance capabilities, drones can also perform a vast number of tasks that previously required human labor: planting crops, fighting pests and infections, agriculture spraying, crop monitoring, etc.

Predictive analytics for smart farming: Precision agriculture and predictive data analytics go hand in hand. While IoT and smart sensor technology are a goldmine for highly relevant real-time data, the use of data analytics helps farmers make sense of it and come up with important predictions: crop harvesting time, the risks of diseases and infestations, yield volume, etc. Data analytics tools help make farming, which is inherently highly dependent on weather conditions, more manageable, and predictable.

End-to-end farm management systems: A more complex approach to digital solutions in agriculture can be represented by the so-called farm productivity management systems. They usually include a number of agriculture IoT devices and sensors, installed on the premises as well as a powerful dashboard with analytical capabilities and in-built accounting/reporting features.

Robots and autonomous machines: Robotic innovations also offer a promising future in the field of autonomous machines for agricultural purposes. Some farmers already use automated harvesters, tractors, and other machines and vehicles that can operate without a human controlling it. Such robots can complete repetitive, challenging, and labor-intensive tasks. For instance, modern agrobots include automated tractors that can work on assigned routes, send notifications, start work at planned hours, etc. Such tractors are driverless and cut farmers' labor costs.

5GPPP Projects

Two of 5GPPP phase 3 projects have developed and experimented Smart-agriculture use cases

- **5G-HEART:**

  UC15: Experiments with automation and actuation functionalities required in the operation of an underwater drone used to inspect the condition of the physical fish cage.

  UC16: Experiment on the utilization of technology enablers such as edge/cloud computing and 5G-based cage to cage on site communication to facilitate deployment of local AI-powered applications at remote sites.

- **EVOLVED 5G:**

  The smart irrigation use case reflects the deployment within the fields of a large number of sensors that are able to measure several parameters of interest, such as the Vapor Pressure Deficit (VPD) or Frequency Domain Reflectometry (FDR), which can be used to monitor the status of the terrain. This information, along with other parameters can be used for the creation of optimized irrigation plans, in order to make better use of water resources.

SNS JU Call 1 projects

Technical requirements

To put in place these digital technologies, connectivity is required with relevant bandwidth, latency, localization and security.

The need to transmit data between many agricultural facilities still poses a challenge for the adoption of smart farming. Needless to say, the connection between these facilities should be reliable enough to withstand bad weather conditions and to ensure non-disruptive operations.

Today, IoT devices still use varying connection protocols, although the efforts to develop unified standards in this area are currently underway. The advent of 5G and technologies like space-based Internet will, hopefully, help find a solution to this problem.

Looking to the future, the demands on communication networks in digital farming are expected to grow exponentially. The farming industry will require even more reliable, high-speed, and low-latency connectivity going beyond the capabilities of current 5G networks. The future 6G networks should not only enhance data transfer capabilities but also support the integration of artificial intelligence, machine learning, and advanced services in future agriculture and aquaculture. Indeed, the main purpose of this document is, by taking a forward-looking approach, to figure out how the evolving needs of digital farming could shape the requirements of future 6G networks.

Table 2: 6G Technological challenges in the agricultural sector.

Technology	Challenges relevant to future 6G networks
Sensing and monitoring	• Ultra-low-power communications to gather data generated by miniaturized and autonomous sensors in a sustainable manner • Ubiquity of communications, esp. in remote areas • Accurate geo-location to allow high-precision application of treatments • High spatial density of sensing devices → scalability
Farm management systems	• High throughput for managing high-definition remote sensing imaging • Decentralized data analysis and decision making (in autonomous sensors and actuators)
Digital farm twins	• Synchronization of the physical measurements and virtual representations in real time
Autonomous and cooperative machines	• Accurate geo-location • Autonomous decision making • Safe operation in collaborative environment with human workers • Cybersecurity • High-quality image/video communications: both for safety reasons and for automating farm tasks like health analysis, harvesting, etc.

Source: AIOTI White paper on Agriculture: challenges in agriculture and aquaculture relevant to 6G networks [11]

2.7 Health

The healthcare vertical sector stands for more than 12% of the European GDP and is situated at the forefront of technological innovation. The advent of 5G and the impending arrival of 6G technologies is of utmost relevance especially in the context of the ongoing digitization of the sector. Due to the demographic development and the ongoing shortage of medical personal advanced 5G and prospective 6G technologies display enabling technologies for the virtualization of care and the use of AI and predictive algorithms.

The health vertical encompasses a broad range of applications, from remote patient monitoring to advanced diagnostics, expert systems and smart pharmaceuticals, all poised to be enabled and enhanced by the latest advancements in telecommunications. The integration of advanced 5G technologies and the medical metaverse promises to revolutionize healthcare delivery, making it more efficient and effective, accessible, and patient-centric [12].

One of the critical aspects of integrating 5G and 6G technologies in healthcare is the diversity of applications and their varying stages of technological maturity. Some e-health applications, already close to market readiness, can operate effectively with 4G technology but will see significant enhancements with 5G and 6G. Others will require enhanced networking technologies which are not even available commercially at this point in time. Commercially viable solutions for the transition of the pharmaceutical and the medical device industries from manufacturing (industry 3.0) to service delivery with cyber-physical systems (industry 4.0) will require network slicing, non-terrestrial networks, enhanced security including post-quantum cryptography and semantic routing, all technologies which are not yet readily available.

This spectrum of applications, from mature to those still in developmental stages, presents unique challenges and opportunities for the healthcare sector and the telecommunication sector alike. It underscores the need for customizable technological solutions that can adapt to a wide range of healthcare scenarios [13].

This chapter has been co-authored with Christoph Tuemmler, Chief Medical Officer of the 6G Health Institute.

2.7.1 Trends and Challenges

The performance of e-health applications in the 5G and 6G era is measured by several key indicators such as coverage / availability, reliability, safety, security, effectiveness and efficiency. These factors are critical in ensuring that technologies like virtualized care, remote device and patient monitoring, smart pharmaceuticals, robotics, augmented reality, video setups, real-time cloud processing of medical data and others meet the demanding requirements of healthcare services. However, the deployment of these technologies also faces real-world challenges. The rate of technology maturity, particularly evident in the slower-than-expected advancement of 5G, suggests potential hurdles in the widespread implementation of cellular technology in healthcare. Furthermore, the overall performance of e-health applications often hinges on factors beyond just network capabilities, including economic factors and privacy concerns and trust.

Overall, the healthcare vertical sector is currently undergoing a significant transformation, driven on the one hand by massive socioeconomic changes and on the other hand by the transition from platform-based solutions (hospital information systems) towards protocol-based systems (FHIR, Health Data Spaces). These advancements are introducing new trends that promise to reshape the landscape of healthcare delivery in Europe and elsewhere. However, this transition is dependent on the enhanced network capacity and improved coverage which can eventually only be delivered by advanced 5G, 6G, NTNs and future generation mobile networks. Distributed patient centric care can only be advanced further by providing distributed computing (edge cloud computing) and real time access to patient data anywhere, anyhow and at any time at a guaranteed quality (QoS). Service level agreements (SLAs) will have to be an integral part of the deployment of 5G and beyond, especially the roll-out of network slicing.

Virtualization of Care: currently, only a very small number of medical devices show wireless and / or mobile radio capabilities. Devices deployed in masses inside and outside hospitals such as syringe drivers, infusion pumps, feeding pumps, insulin pumps are typically fitted with obsolete interfaces such as optical cables or serial analogue interfaces to interlink. This prevents in many cases a more effective and efficient management of patients and displays an obstacle to timely access to care. The lack of connectivity of portable medical devices and soon smart pharmaceuticals slows down the evolution towards the virtualization of care including the utilization of predictive algorithms, Artificial Intelligence (AI) and Machine learning (ML) and the utilization of digital twins in the health vertical. In the shift towards data-driven healthcare, the immense data capabilities of these advanced networks enable more precise and personalized medical services, optimizing time and resources and reducing long medical hurdle for patients. This evolution towards a more data-centric approach in healthcare is paving the way for treatments and patient care strategies that are more tailored to individual needs. Leveraging advanced and more granular datasets, it is possible to continuously monitor patient's health status, create targeted treatment and administrate medications smartly [14].

Challenges

- **Data Management and Analysis**: this shift also brings forth challenges, particularly in managing and analyzing the vast quantities of data effectively and securely for meaningful insights and applications in healthcare.

European Health Data Space / Data Spaces:

The European Health Data Space is a major initiative of the European Commission, published on 3 May 2022 [15] to

- allow for cross border access to health data in line with the fundamental European notion of free movement of people.
- provide easier and faster access to electronic health data for citizens and authorized medical personal.
- improve the policing of data usage and prevent abuse of personal information.

- provide researchers with and policy makers with access to specific kinds of anonymized, secure health data.
- ensure interoperability by driving an European electronic health record exchange format

The above specifications have recently been released by the European Commission [15].

Challenges

- Rapid development of the EU Digital Identity and the EU Digital Identity Wallet
- Rapid concept development and decision on pan European identity providers.
- Post quantum security for identity management frameworks by design
- Accessibility to identity providers from anywhere, anyhow and at any time

Telemedicine: the high-speed connectivity and low latency offered by 5G and 6G technologies are making remote healthcare more feasible and efficient than ever before. This trend is particularly relevant in the context of demographic developments across Europe and public health challenges such as pandemics. Telemedicine will make healthcare more accessible especially for remote and rural areas in Europe. It will also lower the threshold for consultations among health professionals and foster and enhance the building of inter professional teams. Specialized health professionals can be reached by local team to review datasets and help the on-site team making decisions [14].

Challenges

- **Cybersecurity and Data Privacy**: Safeguarding sensitive medical data against cyber threats and breaches, ensuring compliance with regulations like GDPR, ensuring the reliability and security of these virtual services, especially given the sensitive nature of medical data.
- **Digital Divide and Access Equity**: Addressing the digital divide that may prevent certain patient populations from accessing advanced healthcare technologies due to socioeconomic or geographical factors, particularly in rural or underprivileged areas where network coverage might be limited.

Health Vertical Transition towards Industry 4.0

Advanced 5G, 6G and next generation mobile networks will support the transition from Industry 2.0 / Industry 3.0 characteristics to Industry 4.0.

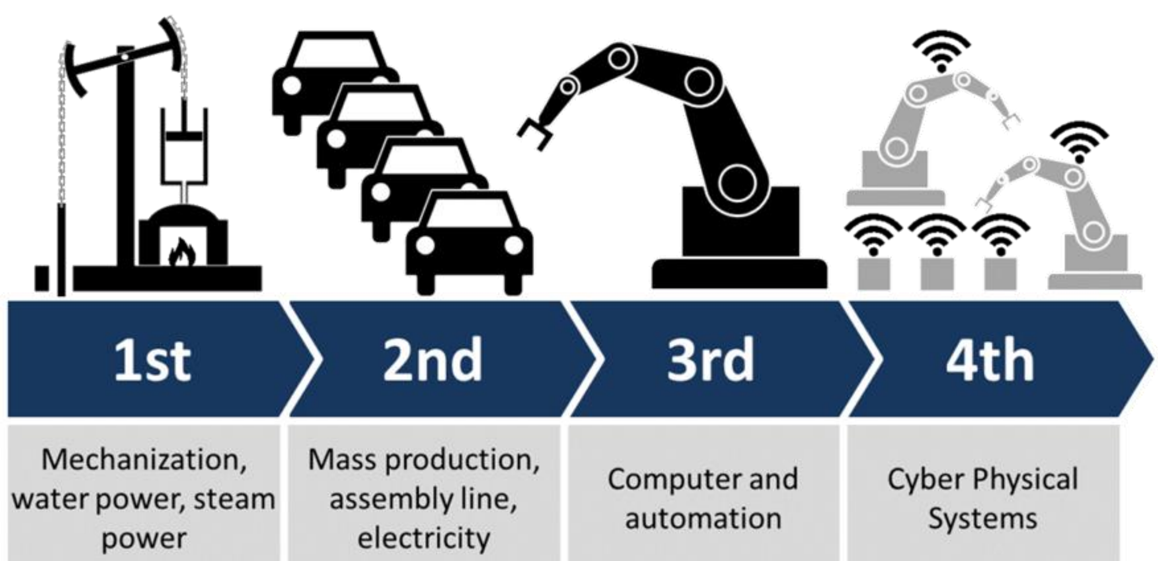

Figure 9: Industry Revolutions.

While the vast majority of processes across the health domain are still based on Industry 1.0 – Industry 3.0 strategies, some of these processes are ready to be taken to the next level and follow the example of other verticals such as automotive, FinTech, retail etc. [16]. We can observe the emergence of algorithms for diagnostic purposes, robotics, predictive algorithms and machine learning. Without suitable and affordable connectivity with good coverage smart pharmaceuticals such as smart asthma inhalers, smart insulin pens, precision medicine in oncology and chronic diseases will not be able to take off and unfold their benefits to patients and their economic opportunities to the European and global economies. The health industry will not be able to tackle the challenges of staff shortages, socioeconomic developments and the urgently needed increase in efficiency without improved coverage and enhanced network capacity.

Challenges

- Enhanced network capacity with intelligence not only in the terminals but in the network to enable cyber-physical systems deployment in the periphery.
- Semantic routing

European Resilience and Disaster Readiness

Furthermore, the rise and evolution of slicing technology will allow for an improved readiness in case of natural disaster and / or crisis. Slicing in connection with NTN will allow for instant deployment of connectivity in any given geographical area. Beyond 5G technology and virtualized private networks will allow for enhanced scalability and improved local control through local user pane deployment allowing for policy alterations within the slice and several sub-slices (SDN). This will allow for the ad-hoc formation of geographical and logical load-balancing across the network. This needs to go hand in hand with an improvement of network resilience and security ideally to post-quantum level.

Challenges

- Time constraints through rapidly changing environmental conditions and geopolitical climate.
- Need for post quantum security and post quantum cryptography.
- EU-US harmonization – currently leveraged by the EU-US Trade and technology Council (TTC)

IoT integration: Integrating Internet of Things (IoT) devices in healthcare is another trend set to revolutionize the sector. The proliferation of IoT devices, from wearable health monitors to smart medical equipment, is enabling continuous patient monitoring and could enable revolutionary applications such as remote surgery, making healthcare management more efficient [14].

Challenges

- **Network Reliability and Coverage**: Ensuring consistent and widespread network coverage, especially in remote or rural areas, to facilitate equitable access to telemedicine and other digital health services.
- **Training and Skill Development**: Equipping healthcare professionals with the necessary skills and knowledge to effectively utilize advanced technologies in their practice.
- **Interoperability of IoT Devices**: Achieving seamless interoperability among diverse IoT devices and systems used in healthcare for integrated patient care and management.

2.7.2 Health relevant use cases

The introduction of 5G and the upcoming 6G networks is not just about faster internet speeds; it's about enabling a range of new use cases in the healthcare sector that were previously unfeasible.

Remote patient monitoring: one of the most impactful use cases is remote patient monitoring, which allows healthcare providers to continuously track patients' health metrics in real-time, regardless of their location. This capability is especially crucial for patients with chronic conditions or those in post-operative care, enabling timely interventions and reducing the need for frequent hospital visits.

AR/VR enabled medical training: another significant use case is the application of augmented reality (AR) and virtual reality (VR) in medical training and procedures. These technologies, powered by high-speed and low-latency networks, can provide immersive training experiences for medical professionals and assist in complex surgical procedures through enhanced visualization techniques. This not only improves the training process but also enhances the precision and efficacy of medical procedures.

Advanced diagnostic tools: AI and machine learning algorithms, combined with the high computational power provided by 5G and 6G, can analyze medical images and data more quickly and accurately. This advancement can lead to earlier and more accurate diagnoses, potentially saving lives by allowing for timely treatment.

Emergency medical services: the low latency and high reliability of 5G/6G networks can revolutionize response times and the effectiveness of emergency care. For instance, real-time data transmission from the scene of an emergency to the hospital can prepare medical teams in advance, ensuring immediate and effective treatment upon the patient's arrival.

Smart health: the integration of IoT in healthcare is enabling a more connected and efficient healthcare system. This encompasses everything from smart hospital rooms that adjust conditions for optimal patient comfort and recovery to intelligent drug delivery systems.

Smart Pharmaceuticals: There are far more than 1 billion people globally suffering from Asthma, COPD, Diabetes and Cardiac Insufficiency. Many of these patients are utilizing inhalers, insulin pens or insulin pumps which are currently not connected. In time, pharmaceutical companies will not only sell pharmaceuticals but will be offering services to enhance the effectiveness of these drugs this adding value to the treatment. This is a multi-billion Euro business-model in the waiting which will only be feasible with appropriate connectivity anywhere at any time. Cellular wireless technology is the technology of choice for transmitting and receiving information. This business model will apply in many other treatments from home-dialysis to fertility treatments.

2.8 Rail transport

Rail transport consists of both passenger & freight transport use both rolling stock and infrastructure. The infrastructure and rolling stock include rail tracks and supporting ICT networks & systems. In US freight over rail accounts 7% of total transport in USA. In Europe this is less with 5% [9].

At worldwide level there are large differences, in Africa and South America there are very little train tracks compared to other areas (see Figure 10). Whereas China is growing fastest its (high speed) track, being second in total track after USA.

[9] Freight transport statistics - modal split - Statistics Explained (europa.eu)

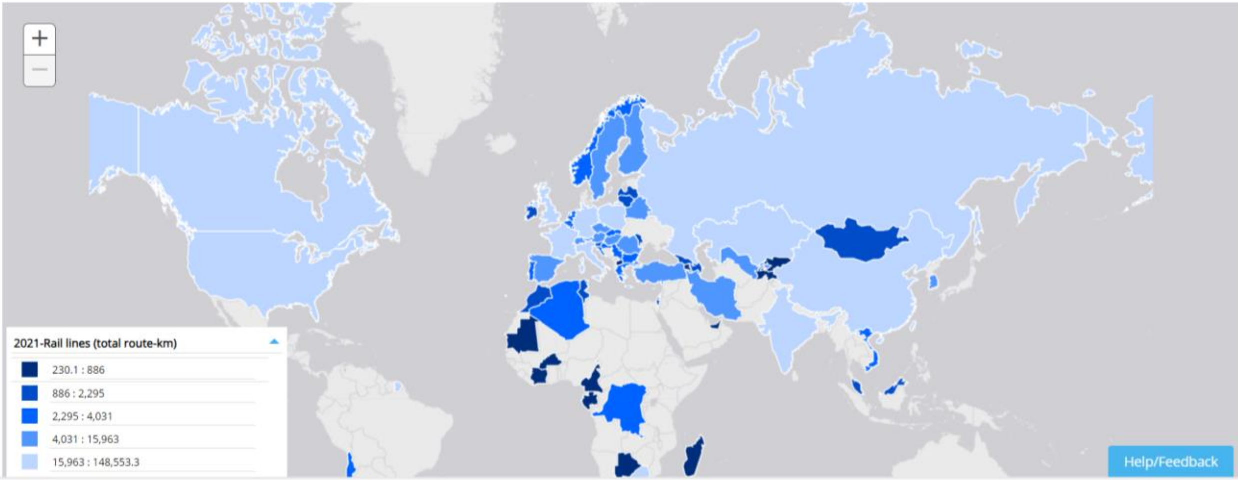

Figure 10: World Bank overview total tracks 2021 [17].

2.8.1 Government (sustainability) policy as driver for change

The Paris agreement in 2015 to limit warming of the earth has put rail in a renewed context. Europe sees rail transport as one of the cleanest modes of transport [17]. Consequently, within the context of 'the green deal' EU policy drives change & investment: 90% reduction in transport emissions by 2050, doubling passenger high-speed rail traffic by 2030 and tripling it by 2050, while increasing rail freight by 50% by 2030 and doubling it by 2050 [18].

Some concrete initiatives supporting this policy: Trans European Transport Network (Ten-T) aims to deliver 9 core corridors by 2030 in Europe and an comprehensive network by 2050. This European network is cross-border is standardized across countries e.g. to speed (160 km/h), rail safety system ERMTS and a standard gauge [19]. The financing vehicle of Europe "Connecting Europe Facility" in which rail receives 25 out of 33 billion [20]. EU does invest in national infrastructure also part of the social cohesion fund [21]. Policies for rail transport within the countries are foremost set by the member states, obviously these differ depending on the history, geography, utilization rates and economic situation. In this context 33 rail operators & infrastructure managers signed a pact in which they called for investments to modernize rail & rolling stock to become carbon neutral in 2050.[10]

In China the transport policy is set centralized - outline people centered mobility policy for 2035 is integrally set on CPC congress in 2020: e.g. the National 1-2-3 Travel Circle (one hour to commute in cities, two hours to travel / (freight) within city clusters, and three hours to travel between major domestic cities) [22] and to become a leader on sustainability & innovation to meet the UN goals [23].

In USA rail policy is set on national and state level. Early last year US senate passed a law to invest 66 billion US dollars in safety, sustainability and improvements of interstate rail transport for '22- '26 [24][25]. On state level the investments are differ, sometime also driven by incidents [26].

2.8.2 Development of wireless communication networks for rail operations

For wireless communication rail in Europe is using foremost GSM-R technology, also in India, China and some countries in Africa GSM-R is used. Wireless offers over wired & track side signaling great advantages in safety and capacity as the onboard systems train better support the driver reducing human errors.

With 130 000 km track in Europe, 210 000 km worldwide it is a true European success. Due to planned sunsets of GSM networks worldwide the GSM ecosystem is becoming obsolete. The GSM-R Industry Group indicated that they are committed to support GSM-R technology and GSM-R products at least until 2030.

[10] 33 European rail players sign pact: 'massive investment in rail is needed' New tab (railtech.com)

After this date, it will become technically more difficult to sustain product and technology based on the second-generation cellular technology (2G). The International Union of Railways sees overall system risk on safety for rail because of this from 2035 [27].

Because of the foreseen obsolescence of GSM-R and the foreseen advantages of digitization & automation, in 2015 the Future Railway Mobile Standard For Mobile Communications (FRMCS) was initiated by International Union of Railways (UIC) and provided its first specification in 2020. Alongside a test program was launched '5G rails' in Europe.

China is a player for communication in its home market for rail. For high-speed rail China is able to offer complete innovative solutions for the communication network, signaling application and operations adhering to the Future Railway Mobile Standard For Mobile Communications (FRMCS) standard [28][29].

2.8.3 Future Railway Mobile Standard For Mobile Communications (FRMCS)

An important architectural change FRMCS brings, is the separation of the application (Traffic Management) and the communication network. By doing so, the large 3GPP ecosystem can be leveraged to lower cost, increase innovation and improve services. For rail it is prerequisite that innovation in the network can be done without the need to re-certify the complete system for Traffic Management. With the introduction of MC (Mission Critical) in 3GPP this is achieved[11]. In that sense it allows transition from FRMCS based on 5G SA technology to 6G without a redesign of the applications or re-certification.

In Figure 11 the UIC timeline of the transition from legal anchor to FRMCS availability in early '27, is depicted.

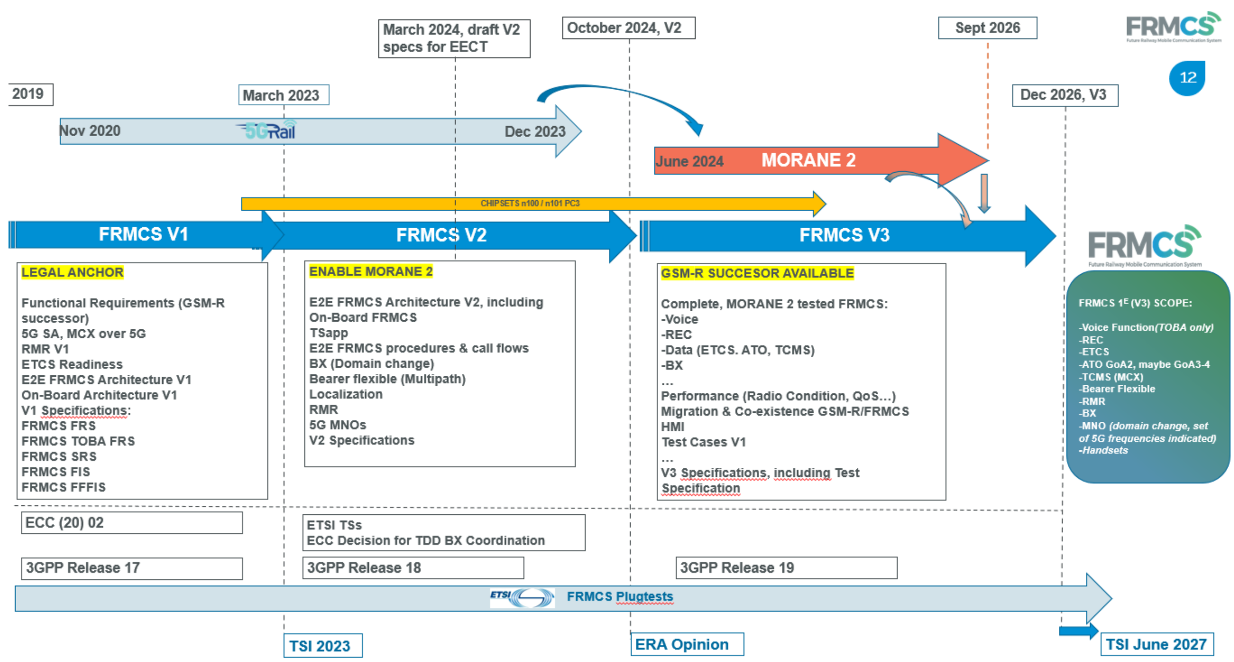

Figure 11: Timeline UIC FRMCS standardization and market readiness[12].

[11] 5GRAIL PROJECT CONCLUSIONS. 5Grail Final Conference, Brussels, 7 of December 2023, Dan Mandoc, UIC.

[12] FRMCS and 5GRail Scope, 5GRail Final Conference, Brussels, 7 of December 2023, Dan Mandoc, UIC.

2.8.4 The transition from GSM-R to FRMCS over 5G SA and beyond

Rail operators and infrastructure managers typically foresee a hybrid strategy with a prolonged period supporting both GSM-R and FRMCS over 5G SA after which GSM-R can be switched-off. The switch-off is determined by the last track / rolling-stock which is equipped by FRMCS. The indicative transition period foreseen is depicted in Figure 12.

Figure 12: Indicative transition from GSM-R to FRMCS 5G SA and beyond.

There are different strategies on leveraging public mobile for rail within Europe, based on the context and installed base in the different countries. Finland (DigiRail) intends to fully leverage the mobile networks for all (future) rail applications. Digirail has in 2023 shown suitability of existing public coverage & performance to meet basic FRMCS performance requirements (note: not all functional requirement) [30]. Switzerland is deciding between a more hybrid approach where public networks may play a role on rural tracks and a dedicated rail 5G network for the other parts and fully dedicated [31]. An approach is to leverage public networks to offer broadband for the gigabit train and leave the traffic management on a dedicated network.

2.8.5 Digitization benefits for rail which FRMCS may enable

Going beyond the existing traffic management application or a very technical approach - digitization should help to improve the experience of travel (remove friction, adding memorable experiences) to develop the customer relationship and reduce cost / nuisance in operations. FRMCS allows exchange of broadband between rail management applications, various sensors, the train and passengers to improve the experience and reduce cost.

Addressing passenger pain-points like the lack information prior to and during disturbances. Enabling real-time and personal response in case of disturbances - e.g. if the train / platform is detected to be overcrowded or delayed offer personalized advice for an alternate route, alternatives modes of transport, upgrade to first class or additional credit for future travel during or prior to travel.

Facilitate intermodal travel / freight with a single touch point and real-time responsiveness to change and leveraging preferences or patterns of the user. Obviously, all with the consent (opt-in) of the user. A simpler case, it is desired where a passenger can pass frictionless a train station and towards the right bus / tram / bike for the last mall when his/hers intend is known on its smartphone.

Same ICT facilities on the rail as at home or the office (Gigabit train) is setting the norm - so the experience is not lost hours, but being productive and engaging with the passenger may contribute to distributing the (most expensive / nasty) busiest hour on rail in morning and evening rush.

For personnel removal of (unpopular) graveyard shifts of drivers where trains are moved at the beginning and end of the operations can become fully driverless and prior. Also moving parts of the traffic management processes towards the driver allows higher productivity and purpose.

Employee on the train should not be integral part of safe starting and stopping process at a station - this manual process can be replaced by digitization; this allows focus on (personalized) service.

Facilitation of cross-border corridors as the train remains in the same country, with fast network handovers < 150ms. This reduces between different rail networks the tedious the need for voice communication.

The advent of co-bots allow safer and more productive maintenance of track allowing cost reduction and even repairs during track operations. Improved localization & sensing should allow safer crossings, less disturbances and may even further increase the track capacity by reducing intertrain distance.

Similar real-time digital twinning may simplify the ever-complicating onboard systems, wiring, reducing failures, unique spare parts and repair times.

3 Non terrestrial Networks trends

Recent advances in space technologies (including new launch and propulsion concepts) have helped to significantly improve the performance and reduce the deployment cost of space-based infrastructures. Collectively they have enabled a new generation of Low Earth Orbiting (LEO) satellites that allow to reduce round-trip air interface latency and make mega-constellations viable. The promise of service continuity, ubiquity and scalability that space-based assets can provide has drawn increased attention to the use of **satellite communication** technology as an inherent part of future communications infrastructures in the context of beyond 5G and 6G.

3GPP, the main standardization body for 5G/6G mobile networks has recognized this development and made **non-terrestrial networks** (NTN) an integral part of Release 17. Rel.18 enhances the features of NTN while the recently approved Rel.19 aims to address even more advanced capabilities of space 5G advanced infrastructure including regenerative payloads (gNB) and edge computing onboard, capacity enhancements techniques, and higher power UEs to address vehicular mounted reception and use of both FR1 and FR2 frequency spectrum bands to enable both narrowband and wideband services.

Traditionally, satellite communications (satcom) represent a substantial segment of the global space market – 32% of upstream and 38% of downstream market, while Europe represents 24% of the commercial satcom services market. Traditionally, satcom provides Universal Broadband Access services to Enterprise market, cellular backhaul and consumer broadband, serves the mobility market sector (comms-on-the move: maritime, aero and land mobile), video -distribution and contribution and defense sector. Over the next 10 years, double digit growth is expected from data segments with anticipated CAGR of >10% while video services further decline by 30%[13]. Last years have seen a dramatic increase of GEO and NGSO supply with new constellations entering the market like Starlink and OneWeb. This has pulled down the cost of capacity with a 70% drop over the last 5 years.

The progressive expansion of society digitization, the state of economy, the deployment and use of 5G public and private networks, from consumer connectivity requirements to security related connectivity requirements for infrastructure, to supply domains such as energy, water and other market verticals such as business/enterprise, media, rail, automotive, freight transportation, air traffic and governmental/institutional users call for global resilient communication networks including NTN. These contribute to NTN becoming mainstream and attracting multinational corporations, large companies such as Amazon, Apple becoming satellite operators and MNOs investing into space companies (for example AST Mobile, SkyLo) for complementary coverage.

The emergence of private investments and new entrants in space led to 'New Space sector' taking forward 'game changing' business models, and use of small satellites, even cubesats, nanosats, and that can be either competitive or complementary to existing commercial space services. These aim to achieve shorter ROI cycles and lower development/manufacturing costs by using COTS when available and reuse of and reduce launch costs by rocket stages reuse if possible. However, in connection with LEO networks, there is risk that collisions could occur in space due rapidly increasing low-cost LEO satellites in the scares Earth orbits and that inoperable satellites -Space Debris will not be removed from orbit in a targeted manner.

Consolidation is visible over the past year between traditional satcom players (Eutelsat/Oneweb, Inmarsat/Viasat, Dish/Echostar mergers) both globally and in regional operators. Key market drivers for additional value to customers and expansion of addressable market, lead to number of emerging multi-orbit satellite strategies, which are still to be confirmed, however, they are expected to be accelerated in the near term globally. Figure 13 below provides an overview of leading NGSO-HTS constellations, while Figure 14 provides an overview of selected 'emerging' NGSO-HTS constellations.

[13] Euroconsult 'Satellite Connectivity and Video Market', Sept 2023. Available at https://digital-platform.euroconsult-ec.com/product/satellite-connectivity-and-video-markets-survey/.

Reference status and information on key NGSO constellations (Q3 2023)

	TELESAT	SES O3b mPOWER	STARLINK	eutelsat ONEWEB	amazon
Planned Constellation Size	**198 satellites** (0% launched)	**11 satellites** (36% launched)	**4,408 Gen1 satellites** (>91% launched) **7,500 Gen2 satellites** *(9% launched)*	**648 Gen1 satellites** (100% launched) **360 Gen2 satellites** *(0 launched)*	**3,236 satellites** (0% launched)
Total Capacity	~10 Tbps (50 Gbps per sat.)	~2.7 Tbps (200-315 Gbps/sat.)	Gen1: ~88 Tbps Gen2: ~750 Tbps	Gen1: ~5 Tbps Gen2: ~22 Tbps	~164 Tbps (50 Gbps/sat.)
Usable Capacity (est.)	~5 Tbps	~1.9 Tbps	Gen1: ~22 Tbps Gen2: ~187 Tbps	Gen1: ~1.2 Tbps Gen2: ~5.4 Tbps	~40 Tbps
Frequency (user)	Ka-band	Ka-band	Ku-band	Ku-band	Ka-band
Orbit	LEO (1,000-1,350 km)	MEO (8,062 km)	LEO (550 km)	LEO (~1,200 km)	LEO (~600 km)
Satellite Mass	~750 kg	~1,700 kg	~290 kg	~150 kg	~650 kg
Satellite Life	~11 years	>10 years	~5 years	~5 years	5 to 7 years
Latency	< 50 ms	~150 ms	< 50 ms	< 50 ms	< 50 ms
Payload flexibility	Beam-hopping, optical ISLs, OBP	Dynamic beam-forming, steering, sizing	Steerable beams, ISLs (as of Q3 2021)	None	Beams: flexible shape, steering, capacity
Funding	Fully funded (internal and external)	Fully funded (internal)	$10.1b raised since 2015	$3.4b pre-bankruptcy, $2.7b post-	Likely internal (from cashflows)
Service start	Late 2027	Q4 2023	2021 (partial) Q4 2022 (global)	2022 (polar) Q4 2023 (global)	Likely >2026

Figure 13: Leading emerging NGSO-HTS constellations.

Overview of select "emerging" NGSO-HTS constellation projects

Operator	Country	#Sats	Orbit	Band	Target Markets	Description/Status
			Government Projects			
IRIS²	Europe	>170	LEO	TBD	Civil Govt., Military, Backhaul	Government-led, with a projected cost of €6bn (~40% will be financed by the EU, the remainder through national and private contributions). Targeting rural broadband and secured civil/military comms in EMEA. Design TBD.
Proliferated Warfighter Space Architecture (PWSA)	U.S.	650 (up to)	LEO	Ka-/ Optical	Military	Space Development Agency's PWSA constellation aims to build a resilient, low-latency, high-volume data transport communication system meshed by OISLs. 146 satellites contracted to date for ~$2b. Service target: 2025.
GuoWang	China	12,992 (up to)	LEO	Ka-band	Backhaul (5G), Govt./ Enterprise	Project composed of two distinct sub-constellations managed by state-owned enterprise China SatNet Ltd. Limited information on design, timing, user markets
			Commercial Projects			
Mangata Networks	U.S.	791 (up to)	HEO/ MEO	Ka-band	Telecom, Mobility, Govt. Enterprise	Scalable constellation to start with 8 HEO satellites (made in-house) targeting high data volume connectivity services. $33 million in funding secured, KTSat as strategic investor.
Rivada Networks	Germany	600	LEO	Ka-band	Telecom, Maritime, Govt. Enterprise	Spectrum formerly held by Kleo Connect. Targeting enterprise-grade services. $2.4B manufacturing contract for 300 sats. w/ Terran Orbital & launch contract w/ SpaceX.
BeetleSat	Israel	250	LEO	Ka-band	Backhaul, Mobility, Gov., Enterprise	Planned to be the first constellation with only intersatellite links (no ground infrastructure), based upon expandable antennas. Service target: 2026.
Intelsat	U.S.	18	MEO	Ku-Band	Aero	Plans to embrace a multi-band approach via their existing GEO satellites and a new MEO constellation. Service target: 2027.

Figure 14: Selected 'emerging' NGSO-HTS constellations.

In particular, the 5G NTN offers new opportunities for both MNOs and SNOs to unleash addressable market new use cases as varied as remote communications, first responders, IoT, XR-based services, etc., and enhance customers experience, reduce coverage gaps, and reduce network deployment costs.

Recent market analysis, as depicted in Figure 15, estimates that the global 5G NTN (excluding HAPs) services revenues raise to 110.90 Bn $, in 2022-2032. A conservative market size estimation for FR1 based Direct-to-Handheld and IoT services is of the order of 48.6 Bn$, 2022-2032 cumulative, excluding HAPs [32][33]. The 2022-2032 cumulative FR1, FR2 5G NTN services revenues (excluding HAPs) per vertical, worldwide is shown below.

Consumer market seems to dominate revenues, but IoT and governmental/military segments represent lower hanging opportunities although timelines and budgets for the governmental/military segments are not clearly defined yet. Therefore, conservative assumptions are considered in the mentioned market value estimates. Finally, adoption of 5G/B5G standalone, and 5G Private networking in case of specific verticals, are expected to further accelerate deployment of 5G NTN and increase revenues.

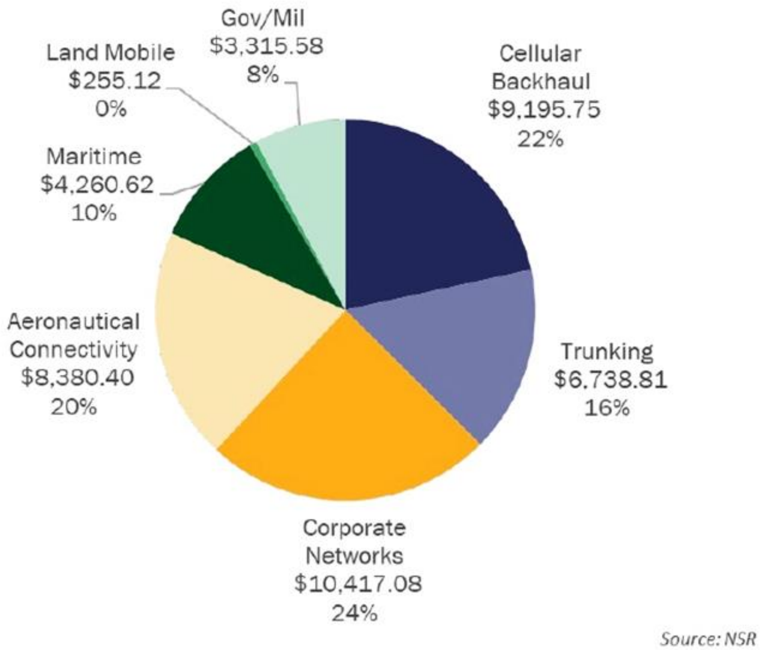

Figure 15: 2022-2032 cumulative 5G NTN services revenues (excluding HAPs) per vertical, worldwide.

To unleash these opportunities, ESA in collaboration with SNS-JU and the European/ESA Member States Satellite Industry have undertaken to:

- Constantly support NTN standardization effort in 3GPP in 5G Advanced (Rel. 18, 19, 20, and beyond) to ensure NTN evolution in the overall telecom ecosystem.
- Constantly support NTN inclusion in design implementation driving initiatives such as O-RAN to accelerate developments and deployments.
- Work closely with MNOs and vertical sectors to demonstrate integrated NTN/TN technology performance enhancements through validation and vertical pilot trials.
- Jointly develop business cases, deployment models and revenue-share engagements with MNOs and vertical representatives.
- Design and develop advanced features Software Defined Satellites incl. advanced onboard and UE antennas (i.e., automotive, comms-on-the-move, etc.),
- Design and develop joint network and services management, control, and orchestration.
- Design and develop user segment for multi-orbit NTN systems.
- Develop cost effective launch sharing products.

- Develop products to propose 5G/B5G/6G Satellite-as-a Service i.e. Payload as a Service, Ground-Segment as a Service
- Design and develop products to unleash opportunities in NTN joint sensing and communications (JSAC), and further in joint communications and navigation.
- Design and develop products leveraging usage of edge computing, AI/ML technologies when/as appropriate for both space and ground segment and joint networks operations.
- Co-design, co-develop advanced mechanisms for both ground and onboard routing to enable Multi-orbit NTN deployment.
- Accelerate design and development of 3GPP technology chipsets and servers for onboard applications, boosting European technology autonomy.
- Adopt zero-debris design and implementation drivers as led out by ESA zero-debris initiative to decrease the space debris risk.[14]

[14] Learn more at https://www.esa.int/Space_Safety/Clean_Space/ESA_s_Zero_Debris_approach.

4 5G Trials

The 5G Infrastructure Public Private Partnership (5GPPP) comprised a set of 93 research and innovation projects running from mid-2015 to the beginning of 2024. Projects were organized in three distinctive phases, namely specification and 5G core research (Phase 1), development, and experimentation/pilots (Phases 2 and 3). Those projects created a plethora of advanced European telecommunication solutions, and achieved an outstanding impact as it has been regularly highlighted in the 5GPPP and the corresponding project websites. Starting in mid-2017, Phase 2 of the 5GPPP already included a portfolio of 21 projects devoted to investigating the applicability of 5G to specific verticals (e.g., connected and automated mobility, smart cities, industry 4.0, consumer and professional services, transportation, and public services) for a total funding of 143.2 M€. Phase 3 began with a call on platform projects (Phase 3.1) where a set of pan-European experimental infrastructures were built (5G Eve, 5Genesis, 5G-Vinni) for their use by subsequent Phase 3 projects. This included the following calls and work areas:

- Phase 3.2: Automotive projects;
- Phase 3.3: Advanced 5G validation trials across multiple vertical industries;
- Phase 3.4: 5G core technologies innovation;
- Phase 3.5: 5G for Connected and Automated Mobility;
- Phase 3.6: 5G innovations for verticals with third party services and Smart Connectivity beyond 5G.

The total number of projects in Phase 3 was 53, for a funding of 439.5 M€. Those investments, on one hand, have allowed Europe to gain a very valuable experience in conducting large-scale trials and pilots for B5G and 6G technologies; and, on the other, have laid the groundwork for the continuation of this work under the umbrella of the 6G Smart Networks and Services Joint Undertaking (SNS-JU).

4.1.1 Key vertical use cases that are descriptive of ongoing or future trends (5GPPP)

In this section, we discuss the alignment of the shorter-term vertical use cases addressed by 5G-PPP projects with the on-going and future trends described in Section 2. To that aim, we have leveraged the information available in the 5G-PPP Verticals Cartography, as depicted in Figure 16.

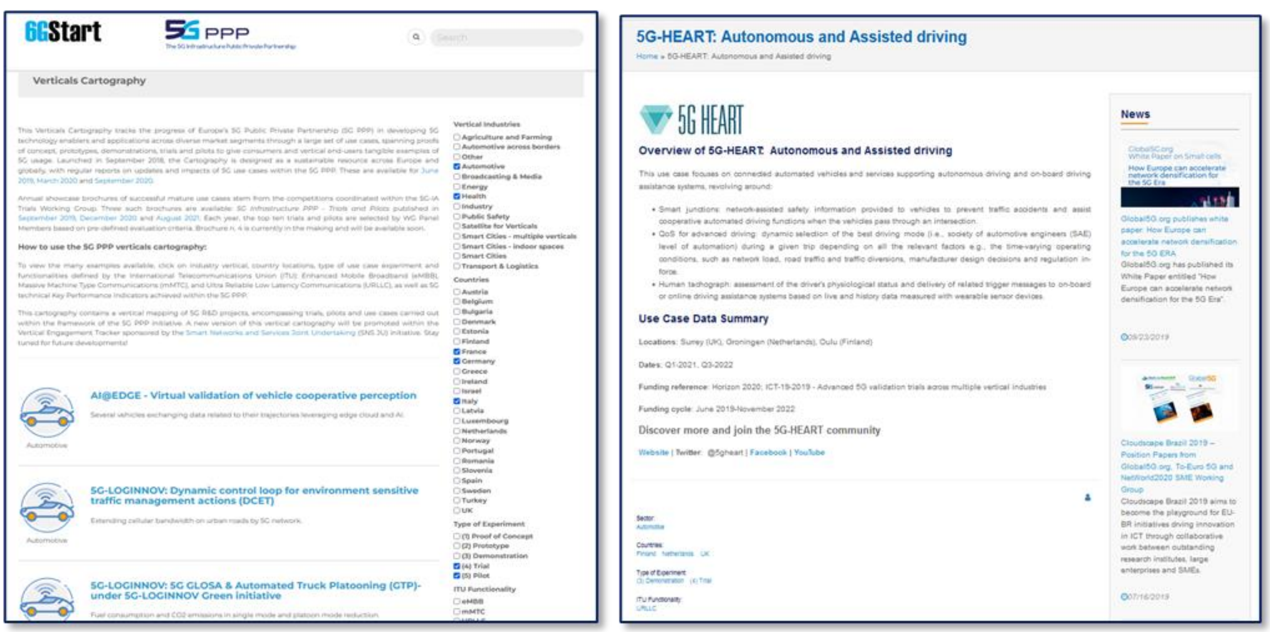

Figure 16: Screenshots of the 5G-PPP Verticals Cartography website: user interface (left), example of use case description (right).

This cartography was aimed to monitor the progress of 5G-PPP projects in developing 5G technology enablers and applications across diverse market segments through a large set of use cases. The experimental work carried out by those projects includes proofs-of-concept (TRL3), prototypes/demonstrations (TRL4), trials (TRL 5-6), and pilots (TRL7) which were aimed to provide consumers and vertical end-users with tangible examples of 5G usage. Launched in September 2018, the Cartography was designed as resource across Europe and globally collecting the latest results and impact of the use cases under investigation by 5G-PPP projects. It included regular reports and a website[15] which is shown in Figure 16. The Cartography website comes with several filters: the vertical industry associated to the use case, the country where the experimental work was carried out, the type of experiment (proof-of-concept, demonstration, trials, etc.), and the ITU functionality being trialed.

First, we investigate the interest that the various verticals have spurred in 5G-PPP projects. To that end, we count the number of use cases addressed for each vertical industry throughout the 5G-PPP initiative. Results are shown in Figure 17 below.

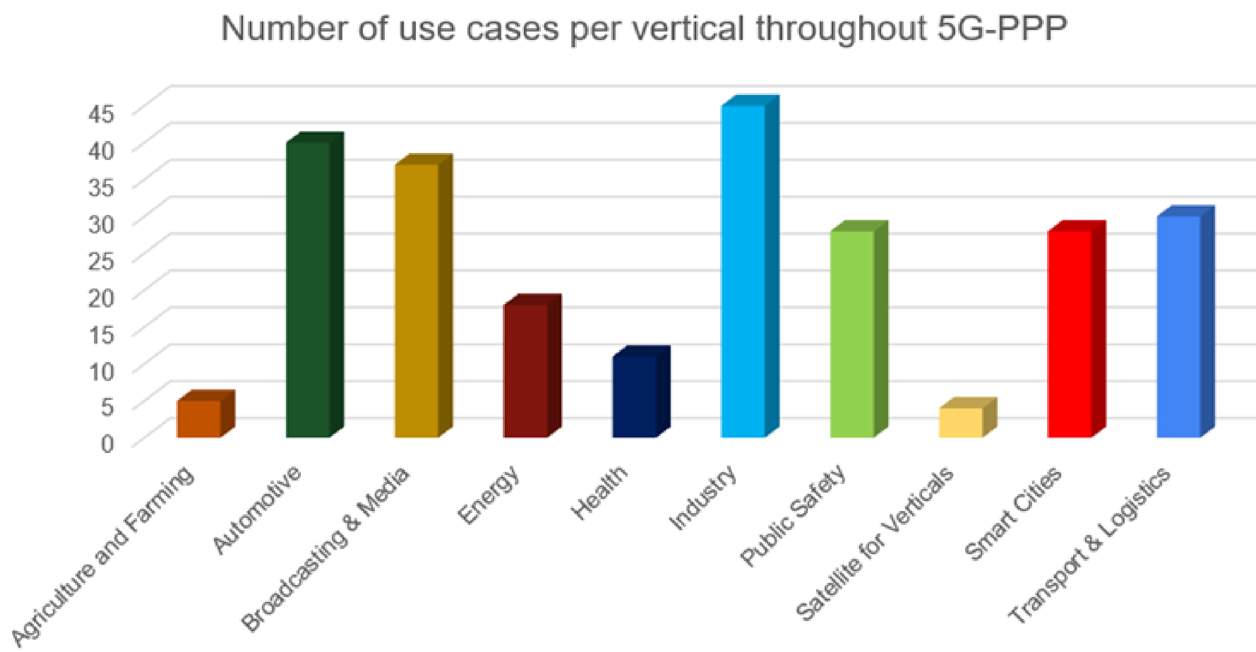

Figure 17: Number of use cases for each vertical in the experimental activities (demonstrations, proof-of-concept, lab tests, trials and pilots, etc.) run by projects throughout the 5G-PPP program.

This figure reveals that the three most popular verticals in 5G-PPP projects were **Industrial Manufacturing**, **Automotive** and **Media**. This is clearly in line with the strength of such industrial sectors and their contribution to the European GDP. A second tier of verticals, closely following the first three, includes **Public Safety**, **Smart Cities**, and **Transportation & Logistics**. On the low end, we have **Agriculture/Farming** (1.6% of European GDP vs. roughly 15 % for manufacturing industry, according to EUROSTAT) and **Satellite** for verticals. The latter can be explained by the intrinsic difficulties in carrying out experimental work in this domain and, also, the limited alignment of terrestrial and satellite networks in past years. It is worth noting that figures are for all types of experiments, i.e., also including for instance proofs-of-concept and demonstrations. On the contrary, Figure 18 focuses on higher TRL activities, that is, Trials (TRL 5-6) and Pilots (TRL 7). The reason is two-fold. On one hand, the higher the TRL level, the stronger the involvement of verticals needs to be in the experimental work; and, on the other, the closer it is to actual deployments in the future. In other words, the results and conclusions are more realistic.

15 Learn more at https://verticals-cartography.5g-ppp.eu

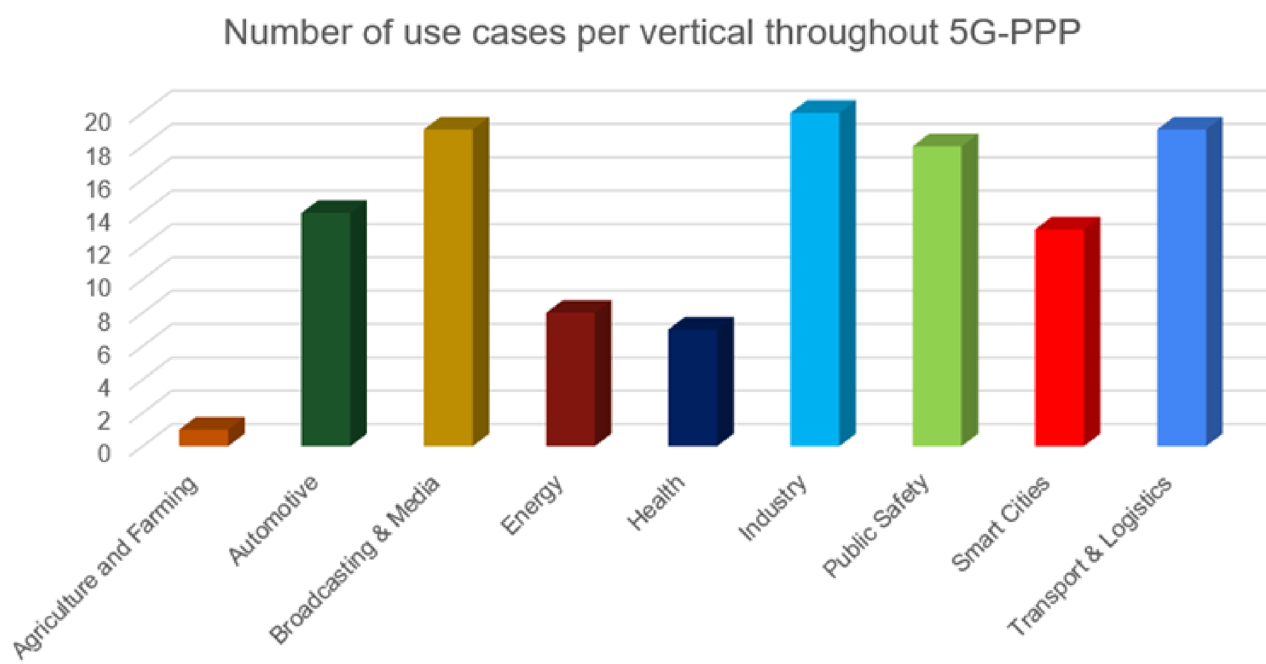

Figure 18: Number of use cases for each vertical in the trials and pilots run by projects throughout the 5G-PPP program.

Interestingly, the three most popular verticals continue to be the same, yet now we have more use cases in the broadcasting & media vertical than in automotive. The main differences with respect to the previous figure come from the fact that, unsurprisingly, no trials or pilots with satcom networks were conducted, given their technical difficulty. Besides, the percentage of public safety use cases is substantially higher here. All this said, overall, the same trends can be observed in both graphs (i.e., with or without lower TRL activities). For this reason, in the sequel we will focus our analysis on use cases where the experimental work is exclusively performed via trials and pilots.

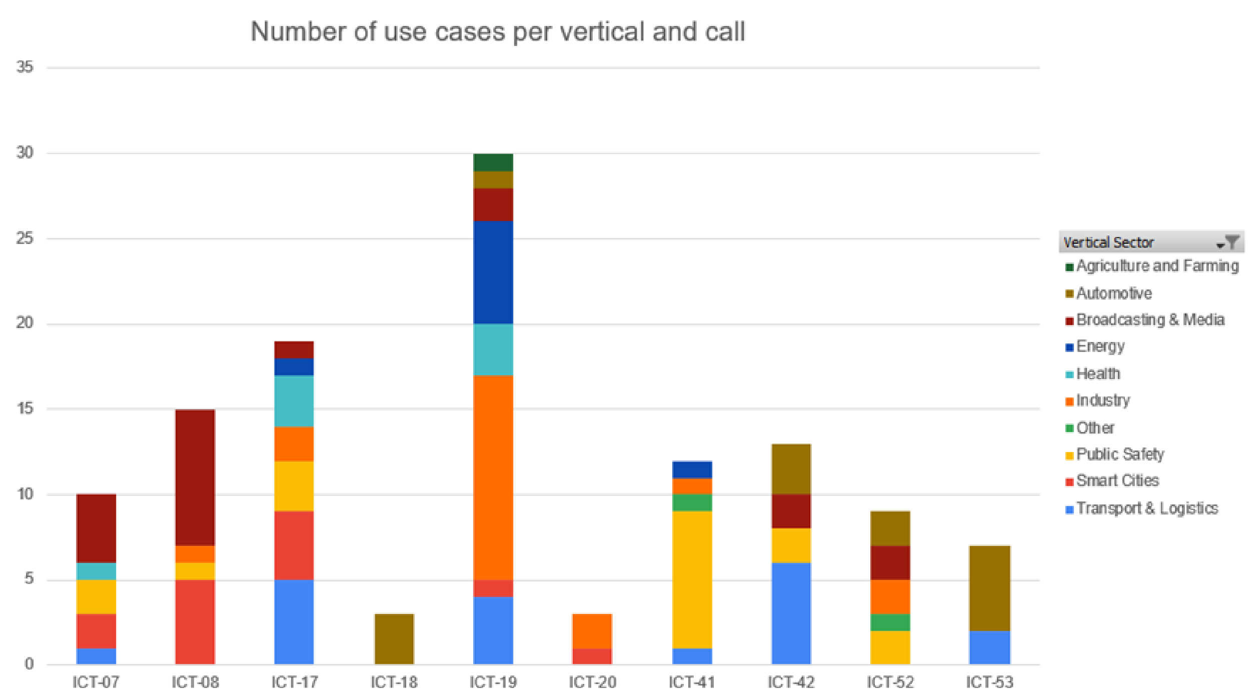

Figure 19: Number of use cases for each vertical in the trials and pilots run by 5G-PPP projects in each call.

Next, we investigate the interest raised by the various verticals in Phase 2 (ICT-07 and ICT-08) and Phase calls (all the rest) which is show in Figure 19. Clearly, the transportation and logistics; and the automotive vertical exhibit a sustained interest in calls. On the contrary, most of the work in the industrial manufacturing and energy verticals was carried out in the ICT-17 call ('Advanced 5G validation trials across multiple vertical industries'). Besides, in the ICT-18 call only T&Ps in the automotive sector were allowed, as this figure proves. Finally, Table 3 provides further details on the scope of the use cases involving the realization of trials and pilots.

Table 3: Vertical sectors and use cases addressed in the trials and pilots run by 5G-PPP projects.

Vertical Sector	Code	Use Case	Trial/Pilot	Project
Agriculture and Farming	AF1	Remote monitoring of water and fish quality	Trial	5G-HEART
Automotive	AU1	Use Case on CACC BASED PLATOONING	Pilot	5G-BLUEPRINT
	AU2	Platooning	Trial	5G-HEART
	AU3	5G GLOSA & Automated Truck Platooning (GTP)	Pilot	5G-LOGINNOV
	AU4	Dynamic control loop for environment sensitive traffic management actions	Pilot	5G-LOGINNOV
	AU5	Floating Truck	Pilot	5G-LOGINNOV
	AU6	Vehicle Platooning across borders	Trial	5G-MOBIX
	AU7	Anticipated Cooperative Collision Avoidance	Pilot	5GCroCo
	AU8	5G Cross-border service continuity for CAM	Trial	5GCroCo
	AU9	Automated Cooperative Driving Use Cases	Trial	5GROUTES
	AU10	Multimodal Services	Trial	5GROUTES
	AU11	Sensing Driving	Trial	5GROUTES
	AU12	Uninterrupted infotainment passenger services on the go	Trial	5GROUTES
	AU13	Virtual validation of vehicle cooperative perception	Trial	AI@EDGE
	AU14	Smart Highway	Pilot	DEDICAT 6G
Broadcasting & Media	BM1	5G Edge network acceleration for stadium	Pilot	5G ESSENCE
	BM2	Next-Generation integrated in-flight connectivity and entertainment systems	Pilot	5G ESSENCE
	BM3	UHF Media, On-site Live Event Experience and Immersive and Integrated Media	Pilot	5G-EVE
	BM4	Immersive Media and Virtual Reality	Trial	5G-MEDIA
	BM5	Remote Production	Trial	5G-MEDIA
	BM6	Ultra-High Definition over Content Delivery Network	Trial	5G-MEDIA

	BM7	Live immersive content production	Trial	5G-Records
	BM8	Multiple camera wireless studio	Trial	5G-Records
	BM9	Trial on Ultra-High Fidelity Media	Trial	5G-SOLUTIONS
	BM10	Cooperative Media Production	Trial	5G-SOLUTIONS
	BM11	Distribution of media content at scale in future 5G networks	Trial	5G-XCast
	BM12	Object oriented broadcasting	Trial	5G-XCast
	BM13	Mobile Backpack Unit for Real-time Transmission	Pilot	5GCity
	BM14	Ultra-high definition Video Distribution and Immersive Services	Pilot	5GCity
	BM15	Video Acquisition and Production with Community media engagement in live events	Pilot	5GCity
	BM16	Communications Suite	Pilot	5Gtango
	BM17	Immersive Media	Pilot	5Gtango
	BM18	Smart content & data curation for in-flight entertainment and connectivity (IFEC) services	Trial	AI@EDGE
	BM19	Enhanced experiences	Pilot	DEDICAT 6G
Energy	EN1	Inspection and surveillance services for critical industrial infrastructures new	Pilot	5G INDUCE
	EN2	Fault management for distributed energy generation in Smart Grids	Pilot	5G-EVE
	EN3	Electric Vehicle (EV) Smart Charging	Trial	5G-SOLUTIONS
	EN4	Electricity network frequency stability	Trial	5G-SOLUTIONS
	EN5	Industrial Demand Side Management	Trial	5G-SOLUTIONS
	EN6	Electricity network frequency stability	Trial	5G-SOLUTONS
	EN7	Advanced critical signal and data exchange across wide smart metering & meas. Infrastr.	Pilot	5GROWTH
	EN8	Advanced monitoring and maintenance support of secondary substation	Pilot	5GROWTH
Health	HE1	Remote eHealth monitoring and forecast	Trial	5G-EVE
	HE2	5G connected ambulance	Trial	5G-EVE
	HE3	Pillcam	Pilot	5G-HEART
	HE4	Remote interventional support	Trial	5G-HEART
	HE5	Vital-sign patches with advanced geo-localisation	Trial	5G-HEART

	HE6	Mobile Ultrasound for Healthcare	Trial	5G-VINNI
	HE7	BlueEye Pilot	Trial	SLICENET
Industry	IN1	Autonomous Fleet Management	Pilot	5G INDUCE
	IN2	Alternative network for production-data exchange	Pilot	5G-CLARITY
	IN3	Enhanced automated guided-vehicle (AGV) positioning in intralogistics	Pilot	5G-CLARITY
	IN4	Industry 4.0 : Autonomous vehicles in manufacturing environments	Pilot	5G-EVE
	IN5	Cloud-based Mobile Robotics	Trial	5G-SMART
	IN6	Industrial LAN over 5G	Trial	5G-SMART
	IN7	5G for Enhanced Industrial Manufacturing Processes	Trial	5G-SMART
	IN8	5G in Semiconductor Factory	Trial	5G-SMART
	IN9	5G-Enhanced Industrial Robots	Trial	5G-SMART
	IN10	Connected Goods	Trial	5G-SOLUTIONS
	IN11	Non-time-critical communication inside the factory	Trial	5G-SOLUTIONS
	IN12	Rapid deployment, auto/re-configuration, testing of new robots	Trial	5G-SOLUTIONS
	IN13	Remotely controlling digital factories	Trial	5G-SOLUTIONS
	IN14	Time-critical process optimisation inside digital factories	Trial	5G-SOLUTIONS
	IN15	Remote Robotic Control with 360° VR-based Telepresence	Trial	5G-VINNI
	IN16	E2E transport-aware orchestration	Pilot	5GROWTH
	IN17	Industry 4.0 - Remote operation of metrology over 5G	Trial	5GROWTH
	IN18	Smart Manufacturing	Pilot	5Gtango
	IN19	Secure and resilient orchestration of large (I)IoT networks.	Trial	AI@EDGE
	IN20	Smart warehousing	Pilot	DEDICAT 6G
	IN21	Drone assisted network perf. and coverage monitoring for industrial infr.	Trial	5G INDUCE
	IN22	Automated Anomaly Detection	Pilot	DAEMON
Public Safety	PS1	AR and AI wearable electronics for PPDR	Pilot	5G-EPICENTRE

	PS2	AR-assisted emergency surgical care	Pilot	5G-EPICENTRE
	PS3	Fast situational awareness and near real-time disaster mapping	Pilot	5G-EPICENTRE
	PS4	IoT for improving first responders' situational awareness and safety	Pilot	5G-EPICENTRE
	PS5	Multi-agency and multi-deployment mission critical comms. and dynamic service scaling	Pilot	5G-EPICENTRE
	PS6	Multimedia MC Communication and Collaboration Platform	Pilot	5G-EPICENTRE
	PS7	Ultra-reliable drone navigation and remote control	Pilot	5G-EPICENTRE
	PS8	Wearable, mobile, point-of-view, wireless video service delivery	Pilot	5G-EPICENTRE
	PS9	Public Safety and Environment Protection	Trial	5G-EVE
	PS10	5G Network Slicing for the Norwegian defence	Trial	5G-VINNI
	PS11	Public warning system (PWS)	Trial	5G-XCast
	PS12	Spectrum for 5G bands	Trial	5G-XCast
	PS13	Mobile Video for Public Safety	Trial	5GENESIS
	PS14	Emergency Communication	Trial	Affordable5G
	PS15	Smart City Use Case	Trial	Affordable5G
	PS16	Edge AI assisted drones in beyond-visual-line-of-sight operations.	Trial	AI@EDGE
	PS17	Public safety	Pilot	DEDICAT 6G
	PS18	5G for Public Protection and Disaster Relief	Trial	MATILDA
Smart Cities	SC1	Enabling Enhanced Human-Robot Interaction	Pilot	5G-CLARITY
	SC2	Augmented reality for smart tourism	Pilot	5G-EVE
	SC3	Smart Turin: safety and environment	Pilot	5G-EVE
	SC4	Experiential tourism through 360-degree video and VR over 5G	Trial	5G-EVE
	SC5	Smart City : Safety and Environment	Trial	5G-EVE
	SC6	5G Touristic City	Trial	5G-MoNArch
	SC7	PON-overlaid Dense City Area	Trial	5G-PHOS
	SC8	Ultra Dense City Area	Trial	5G-PHOS

	SC9	Intelligent Street Lighting	Trial	5G-SOLUTIONS
	SC10	5G Neutral Host	Trial	5GCity
	SC11	Unauthorised Waste Dumping Prevention	Pilot	5GCity
	SC12	Indoor 5G Visible Light Communication and mmWave System	Trial	IoRL
	SC13	Smart City Intelligent Lighting System	Trial	MATILDA
Transport & Logistics	TL1	Automated Driver-in-Loop Docking Functionality	Pilot	5G-BLUEPRINT
	TL2	Remote Takeover Operations	Pilot	5G-BLUEPRINT
	TL3	Media content in high-speed trains	Pilot	5G-EVE
	TL4	Urban mobility flow management	Pilot	5G-EVE
	TL5	Smart Transport : Intelligent Railway for Smart Mobility	Pilot	5G-EVE
	TL6	Smart Wi-Fi Scanners	Pilot	5G-EVE
	TL7	5G mission critical communications in ports	Pilot	5G-LOGINNOV
	TL8	5G&AI Enabled Container Seal Detection in 5G Crane Operations	Pilot	5G-LOGINNOV
	TL9	5G&AI Enabled Rapid Alert System in Yard Truck Operations for Collision Avoidance	Pilot	5G-LOGINNOV
	TL10	5G&AI Enabled Surveillance and Video Analytics	Pilot	5G-LOGINNOV
	TL11	Automation for ports : port control, logistics and remote automation	Pilot	5G-LOGINNOV
	TL12	Management and Network Orchestration platform (MANO)	Pilot	5G-LOGINNOV
	TL13	5G Smart Sea Port	Pilot	5G-MoNArch
	TL14	Autonomous assets and logistics for smart harbour/port	Trial	5G-SOLUTIONS
	TL15	Public Safety, Security and Infotainment	Trial	5G-VICTORI
	TL16	Trial of UAV flight with Communication and Control over 5G cellular network	Trial	5GENESIS
	TL17	Non-safety Critical Communications	Pilot	5GROWTH
	TL18	Safety Critical Communications	Pilot	5GROWTH
	TL19	Automation and Remote Operation of Freight logistics	Trial	VITAL-5G

Next, in Table 4 we discuss the mapping of the more futuristic use cases described in Section 2 ('Monitoring and Analysis of Vertical Trends') onto the use cases addressed in the trials and pilots run by 5G-PPP and SNS-JU projects.

Table 4: Mapping of the use cases described in Section 2

Vertical	Use case	Related 5GPP UCs	Related SNS JU UCs
Public Safety	Real-Time Emergency Response Coordination	PS5	SCI5
	Smart Surveillance and Public Safety Monitoring	PS3,PS8,PS11,PS13, PS16	SPP1, SCI2, SIC3, SCI5
	Enhanced Disaster Management and Recovery	PS3,PS18	
Automotive & Transportation	Local Hazard and Traffic Information	AU7, AU11, AU13, AU14	
	Hazard Information Collection Sharing	AU11, AU13	
	Basic Safety	AU11, AU13, AU14	
	Intersection Safety	AU7, AU11	
	VRU Collective Awareness	AU7, AU11	
	Group Start	AU9	
	Cooperative Adaptive Cruise Control	AU1, AU2, AU3, AU5, AU6	
	Cooperative Manoeuvres	AU9, AU13	
	VRU Complex Interactions	AU7, AU11	
	Data Collection and Sharing for HD Maps	AU8, AU9, AU11	
	Data Sharing of Dynamic Objects	AU11, AU14	
	Non-analysed Sensor Signal Sharing	AU11	
	Dynamic Intersection Management	AU4	
	Dynamic Cooperative Traffic Flow	AU5, AU7, AU9, AU13	
	Automated Valet Parking (AVP)		
	Tele-operated Driving	AU8	
Smart Manufacturing	Integrated Sensing and Communication		
	Non-Terrestrial Networks		
	Novel network infrastructures	IN2,IN6,IN11,IN19.	

Media	Real-Time High-Definition Broadcasting	BM6, BM11, BM12, BM14	
	Interactive and Personalised Streaming Services	BM2 BM11, BM14, BM16	MXR1, MXR2
	Enhanced Remote Production Capabilities	BM5, BM7, BM10, BM13	
Agriculture	Monitoring of climate conditions		
	Greenhouse automation		
	Crop management		
	Cattle monitoring and management:		
	Precision farming		
	Agricultural drones	AF1	
	Predictive analytics for smart farming		
	End-to-end farm management systems		
	Robots and autonomous machines	AF1	
Health	Remote patient monitoring	HE1,HE4, HE7	SHL2
	AR/VR enabled medical training		
	Advanced diagnostic tools	HE4, HE6	SHL4
	Emergency medical services	HE4	SHL1, SHL3
	Smart health	HE5	
	Smart Pharmaceuticals	HE3	

Here we observe that many 5G-PPP projects have produced initial results for most of the use cases in the public safety, automotive and transportation, media and health verticals. The only exceptions are the Automated Valet Parking and AR/VR enabled medical trainings. The alignment, however, is poorer for the Smart Manufacturing and Agriculture verticals. For the former, this happens despite that the number of use cases investigated in 5G-PPP projects was very high. Therefore, one concludes the use cases of interest in the short term (5G-PPP) and long term (Section 2) are substantially different since, for example, the integrated sensing and communication technology is relatively new. As for agriculture, the explanation is that this vertical remained largely unexplored in the 5G-PPP with only one project addressing it and, further, it focused on aquaculture facilities rather than on farming/agriculture.

Figure 20: Pictures from 5G-PPP Trials and Pilots. cross-border service continuity for tele-operated driving (5G CroCo project).

Finally, we summarize **the main lessons learnt and 5G key enabling features demonstrated** in 5G-PPP Trials and Pilots (Figure 20 depicts such a trial). This list, which is based on the (representative) subset portrayed in the T&P brochures (see next subsection), is organized in three main areas, namely:

1) Service creation, provision and application deployment:

- Effective support of advanced services with diverse and/or challenging network KPIs requirements over a programmable infrastructure: collaborative collision avoidance, truck platooning, routing and see-what-I-see applications, operations at (train) level crossings, enhanced healthcare services in ambulances, sophisticated air quality monitoring, or prevention of worker accidents.
- End-to-end orchestration of services across a distributed cloud involving edge and central sites.
- Reduced network service creation time and multi-tenant deployments.
- Efficient integration of 5G Core with diverse cloud-based vertical applications.

2) Network management and performance:

- Feasibility of continuous optimization of network and computational resources.
- Validation of 5G network capabilities including very high reliability and data throughput for uplink and downlink communications.
- Seamless cross-border connectivity with reduced latency handover times for connected and automated mobility (CAM) services such as teleoperating driving.
- Rapid deployment secure, portable 5G bubble networks for first responder teams and special forces (PPDR).
- Automatic management of end-to-end network services in multiple administrative domains.

3) Usage of network slicing and network function virtualization:

- Provision of demanding end-to-end services in a dedicated slice by multiple service providers.
- End-to-end network and service monitoring and resource allocation with network slices.
- End-to-end transport-aware orchestration for QoS slices.

- Onboarding of security-as-a-service into network slices.
- Use of dedicated slice for isolated computing resources.
- Feasibility of 5G neutral hosting solutions for a more efficient use of 5G virtualization infrastructures.

For further details, on those findings the interested reader is referred to Appendix 1.

Additional sources of information on 5G-PPP Trials and Pilots

The 5G-IA Trials Working Group in close collaboration with the Technology Board elaborated and published four **PPP Trials and Pilots brochures** in the 2019-2023 period [34][35][36][37]. Each brochure featured details on 10 Trials and Pilots carefully selected from an open call addressed to Phase 2 and Phase 3 PPP projects. Each of the selected projects produced a two-page flyer (see Figure 21) including an overview of the corresponding Trial & Pilot, its network architecture, deployment aspects, obtained key results and key features brought by 5G technology, stressing the benefits and value brought by 5G networks that previous generations of mobile networks cannot provide (i.e., their 5G empowerment). In the brochures, particular attention was paid to have a visually appealing layout and conveying key messages in proper way for audiences beyond the technical one (e.g., decision makers, politicians, authorities etc.). The brochures were massively disseminated via the 6G-IA website and related social media (e.g., LinkedIn), the email reflectors of several 5G-PPP and 5/6G-IA working groups (Trials, Vision, TB, etc.), the European Commission and, also, via selected SNS/5GPPP projects.

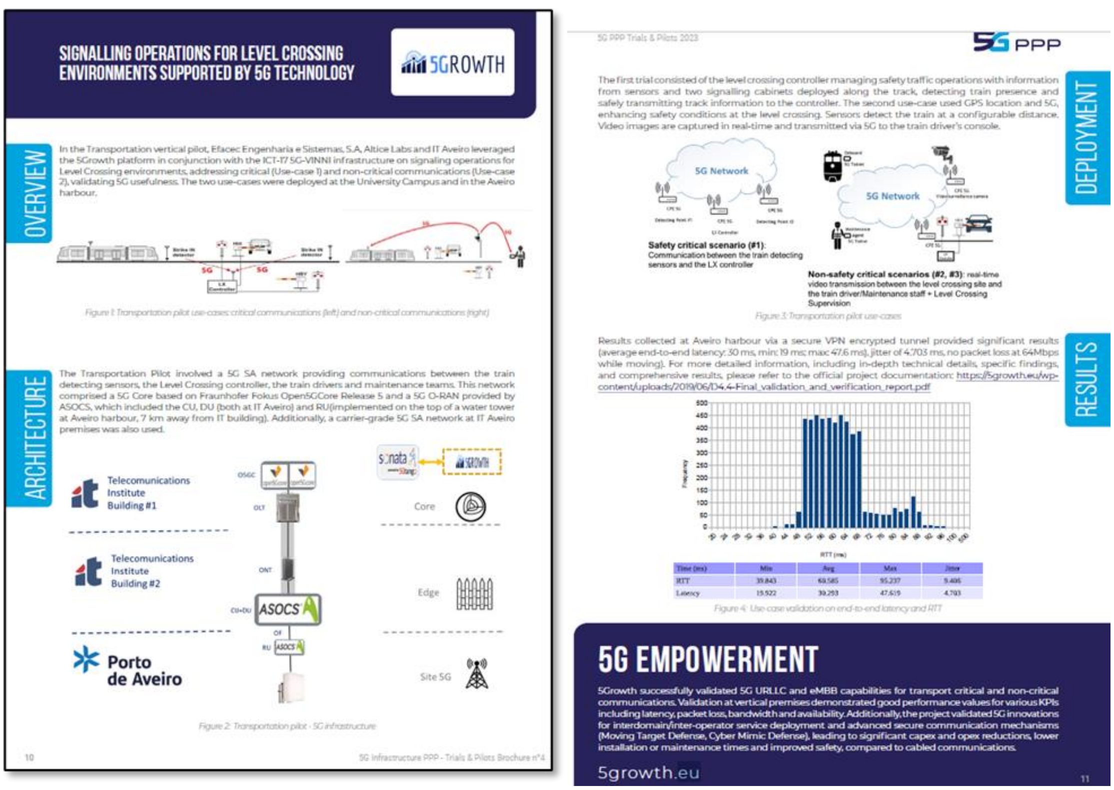

Figure 21: Two-page flyer of the 5Growth project included in the Trials and Pilots brochure no. 3.

At the time of writing these lines, a final **5G-PPP Trials and Pilots Summary Brochure** is in preparation. The plan is to release it by mid-February 2024, on the occasion of the Mobile World Congress 2024 in Barcelona

Complementarily, the **Heritage Brochure** summarizes the interconnections between the PPP projects for three specific categories, namely, (1) Projects follow-up (orange solid lines in Figure 22 (2) Components use/re-use (light blue dashed); and (3) ICT-19 Verticals Pilots / ICT-17 Platforms use (dark blue, dashed). The work consolidates and refines the first PPP Heritage figure[16] released in June 2020 which became one of the reference figures depicting the programmatic connections between 5G-PPP projects.

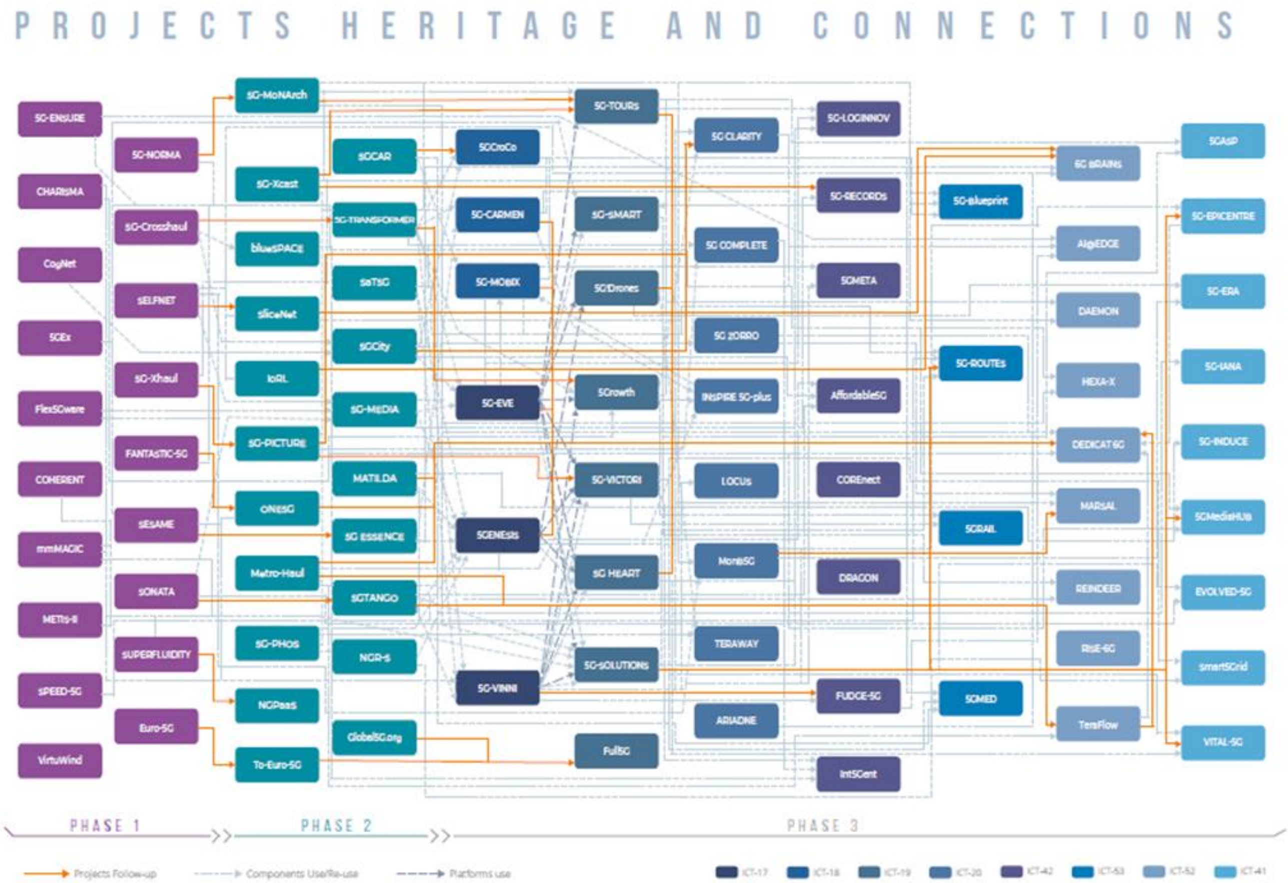

Figure 22: Heritage figure of 5G-PPP projects.

4.1.2 New vertical use cases (SNS JU)

The first R&I Work Program of the SNS JU also included work on large-scale trials and pilots with verticals (Stream D, 46 M€) and experimental activities in SNS enablers and proof-of-concepts (Stream C, 25 M€). In the first call, four Stream D projects were retained, namely **Trial Platform for 5G Evolution Cross-Industry on Large Scale (**Target X); **Trials Supported By Smart Networks Beyond 5G** (TrialsNet); **Field Trials beyond 5G** (FIDAL); and **Advanced 5G Open Platform for Large-Scale Trials and Pilots Across Europe** (Imagine B5G). Two more Stream D projects from Call 2 are set to start in January 2024, namely, **6G Pilots and Trials Through Europe** (6G PATH), and **Evaluation and validation of connected mobility in real open systems beyond 5G** (ENVELOPE). The former will focus on several use cases spread across four key verticals: Health, Education, Smart Cities and Farming. The latter will revolve on Connected and Automated Mobility (CAM) vertical services in and around vehicles, including both safety-related and other services enabled or supported by 5G.

Additional **Stream D projects** will be invited in **Call 3**, while no restrictions will be imposed on specific verticals. However, the proposed use-cases will have to demonstrate a **high impact in terms of environmental, societal, and/or economic sustainability**.

[16]Learn more at https://5g-ppp.eu/5g-ppp-heritage/.

Table 5 summarises the main use cases to be to be addressed by SNS-JU Call 1 projects, as per the SNS-JU Cartography[17] The mapping of the more futuristic use cases described in Section 2 ('Monitoring and Analysis of Vertical Trends') onto the use cases addressed by SNS-JU Call 1 projects.

Table 5: Vertical sectors and use cases in the trials and pilots to be addressed by SNS-JU Call 1 projects.

Vertical Sector	COD	Use case	Project	Trial/Pilot
Automotive/Transport/Logistics	ATL1	Secure smart LRT (Light Rail Transit) systems	HORSE	Pilot
	ATL2	Public Infrastructure Assets Management	TRIALSNET	Trial
	ATL3	Autonomous Apron	TRIALSNET	Trial
Media & XR	MXR1	Advanced sports area media services	FIDAL	Trial
	MXR2	Immersive Fan Engagement	TRIALSNET	Trial
	MXR3	Extended XR Museum Experience	TRIALSNET	Trial
Smart Health	SHL1	MCI and Emergency Rescue in Populated Area	TRIALSNET	Trial
	SHL2	Remote Proctoring	TRIALSNET	Trial
	SHL3	Smart Ambulance	TRIALSNET	Trial
	SHL4	Adaptive Control of Hannes Prosthetic Device	TRIALSNET	Trial
Security/PPDR	SPP1	PPDR IoT Situational Awareness	RIGOROUS	Pilot
Smart Cities	SCI1	Utilities Management and security	RIGOROUS	Pilot
	SCI2	Smart Crowd Monitoring	TRIALSNET	Pilot
	SCI3	Protection of people in crowded public spaces.	TRIALSNET	Pilot
	SCI4	Smart Traffic Monitoring	TRIALSNET	Pilot
	SCI5	Control Room in Metaverse	TRIALSNET	Pilot
Tourism & Culture	TCU1	Extended XR museum experience	TRIALSNET	Trial
	TCU2	City Parks in Metaverse	TRIALSNET	Trial
	TCU3	Service Robots for Enhanced Passenger's Experience	TRIALSNET	Trial

However, the analysis at this stage is rather preliminary for several reasons: (i) the number of funded projects with T&P activities is still relatively low; and (ii) many of the use cases to be investigated will not be tackled by

[17]Learn more at https://verticals-tracker.sns-ju.eu/vertical-cartography.

the partners in the original consortium. Instead, they will be proposed and studied by the additional beneficiaries that will be selected from the open calls to be run by Stream C and Stream D projects which have just started.

5 Verticals in the SNS Work Programme

The SNS JU Work Programs have been created with the direct involvement of vertical industries in mind. As such, since the very first SNS Work Program in 2022, specific goals have been set with regards to the vertical sector coverage that would be achieved across the entire SNS JU program. Stream A, B and C projects tend to involve vertical industry partners in their research as a means to get specific requirements for a specific technological solution being developed and/or for the validation of such solutions by the vertical end-users. Stream D projects have an even more targeted approach towards vertical stakeholders as they are an integral part of the stream D project scope, constituting the main experimenters for the Phase 1 tests/trials. Moreover, additional experimenters from different vertical industries are expected to be involved within the SNS ecosystem via the open calls of Stream C and D projects.

In an attempt to understand the coverage that has been achieved by SNS Phase 1 projects in terms of the involvement of vertical industries, the pie chart depicted in Figure 23 has been drawn, based on the projects responses to a relevant gap analysis questionnaire. It can be observed that more than 11 different vertical industries are covered by Phase 1 projects, providing a very broad range of engaged verticals. The most popular vertical industries seem to be ***Media/xR communications, Industrial IoT*** and ***PPDR / Security & Safety***. The other verticals mentioned in the figure are also relatively well covered by the projects, ensuring a well-rounded approach and the continuous involvement of multiple vertical industries.

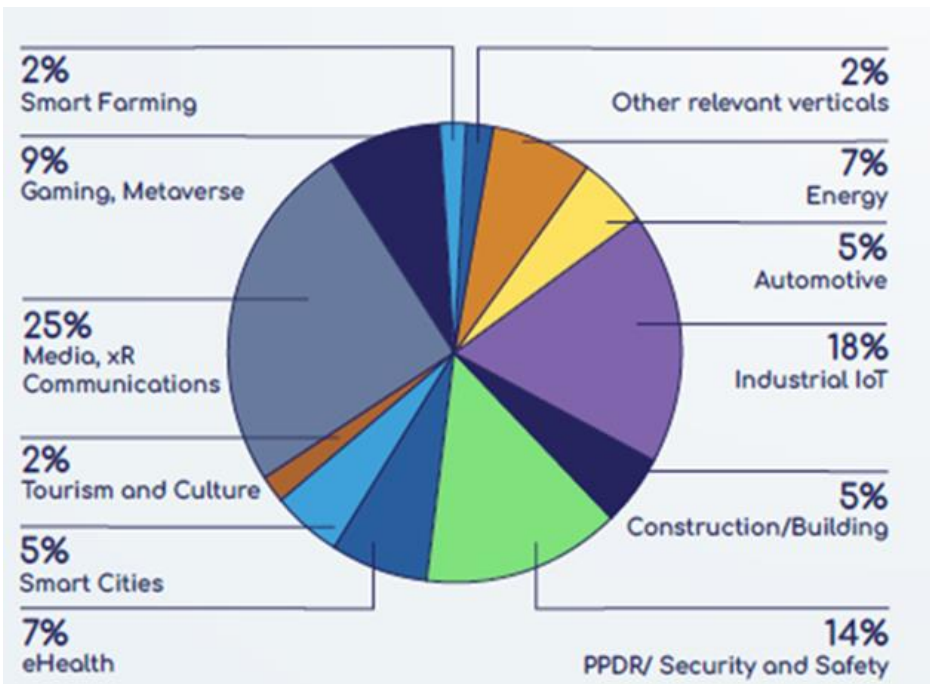

Figure 23: SNS Phase 1 projects – Verticals coverage.

The above presented analysis serves an additional purpose, as it is taken into account from the SNS JU work teams that define the next work program (WP). As such, the good coverage of key vertical industries can be ensured, by adjusting the follow up WPs to attract project proposals addressing specific verticals and ensuring that EU funded R&I efforts do not exclude any important vertical stakeholders. Based on the above findings, it became clear that certain vertical industries, such as ***Automotive, eHealth, Smart cities*** and ***Smart farming*** were not that well represented in the SNS JU projects of Phase 1. To balance this, specific call for proposals were incorporated in to the SNS JU WP 2023, addressing these specific verticals. As a result, two new projects have been selected as part of the Call 2 of SNS JU that are bound to start on January 2024, which address the above verticals. With the addition of these projects the overall SNS Ju project portfolio now nicely covers all above mentioned verticals.

As the range of verticals covered by Call1 and Call 2 projects of SNS was now deemed satisfactory, there was no specific vertical sector targeted in the Call 3 of SNS JU, which was recently published and invited proposals for projects that will commence their operations in the beginning of 2025. Instead, the WP 2023, focuses on one of the key pillars of the entire SNS JU program, inviting proposals that include vertical stakeholders from any vertical industry, but are focused (or have a strong component) on ***sustainable solutions*** for such verticals. In this way, vertical stakeholders interested in developing sustainable solutions or employing B5G/6G networks to increase the sustainability in their respective sectors will be attracted to the SNS JU ecosystem.

This vertical sector analysis and feedback loop towards the SNS JU work teams, based on the selected projects, is a continuous exercise meant to keep track of the SNS JU footprint in the various vertical sectors and to ensure the wide coverage of vertical sectors. Each time new projects are funded, a similar analysis is performed and taken into account for the design of the next SNS work program (along with other factors). SNS ICE partners are an integral part of this loop and assist in the analysis of the impact towards the vertical sectors, based on the collected information from the SNS ICE ecosystem, as presented in this report.

6 Key Trends vs Future Use Cases

This chapter retains fundamental shifts in trends that Evolution Beyond 5G must support from 2030.

Table 6: B5G Use cases & requirements in vertical sector trends.

Sector	Key Trends	B5G Use Cases & Requirements
Public Safety	Critical Communications to Risk & Situational Awareness - from voice centric to data centric public safety networks and services	WORK ACROSS DIVERSE STANDARDS & APPLICATIONS
		MAINTAIN CONTINUOUS COVERAGE OF NETWORK & SERVICES
		SUPPORT COMPLEX ENVIRONMENTS
		IMPROVE INFRASTRUCTURE
		BALANCE LOCAL, NATIONAL & EU REQUIREMENTS
		BUILD ECOSYSTEMS, NOT NETWORKS
		ENSURING TRUST, IN ALL ITS MODULARITY
		CREATE SIMPLE & WORRY-FREE PROCESSES
		BE AFFORDABLE & AVAILABLE
Automotive	Higher levels of vehicular automation	*Extreme networks availability and reliability*
	Availability of relevant travel and traffic information	*Predictability of performance*
	Proliferation of connected devices and services	*Harmonized Quality of Service (QoS) and policy framework*
	Digital roads	*Enhanced network exposure*
	Diverse mobility services	*Device capability*
		Enhanced privacy and security
		Matched spectrum demands and alignment of regulations, policies and standards
		Integrated sensing and communication
		Integrated terrestrial and non-terrestrial networks
		Distributed on-broad communication systems
		Refractive meta-surfaces
		Data-driven networks and distributed computing
		Novel privacy and *security mechanisms*

Transportation	Urban Mobility	
	CCAM	
	Clean Mobility	
	Transport & Logistics	
Agriculture	Smart Agriculture	Climate Monitoring
		Greenhouse Automation
		Crop Management
		Cattle Management & Monitoring
		Precision Farming
		Drones
		Predictive Analytics
		E2E Farm Management (Digital Farm)
		Autonomous Driverless Machines
Healthcare	Virtualization of Care	Remote patient monitoring
	Health Data Spaces	AR/VR enabled medical training
	Telemedicine	Advanced diagnostic tools
	Health Vertical Transition towards Industry 4.0	Smart health
	Disaster Management	Smart health
	Integration of IoT in Health	Smart pharmaceuticals
Railways		Enhanced CX
		Intermodality
		Gigabit Train
		Driverless Trains
		Operations Automatization

7 References

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Appendix 1 – Vertical Targeted Events

Table 7: Past and future targeted events/activities involving verticals targeted by SNS ICE.

##	Targeted Event / Activity	Date / Location	Involved SNS-ICE partner	Target Audience
International Events				
1	IEEE International Conference on Communications	May 2023, Rome Italy	6G-IA	IETF, ITU, Vertical sectors, 5G Americas
2	5G Techritory	October 2023, Riga Latvia	VASES, 6G-IA, NSN	European National Initiatives, EUREKA, CEF, IMT-2020, NGMN
3	Global5G event (Global6G)	October 2023	NSN, 6G-IA	5G Americas, 5G Forum, IMT-2020 KDT. HPC
4	IEEE Globecom 2023	December 2023, Kuala Lumpur Malaysia	6G-IA, TIM, NSN	KDT, HPC, Photonics, CCAM, AI & Robotics
5	IEEE Wireless Communications and Networking Conference	April 2024, Dubai EAU	CTTC	5G Americas, 5G Brasil, 5G Forum, IMT-2020. TSDSI
European Events				
6	ETSI Research Conference	February 2023, Sophia-Antipolis France	6G-IA, TNO, NSN, TIM	ETSI, 3GPP, IETF, ITU, European National Initiatives
7	IEEE Wireless Communications and Networking Conference	March 2023, Glasgow Scotland	CTTC	5G Americas, 5G Brasil, 5G Forum, IMT-2020. TSDSI
8	INTERACT COST ACTION (on AI for 6G et al.)	May 2023, Barcelona Spain	CTT	AI for Robotics, Smart factories, Industry 4.0
9	EuCNC & 6G Summit 2023	June 2023, Gothenburg, Sweden	6G-IA, EURESCOM, NSN, TIM, TNO, CTTC	European National Initiatives, EUREKA, CEF, 5GAA, 5G-ACIA, ESA, NGMN, PSCE
10	German national initiative workshop	June 2023, Germany	TNO	European National Initiatives, EUREKA, ScoDIHNet

11	Fraunhofer FuSeCo forum	September 2023, Berlin Germany	TNO	KDT, HPC, CCAM, AI & Robotics, 3GPP, ETSI. Industry 4.0
Vertical Events				
12	PSC Europe Conference	May 2023, Athens Greece	TIM	PSCE, 3GPP
13	ITS Congress	May 2023, Lisbon Portugal	TIM	Automotive, Transport, 5GAA, CCAM
Other Relevant Activities				
14	Collaboration & Info Day with ESA 5G/6G Hub	March 2023, Online	6G-IA, TIM	ESA
15	MoU between 6G-IA and the 6G Platform Germany	June 2023 (@EuCNC)	6G-IA	European National Initiatives, EUREKA, ScoDIHNet
16	Where 5G leaders meet	May 2023	CTTC	Technology professionals, senior executives, vice presidents, directors, department heads, broadcasters and service providers.