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D2.2 – VERTICALS CARTOGRAPHY 1ST REPORT

Work Package	WP2, Market Watch
Lead Author (Org)	AALTO
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	RE: Restricted to a group specified by the consortium (including the Commission)
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Executive Summary

This report details the development and online implementation of the Verticals Cartography to classify, map and analyse 5G use-case experiments across vertical clusters within the 5G Infrastructure public private partnership (5G PPP). The report is submitted in June 2019 so as to align it with new findings on experiments with multiple verticals, as emerging from 3GPP standardisation (e.g. asset tracking) and on-going interactions within the Technology Board and Trials Working Group to reflect the specifics of 5G rollouts from EU research and innovation.

Triggered through the Technology Board, the Verticals Cartography has been developed first through collaborative work with 5G PPP Phase 2 projects, followed by consensus building with the Trials Working Group on the clustering of verticals. These activities were both key steps to developing an online tool (*https://www.global5g.org/cartography*) that offers users multiple perspectives: vertical industry coverage, EU country, specific type of use-case experiment, e.g. demonstration, trial, pilot, and targeted 5G functionalities as defined by the International Telecommunications Union (ITU). The Cartography can thus serve multiple purposes for the 5G PPP:

- Transparent tracking of public-private investments into 5G research and development with a statistical analysis on the main findings. 63 use-case experiments are currently tracked through the verticals cartography from phase 2 projects.
- Understanding levels of maturity, which will be further analyzed by Global5G.org through the planned online performance KPI tracker, analyzing the programme-level targets in terms of coverage and intensity to gain further insights into maturity levels (technology and market.
- An online tool showing stakeholders from vertical industries key benefits of 5G, including some examples of cross-vertical use-case experiments as the projects evolve and share results of the use-case experiments.
- A tool to help generate informative material that can be tailored to diverse audiences by vertical or country, and already distributed by Global5G.org, e.g. during the International Robotics Festival (Pisa, September 2018).
- A sustainable online tool that can easily be updated and extended to cover projects funded through forthcoming calls, provided sufficient resources are available.
- A gap analysis for future investments, e.g. ICT-19 phase 3 projects with the official launch of the online tool taking place during the Info Day (Brussels; September 2018).
- Visibility through inclusion in the Pan-EU Trials Roadmap V4.0 with dissemination also at relevant events. The Roadmap offers both a cityscape and vertical perspective, with 4 quadrants showing key findings from the first analysis.

The next and final update on the Verticals Cartography will be reported in *D2.4 – Verticals Cartography, Final Report* (December 2019). This report will cover all planned updates on the online tool and its expansion. It will also set out the path towards its sustainability.

Future steps include:

- Triggering requests for updates from projects to highlight the main results from the use-case experiments that are already completed. **Timeline**: April-June 2019, first round (targeting projects ending in Q2-2019); July-September 2019, second round (targeting projects ending in November 2019); October 2019-January 2020 (targeting projects ending in Q2 and Q3-2020).
    - Creation of a new template to help the projects zoom in on tangible benefits for vertical industries so these can also be highlighted in the promotional campaigns. This will be part of a general website revamp with new sections covering 5G for verticals and other project outputs. **Timeline**: starting from April 2019.
- On-boarding of phase 3 projects from ICT-19 using venues like EuCNC 2019 as a catalyst for inputs. **Timeline**: June-September 2019. The first statistical analysis will give a high-level view of the verticals targeted.
- Supporting the new competition organised within the 5G-IA Trials WG aimed at selecting the top ten experiments for inclusion in the EU 5G Observatory. Global5G.org is part of the evaluation committee and has contributed to the template definition.
- Producing a series of showcases to help disseminate success stories.
    - Showcase packages across the involved countries, cities and verticals., building on the successful flier on Italy for the International Robotics Festival. **Timeline**: June-December 2019.
    - Showcase publications zooming in on each vertical industry and use-case experiments to highlight advances and benefits in specific sectors. **Timeline**: July-November 2019.

This deliverable is intentionally submitted in June 2019 as it marks a specific timeline for the 5G PPP, with the ending of four phase 2 projects, and the on-boarding of ICT-19 Research and Innovation Actions. While updates to the phase 2 projects is on-going and will continue to late 2019, the action plan allows Global5G.org to embark on an extended Verticals Cartography with an updated analysis, new findings and a new Blueprint now being developed to cover running phase 2 projects and phase 3 projects from ICT-17, -18 and -19.

1. Introduction

1.1 Purpose and Scope

D2.2 - Verticals Cartography, 1st Version reports on the implementation and analysis of the Verticals Cartography as both an analytical and online tool for the 5G PPP. Its development started with the definition of a Blueprint through collaboration with the Technology Board, and thereafter the Trials WG, with the focus on to phase 2 use-case experiments. It also focuses on the design and rollout of the online tool, showing how it can easily be extended to phase 3 (and potentially beyond Horizon 2020) and to other 5G applications and services for a wide variety of vertical industries.

The main purpose of D2.2 is to:

- Present the main drivers for 5G across vertical industries, offering a general discussion on expected benefits and impacts.
- Define the development of the blueprint and methodological approach for data fields and collection, such as vertical clustering, use-case experiment types and 5G functionalities. This work has been coordinated with the chair of the Technology Board.
- Analyse the data to yield insights into the state of play for 5G use-case experiments in 5G PPP phase 2, shedding light on 1) the level of coverage and intensity of 5G applications in specific verticals, e.g. smart cities with single applications and scenarios that target multiple verticals; 2) major gaps in coverage of verticals, functionalities, locations and stakeholder engagement.
- Show the development of the online tool, its design, launch and maintenance.
- Show examples of early dissemination, such as inclusion in the Pan-EU Trials Roadmap V4.0 (November 2018).
- Plan future evolution of the online tool as a cityscape perspective on 5G use-case experiments, with updates from phase 2 projects and the on-boarding of phase 3 projects (ICT-17-18-19).

1.2 Relationship to 5G PPP Work Programme and Project Outputs

The Verticals Cartography is one of several online tracking tools in various stages of development and evolution designed within the context of the 5G PPP Work Programme. Collectively, these tools offer insights into progress towards 5G developments and rollout:

- **Standards Tracker**: offering practical guidelines on 5G standardisation across verticals, showing the benefits of participation in this process with access to outstanding levels of

expertise, pointing to on-going study and work items, pinpointing common or complementary requirements, and highlighting EU contributions in the global landscape. Its focus is on 3GPP as the main standards body for 5G but extendible to other standards organisations.

- **Performance KPI Tracker**: tracking phase 2 project progress towards the set of performance KPIs set at the 5G PPP programme level. As such, this online tool can help generate data showing KPI coverage and intensity, which leads to insights on different market and technology readiness levels.
- **5G Mapping Tool**: tracking country and city deployments of 5G searchable with diverse economic and readiness-level indicators. As such, it complements the other Global5G.org tools and outputs (e.g. market forecasts, business models) and the EU 5G Observatory, which is one of the data sources for the mapping.

More details on the online tools are given in *D4.3 - Communication, Stakeholder Engagement and Coordination Plan – 2nd report* (June 2019).

Within the context of Global5G.org, D2.2 falls within the scope of *WP2 – Market Watch*, which analyses 5G potential across vertical industries while also relating to the collaboration within 5G PPP and its WGs.

Specifically, D2.2 has close links to the following Global5G.org deliverables:

- *D2.3 - Vertical industries and rollout to markets 1st Report* (May 2019). It draws on some of the key findings of the two Global5G.org webinars on automotive and energy alongside selected IDC and external market analyses.
- *D2.4 – Verticals Cartography, Final Report* (December 2019). It reports on updates to the Cartography and sets out is sustainability path.
- *D3.3 – Report on 5G Standardisation and Verticals* (June 2019). The blueprint for the tracker draws on data regarding targeted standards group as a starting point to trigger further inputs from phase 2 projects within the 5G-IA Pre-Standardization WG.
- *WP4 – Task 4.4: Investigation into emerging Business Models for 5G Vertical Applications and Services (April 2019).* This task is responsible for the development and rollout of the Performance KPI Tracker and online analysis emerging from the Ad-hoc WG on performance KPIs, offering insights into 5G capabilities and market readiness.

At the Work Programme level, the cartography falls under phase 2 of Horizon 2020, with plans to cover phase 3 projects (ICT-17-18-19). For this, an updated Blueprint is being defined in close collaboration with the Technology Board and the Trials Working Group, helping to synchronise on key data points and vertical clustering, as well as future outputs from the Trials WG.

Beside the Phase 2 Blueprint, other 5G PPP references include the Pan-EU Trials Roadmap V3.0, the

Golden Nuggets updated in Q1-2019, and generally inputs to several WGs to which Global5G.org contributes.

The next iterations of the Cartography will incorporate updates from phase 2 use-case experiments (April-May 2019); onboard ICT-19 phase 3 projects (June-July 2019 for a first high-level view), and collect updates from phase 2 and 3 projects (July-December 2019). A showcase publication will be distributed at EuCNC 2019 and updated versions at relevant future events. All these activities will be reported in D2.4 Verticals Cartography - Final Report (December 2019 – M30), including an updated online statistical analysis showing vertical coverage in 5G PPP.

1.3 Abbreviations and Acronyms

The table below lists all the main terms used in relation to 5G within Global5G.org.

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Table 1: Essential Glossary

1.4 Structure of the Document

The rest of this document is structured as follows:

Section 2: Sets the scene for the presentation of the Verticals Cartography by looking at drivers for 5G, key technologies and functionalities, transformation across verticals, and 5G rollout phases, also in relation to the ITU 5G functionalities.

Section 3: Presents the EU context, spanning the 5G Action Plan and national programmes, the 5G PPP and funded projects across three phases. It explains Global5G.org in the EU context, including working groups, task forces, the Pan-EU Trials Roadmaps and the EU 5G Observatory.

Section 4: Focuses on the blueprint for the Cartography design, data fields and harmonisation. It also covers experiments and maturity levels and a comparison between the Blueprint and Online Tool for the Verticals Cartography.

Section 5: Zooms in on the portfolio analysis, assessing the phase 2 projects in terms of an innovation radar analysis, It looks at the Verticals Cartography from multiple perspectives such as ITU functionality definitions, experiment type and maturity. It also shows the results of an updated analysis focusing on examples of multiple vertical coverage in phase 2 projects.

Section 6: Reports on the design and rollout of the of the online tool, the official launch, its inclusion in the 5G-IA Pan-EU Trials Roadmap V4.0. It also presents the impacts achieved so far from disseminating both the Online Tool and Roadmap, as well as the plans to evolve and extend the cartography.

Section 7: Summarises the main findings and next steps.

Section 8: Lists the main references.

2. 5G for Vertical Industries: Context and Drivers

2.1 Drivers for 5G

5G promises to deliver improved end-user experience by offering new applications and services through gigabit speeds, and significantly improved performance and reliability. Its high-speed capability means 5G networks can deliver a range of highspeed broadband services and offer an alternative to last-mile access such as FTTH or copper connections. Combined new technical capabilities and technologies will thus fundamentally change network architectures. 5G aims to satisfy evolving needs by providing ubiquitous connectivity for any kind of device or application that may benefit. Radio access technologies are a fundamental component of 5G. They must support massive numbers of connected devices and meet the real-time, high-reliability communication needs of mission-critical applications in addition to increasing network speed and capacity. By building on the successes of 2G, 3G and 4G, 5G will support new services and business models.

5G is regarded as an opportunity to develop rich solutions and services not just for consumers but also for industry across a range of sectors, and at affordable cost. For example, 5G is expected to significantly reduce latency to below 1ms, making it suitable for mission-critical services where data is time sensitive.

Supporting new use cases: 5G will provide wireless connectivity for a wide range of new applications and use cases, such as wearables, smart homes, traffic safety and control, critical infrastructure, industry processes and ultra-high-speed media delivery.

Its low latency performance characteristics make it suitable for remote surgery, factory automation and the control of real-time processes. 5G's low latency and safety characteristics will play well in the evolution of intelligent transport systems, enabling smart vehicles to communicate with each other, and creating opportunities for connected, autonomous cars and trucks. For example, an autonomous vehicle (AV) operated via a cloud-based, autonomous driving system must be able to stop, accelerate or turn when told to do so. Any network latency or loss in signal coverage preventing the message from being delivered could result in catastrophic consequences. However, wireless operators believe that AVs have a significant way to go before they come into service, despite ongoing pilots and trials.

5G will need to cater for these diverse needs, many of them new, and others yet to come. 5G wireless access capabilities must therefore extend well beyond earlier generations of mobile communication to support:

- Massive system capacity.
- High data rates everywhere.
- Low latency.

- Ultra-high reliability and availability.
- Low device cost and energy consumption.
- Energy-efficient networks.
- Interoperability with existing wireless networks.

The Mobility Economy Europe 2018 by GSMA is a timely and relevant analysis of market trends for the telecommunications industry[1]. Such insights span consumer shifts to 4G, industry plans for 5G adoption, financial outlook and socio-economic impacts. Here, we summarise the main findings.

- **Subscription penetration and financial outlook**: the total addressable European market for mobile operators is nearing saturation point with 465 million people subscribed to mobile services (85% of the population) at year-end 2017. At the same time, there were 285 million 4G connections in the region (up 25% from 2016), accounting for 42% of total connections. Though 4G connections are not expected to peak until 2023, 4G is already Europe's leading technology. Investments in 4G are expected to continue in the short term as operators focus on network performance improvements to meet growing consumer demand for higher speed and always-on connectivity**. Financial outlook**: financials are now beginning to stabilise. Important to track investments also for potential procurement of new services for PPDR.
- **Industry shift towards the 5G era:** By 2025, 5G coverage is forecast to reach three-quarters of the European population, with 203 million 5G connections (29% of total connections). From a world regional perspective, Europe will have the third largest share of 5G connections, behind Asia Pacific and North America. While 5G investments are underway in Europe, most of operators' capex will occur after 2020.

Industry has delivered huge benefits to society through the successful rollout of previous network technologies. Since its early days, the mobile industry has transformed society and will continue to have significant direct and indirect societal benefits. In 2017, the mobile ecosystem supported 2.5 million jobs in Europe. This includes workers directly employed by mobile operators and the ecosystem, and jobs indirectly supported in the rest of the economy by the activity generated by the sector. Mobile also makes an important contribution to the funding of the public sector, with €100 billion raised in 2017, mainly in the form of taxation, including VAT, corporate taxes and employment taxes.

As the expansion of capabilities is implemented as one unified design with the same 5G infrastructure supporting a variety of use cases, mobile technologies are expected to have a deep and sustained impact across a broad range of sectors. Intense standardisation activity has begun to support various business sectors requiring new capabilities and features from 3GPP networks. This work is being

[1] https://www.gsma.com/r/mobileeconomy/europe/.

tracked by Global5G.org, through its participation in the 5G-IA Pre-Standardization WG, the Task Force on Standards for Verticals and the Verticals Task Force.

The work on the Verticals Cartography and the new-to-be-launched Mapping Tool help shine the spotlight on investment impacts and expected deployment timelines across a range of verticals.

2.2 Technologies and Functionalities for 5G

5G is a unifying connectivity fabric that will connect virtually everything around us. 5G service requirements along with the architectural changes introduced in the 5G radio access and core networks will have a major impact on the way Communication Service Providers (CSPs) design and deploy transport capacity and services. Some of the targets for 5G network performance include a peak data rate of 20Gbps with the aim of most users experiencing 100Mbps, while network latency ranges from 20 milliseconds down to 1 millisecond. In short, 5G is expected to be significantly faster and more responsive than today's cellular networks, which will enable CSPs to support a wider range of services and applications.

5G introduces new network architectures and service requirements that will have major implications on how operators design transport networks. Some of the changes that will most affect the transport network in the 5G era include network slicing, the drive to distribute intelligence and processing closer to users at the edge of the network with Multi-Access Edge Computing (MEC), as well as new radio access architectures that require a unified approach to supporting not only backhaul but also fronthaul and midhaul, which are collectively known as X-haul.

5G New Radio (NR): brings new capabilities to a wide variety of services. Major work has been done in 3GPP since September 2015, resulting in the completion of Non-standalone (NSA) capabilities in December 2017 and completion of Release 15 including Standalone (SA) in June 2018. Capabilities developed by 3GPP include ultra reliable low latency communications (URLLC), built from the ground up.

New spectrum: 5G will extend the range of mobile communication frequencies to support increased traffic capacity and data throughput, such as new spectrum below 6GHz and spectrum in higher frequency bands. The new high frequencies, especially those above 10GHz, will complement the low frequencies that will continue to be the backbone of the mobile network, providing additional capacity or wide transmission bandwidths in dense deployments. The millimetre wave (mmWave) will bring very large amounts of spectrum to operators. Advances in this technology include transmitters, receivers and antennas that can fit into handsets that are already densely packed with components. The amount of potential capacity is huge when coupled with highly directional antenna techniques such as massive MIMO (multiple inputs, multiple outputs)

Massive MIMO for increased capacity and spectral efficiency: multi-antenna transmission already plays a key role in mobile communication but will be central to 5G. Multiple-input-multiple output considerably increases the number of transmission points by combining advanced antennas and many

steerable ports. This increases spectral efficiency, network capacity while bringing faster data throughput. User-centric with beamforming using Massive MIMO advanced antenna array: increasing capacity and effectiveness of radio transmissions. Radio signals become highly focused, steerable beams that send out stronger radio signals over a greater distance and with less energy. Beamforming and Beam steering bring higher data throughput throughout the cell, and higher data rates at the cell edge. Intercell interference is reduced because radio data transmission is sent directly to the device with beamforming, thereby improving system performance without having to broadcast across the entire cell. Dynamic control of the number and shape of the beams serves to meet application needs.

Energy performance: Achieving high efficiency in 5G networks comes from ultra-lean radio-access design, minimising transmissions not directly related to the delivery of user data, such as signals for synchronisation, network acquisition and channel estimation, and the broadcast of diverse types of system and control information. Ultra-lean design is especially important for dense deployments requiring a lot of network nodes and highly variable traffic conditions though it is also beneficial for macro deployments and other kinds of deployments.

Virtualised RAN: virtualization helps increase network flexibility. 5G will virtualise several RAN functions that are less sensitive to time delay and that are hosted within the baseband units. For example, 5G will further optimise the multipath-handling function as the anchor point for dual connectivity. This function is thus moved higher up the network to avoid “tromboning” traffic delays and inefficiencies.

Fronthaul: Improved bandwidth efficiency, increased capacities and lower latencies will result from the new industry standards 5G fronthaul (eCPRI) to meet the needs of 5G. eCPRI will use standard Ethernet connections over dedicated fibre.

The transport network is central to the new architecture by providing connectivity between radio sites, edge data centres and cloud service providers. This new transport network and packet-based connectivity fabric will improve performance of the 5G RAN and revenue-generating end-user services.

Backhaul: According to ETSI, wireless backhaul technologies serve more than 50% of total cell site connections worldwide today while, Ericsson reports that 40% of backhaul connections are expected to be based on wireless technologies by 2023. Thus, wireless backhaul links are thus seen as key solutions to address demands of mobile access networks at fast pace economically. However, an article published in light reading, usage varies across countries and continents. For example, usage in the U.S. is currently around 26%.

X-haul (fronthaul, midhaul, backhaul): Mobile network operators preparing for rapid, near-term deployment of 5G RAN are designing network architectures that will scale to device and traffic densities and performance demands that are far beyond what is commonplace in LTE networks today. This is critical preparation for full 5G to enable operators to extend into diverse new service-types and markets over the next ten years and beyond.

Network function Virtualisation (NFV): Element heterogeneity and segmented views per technology have been the norm, conditioning management procedures to accommodate that reality. NFV is an important opportunity to make networks more flexible and operable at scale, leveraging the homogeneity and extreme elasticity that virtualized environments can provide. This marks a major shift away from traditional deployments and operation as an extremely complex task, involving a plethora of equipment, protocols and connections. A major push towards virtualized networks has come from ETSI Industry Specification Group on NFV (ETSI NFV ISG) since 2012. In the same manner as cloud concepts have made a significant impact on IT, network function virtualisation is expected to drive innovations with respect to networking. Orchestration is critical to realising this view of service agility and continuous optimisation that a fully automated network would require. NFV not only initiated the boom of network transformation but is key for 5G services, bringing a lot of benefits to the industry by applying industry-standard high-volume servers, storage and packet switches. NFV implies the simplification of the rollout of network services, reducing deployment and operational costs and facilitating network management orchestration. Originally conceived to help network service providers in the search for cost reduction and agility, NFV has proven to be an essential tool to enhance how these services are requested and consumed by users. It is therefore a necessary ingredient in the emerging 5G.

Multi-access Edge computing (MEC): offers application developers and content providers cloud-computing capabilities and an IT service environment at the edge of the network. This environment is characterized by ultra-low latency and high bandwidth as well as real-time access to radio network information that can be leveraged by applications. MEC is a new value chain. Operators can open their RAN edge to authorized third-parties, allowing them to flexibly and rapidly deploy innovative applications and services towards mobile subscribers, businesses and vertical industries. MEC is a natural development in the deployment of mobile base stations and the convergence of IT and telecommunications networking. MEC will enable new vertical industry segments and services, with use cases including video analytics, location services, internet of things, augmented reality, optimized local content distribution, data caching.

Software applications can tap into local content and real-time information about local-access network conditions. By deploying diverse services and caching content at the network edge, mobile core networks are alleviated of further congestion and can efficiently serve local purposes. MEC industry standards and the deployment of MEC platforms will act as an enabler for new revenue streams to operators, vendors and third-parties. Differentiation can come from the unique applications deployed in the edge cloud.

In summary, small Cells, Cloud-Radio Access Networks (C-RAN), Software Defined Networks (SDN) and Network Function Virtualisation (NVF) are key enablers to meet the demand for broadband connectivity with low cost and flexible implementations. Small Cells, in conjunction with C-RAN, SDN, NVF, pose very stringent requirements on the transport network. Here flexible wireless solutions are required for dynamic backhaul and fronthaul architectures alongside very high capacity optical inter-

connects. Finally, the convergence of mobile and AI will transform the wireless edge, which is opening doors to new opportunities and use cases.

Beyond the technological advances, we also need to see a shift in mindset across the traditional supply side, new entrants and vertical industries to ensure 5G reaches its full potential. A favourable regulatory environment is also crucial for timely investments, both public and private, while ensuring technologies are fit for purpose and future proof. People working on or around networks will have to start thinking in a manner that leads to actions driving the confluence of different streams: infrastructures and networks, business and technology, research and standards, regulations and policies/laws. Work thus needs to focus on challenges from various perspectives: societal, business and technical.

2.3 Transformation across vertical industries

5G has the potential to deliver important societal impacts both in general and through the rollout of vertical applications, where impacts can be direct, related to a specific vertical or cut across several verticals. However, the realisation of 5G use cases will be a step-by-step process, with many still at an early stage or yet to be imagined.

This section offers a snapshot of key findings from Global5G.org, including webinars, work across the 5G PPP WGs, especially on 5G standardisation and interactions with stakeholders of the 5G Vertical User Workshops, described in *D3.3 - Report on 5G Standardization and Verticals* (June 2019).

Automotive: the industry is making a concerted push towards increasing levels of autonomy in vehicle operation, and this will need levels of performance and reliability that today's mobile networks cannot deliver. 5G networks will overcome these limitations by delivering higher capacity, lower latency, denser connectivity and service-level guarantees, while multi-stakeholder co-operation between Regulators, Public Sector, Automotive Manufacturers, Telecom stakeholders will play an essential role in accelerating the societal benefits of connected vehicles[2].

5G will improve latency, reliability, data throughput, mobility, enabling enhanced safety and reliability. 5G is thus expected to bring a set of opportunities emerging over time, such as:

- **Info and Entertainment**: streaming and sideloading of music, videos and information for drivers and passengers. 5G enhancements in terms of high capacity and fast data rate.
- **Navigation and journey**: high-definition and 3D maps. AI route planning. Integration with infrastructure information. Dashcam video sharing. Enhancements through high capacity, fast data rate, low latency, reliability.

[2] https://www.global5g.org/news/webinar-report-5g-automotive-industry.

- **Usage-based services**: services based on data from vehicles, e.g. real-time monitoring, predictive maintenance, usage-based insurance. 5G enhancements through high capacity and connection density.
- **Traffic balance and control**: optimized traffic flow by analyzing vehicles on the road, delivering advice to drivers, controlling vehicles directly. 5G enhancements in terms of high capacity, connection density and low latency.
- **Vehicle autonomy**: driving automation assists or replaces driver, vehicles interact with each other and the infrastructure. 5G enhancements through high capacity, fast data rate, connection density, low latency, reliability.

Energy: In the energy sector, 5G technology will support the next wave of smart grid features and efficiency, integrating many devices into the grid through low-cost connections, managing demand and load balance, helping to reduce electricity peaks and reduce energy costs. However, realising the 5G full potential for the energy sector will require many challenges and changes within the industry, including critical concerns like trust, control and liability, as well as a favourable policy and regulatory environment[3].

- The business potential of 5G in the energy vertical is expected to be very high through the support of critical machine type communication (MTC) applications of energy grid protection and control and the massive volume of MTC type applications coming from smart metering.
- The performance and flexibility promised by 5G will enable a communication infrastructure capable of supporting many use cases for 2020 and beyond, starting from distributed generation and storage of power and micro-grids.
- 5G technologies will play an essential role in the development of the Internet of Energy (IoE), the upgrading and automating of electricity infrastructures for energy producers. Enhanced connectivity, low latency and edge computing features of 5G communications will allow energy production to move forward more efficiently and cleanly with the least amount of waste. In order to manage efficiently the energy supply and demand in the power grid, energy routers will be able to adjust dynamically the energy distribution in the grid, which is so called the Internet of Energy.
- With 5G real-time communications and access to all disperse devices, the current problem of renewable energy systems curtailment can be smoothened. Better data monitoring and more precise energy generation and consumption forecasting will pave the way to fully implement the Internet of Energy.

[3] https://www.global5g.org/news/webinar-report-5g-energy-sector.

- The “last mile” of the smart energy network represents an ideal vertical for demonstrating the added value of 5G: currently little communication or measurement capability in last mile infrastructure, the need for enhanced mobile broadband (eMBB), massive machine-type communications (mMTC), ultra-reliable low latency communications (URLLC).

Healthcare: The digital revolution already apparent in other industries has yet to become mainstream in the health sector, with disruptions coming from improved patient engagement, connected care, unobtrusive monitoring, assisted living for people with chronic conditions, independent and active ageing, and robotic/remote surgery.

5G's technological advancements of faster speeds, lower latency, increased connection density, along with its capability to guarantee use case specific quality of service (QoS) via the network slicing functionality, are features that create the right connectivity environment for value based healthcare, in particular for those digital transformation use-cases that will enable convenient access to care[4].

5G can accelerate precision, personalization and integration across the health value chain. IDC identifies 3 main areas of impact:

- One is certainly around the “connected patient” where 5G accelerates the personalisation of care thanks to real-time monitoring of vital signs and more rapid and content rich interaction with clinicians independently from their location.
- Then the connected healthcare enterprise or connected hospital where the applications further expand beyond patient monitoring (as many devices experimented in Use cases Helios Park-Klinikum Leipzig presented in the webinar), and leverage the capability of 5G to support mission critical connectivity needs with higher capacity and lower latency as for example in remote robotic surgery.
- 5G will also bring benefits to the broader healthcare ecosystem supporting a more rapid cloud-based sharing of large datasets, as in the case of medical imaging, enhancing collaboration and boosting. With 5G the use of innovative user interfaces in augmented and virtual reality environments for clinical and educational purposes.

In the 5G context, **Public Protection and Disaster Relief** (PPDR) is one of the most critical societal impact and life-affecting use of 5G[5]. This is not about the race to be the first and the best but about meeting the most demanding requirements in terms of reliability, availability and scaled quality. Moreover, some providers of PPDR are facing a 15-20-year vendor lock-in situation with only 2G communication capability.

[4] https://www.global5g.org/news/global5gorg-insights-report-webinar-how-5g-can-support-transformation-healthcare-industry.

[5] See for example, TCCA Roadmap for 5G, https://www.global5g.org/news/tcca-calls-action-ahead-critical-communications-europe-2019. See also, D.Lund, D.Corujo, R. Aguiar, *When will 5G be ready for PPDR?*, December 2018, PSCE.

- The security and robustness built into 5G will make it suitable for public safety as well as for use in mission-critical services, such as smart grids, police and security services, energy and water utilities, and healthcare.
- To achieve the societal benefits of PPDR it is vital that we overcome these roadblocks to capability development and innovation. For this to happen, Responders must have the same, if not better, technology than criminals, and rich information capabilities to help find those people lost during a forest fire or to rescue people after an earthquake.
- 5G is also an opportunity to meet underserved communication needs of European public protection and disaster relief and its multiple vertical entities while gaining capability advantage from the most advanced communications solutions for enabling daily and emergency operations.

Smart Cities: 5G is expected to drive the evolution of smart cities and IoT through the deployment of a considerable number of low-power sensor networks in cities and rural areas. ADD MORE HERE examples from cartography. These scenarios are covered in the context of the Verticals Cartography in Section 5.2.7

Bridging the digital divide: ensuring affordable and sustainable mobile wireless communication systems is key to overcoming the dangers of increasing the digital divide. According to the ITU, local authorities and regulators should recognize the risk of increasing the digital divide and support incentives to stimulate investments, where possible[6]. Similar concerns have also been expressed by the Small Cell Forum.

A viable case for investment in 5G can be made for densely populated urban areas – always commercially attractive for operators. More challenging will be a commercial argument for investing outside these areas, especially in the early years of 5G deployment. Rural and sub-rural areas are therefore less likely to enjoy 5G investments, which may further increase the digital divide. That said, novel engineering and manufacturing processes have made rural cell-site solutions cheaper, and also, more versatile. From an economic perspective, this can result in a lower return on investment timeline, with some solutions already radically altering the typical cell-site total cost of the ownership model for operators. The macro base-station is now being complemented by low cost small cells that deliver coverage to a specific rural village or town. Some operators are also taking proactive steps to prioritise the coverage needs of their rural end-users. There are also novel initiatives to combine solar-powered small cells with off-grid lithium batteries to provide communications and power to local communities[7].

[6] *See Setting the scene for 5G: Opportunities and Challenges*, ITU, 2018, https://www.itu.int/pub/D-PREF-BB.5G_01-2018.

[7] https://www.telecomtv.com/content/small-cells/pent-up-demand-for-mobile-connectivity-from-rural-communities-primes-us-20-2-billion-in-rural-cell-site-expenditure-in-2019-35540/. See also, https://www.thinksmallcell.com/Small-Cells/Rural/.

In the context of this Global5G.org report, it is also important to analyse verticals that may be affected by such scenarios, e.g. farming and agriculture; transportation through underserved areas. It should be noted that several cases have emerged from the analysis of the Cartography (e.g. SAT5G underserved areas), on-going work in 3GPP (e.g. non-terrestrial networks), and some national 5G programmes e.g. UK 5G RuralFirst.

2.3 5G Rollout Phases

As with any major technological change, the rollout of 5G networks and the full new service capabilities will happen gradually. The first 5G services will be quite similar to current 4G services, albeit with faster speeds. Indeed, early commercial deployments that are rolling out this year are focused on enhanced mobile broadband and fixed wireless access services. It's not until 2020 and beyond when more advanced 5G services are expected to be introduced, which potentially include mission-critical applications, industrial automation, remote healthcare services, massive Internet of Things (IoT) connectivity and even autonomous vehicles.

The main standards bodies for 5G, including architecture, are 3GPP and ITU IMT-2020, with 3GPP standards in constant evolution through subsequent releases, from the completed release 15, onwards, including a comprehensive Release 16, with Release 17 mostly focusing on verticals. Early standardisation in Release 15 has focused on pushing first rollouts that rely on non-standalone, which is based on 4G core and infrastructure before moving towards full 5G with a complete set of use cases and functionalities.

Phase 1 of 5G deployments is mostly based on 3GPP Release 15 specs, where 5G will enable new and enhanced mobile broadband use cases, e.g. a more capable smartphone, more immersive mobile extended reality (XR) experiences, where split XR reduces the processing burden on the handset by transferring some of the processing to the edge cloud. The low latency coming from the NR air interface and edge processing is a good fit for the low latency requirements of XR.

The overriding goal is to enable the switch from today's tethered environment to true mobile usage while providing photorealistic graphics and visuals. The priority on eMBB means there is no massive change plan for 5G since this first phase has a strong 4G flavour as the starting point before turning 5G up, with work underway to add more capacities.

Phase 2 of 5G brings ultra-reliable low latency communications (URLLC), which is a very different game. These URLLC-type applications meet low latency requirements and are supported by VNF and MEC. Phase 2 is based on 3GPP Releases 16 and 17, expanding 5G to new industries such as autonomous driving with 5G NR C-V2X and dynamically configurable factories with 5G NR wireless industrial ethernet. Full 5G also needs more fibre and more cells across shorter distances, aiming for a

balancing act as cost is also a factor while gaining from the increased robustness of fibre. Other advances will come from optics[8].

CSPs are clearly already thinking about how they will evolve their transport networks to support 5G service requirements. This report analyses operator strategies for 5G transport, including timelines for deploying advanced 5G features as well as the complex challenges that CSPs identified.

2.3.3 5G Functionalities

One of the key promises of 5G is that it will be able to support diverse families of use cases and applications. The International Telecommunications Union (ITU) has defined three important categories of these use cases based on industry stakeholder identification. Such definitions are directly related to the ITU vision for 5G (ITU-R Recommendation M.2083), which defines requirements for International Mobile Telecommunications 2020 (IMT-2020) mobile systems that support new capabilities beyond IMT-2000 and IMT-Advanced. These IMT-2020 systems provide improvements in terms of flexibility, security, reliability etc. for supporting diverse services in three functionality categories or usage scenarios:

The three main families of use cases are:

- Enhanced mobile broadband (eMBB).
- Massive machine-type communication (mMTC).
- Ultra-reliable and low latency communications (URLLC).

These are defined in the table below.

5G functionality	Definition and examples
Enhanced mobile broadband (eMBB)	Massive mobile connectivity enabling eMBB. This extends the existing 4G value proposition by expanding cellular coverage and improving network capacity. Enhanced indoor and outdoor broadband, enterprise collaboration, augmented and virtual reality. eMBB is expected to be the primary use case for 5G in its early deployments, according to wireless operators. eMBB will bring high-speed mobile broadband to crowded areas, enable consumers to enjoy high-speed streaming for in-home, screen and mobile devices on demand, and will allow enterprise collaboration services to evolve. Some operators

[8] On the Global5G.org analysis of small cell deployments, see Study on small cells and dense cellular networks regulatory issues (D3.1), http://www.global5g.eu/sites/default/files/Global5G.org_D3.1-Study%20on%20small%20cells%20and%20dense%20cellular%20networks%20regulatory%20issues_v1.0_rev3_0.pdf. See also, the Global5G.org forthcoming White Paper on Small Cells.

5G functionality	Definition and examples
	are also considering eMBB as the last-mile solution in those areas lacking copper or fibre connections to homes.
Massive machine-type communication (mMTC)	Connectivity of millions of devices enabling mMTC. This is expected to lead to adoption and use across diverse sectors on a massive scale, such as using mobile technologies for mIoT applications. IoT, asset tracking, smart agriculture, smart cities, energy monitoring, smart home, remote monitoring.
Ultra-reliable and low latency communications (URLLC)	Resilient, instantaneous connectivity enabling URLLC. URLLC is key to supporting applications that require high reliability and low latency connectivity such as mission-critical services while also meeting strong security and availability requirements. Autonomous vehicles, smart grids, remote patient monitoring and telehealth, industrial automation.

Table 2: 5G Functionalities and Examples

2.4 The Case for Testing 5G Applications and Services

Successful 5G adoption depends on technical and business validations. 5G trials and pilots can help clarify key questions about 5G, such as:

- The need for 5G to move beyond what is available and/or possible today, demonstrating specific differences that 5G is bringing.
- The transition from 4G to 5G, including concrete examples of 5G applications and standards implementations.
- Business benefits, how they are delivered and to whom.

Validation should therefore cover large-scale deployment scenarios under various vertical use cases and business conditions with their respective technology and business Key Performance Indicators (KPIs). It is also important to assess the type and scope of research and innovation needed to create new or enhanced services and applications across verticals.

As stated in the GSMA Mobile Economy Europe 2018 report[9], *"more coordinated rollouts of 5G services, compared to the staggered approaches of 4G, will result in coverage and adoption levels increasing at a faster pace in Europe in the first few years after launch than with the previous technology generation".*

[9] https://www.gsmaintelligence.com/research/?file=884c77f3bc0a405b2d5fd356689be340&download .

Most of the 5G trials and pilots will be driven through private pre-commercial and commercial trials between network operators and manufacturers/vendors with a gradually increasing number of vertical industries involved. After early work that started validating 5G capabilities, the first deployment phase is now in full swing, planning and performing tests in real conditions as the first 5G smartphones become available in early 2019. At the same time, several EU countries have started showcasing results of national programmes, such as Italy and the UK.

Thus, it makes sense to track use-case experiments to understand what is being tested where, when and how, including examples of vertical applications and services that require a significant amount of research and development. It is also important to have regular updates on progress towards targets.

This is exactly where the Verticals Cartography comes into play.

Actions to develop and implement the Verticals Cartography have taken place through the 5G PPP Technology Board (TB), with the aim of covering the phase 2 projects[10] (2017-2019/20), which are prototyping and trialling 5G technologies and components for specific 5G use cases. However, phase 2 projects are the starting line for the Cartography since the online tool is designed to easily accommodate projects funded through phase 3 and beyond. Validation of the methodology and main findings has taken place through the Trials WG.

The 5G PPP Vertical Cartography includes two tools: 1) a tracking document for analySing vertical coverage and related elements and 2) an online tool drawing on the tracking tool showing the 5G PPP phase 2 projects by **vertical**, **country** and **5G functionality** and other relevant data. The online tool will be increasingly tailored to vertical industries to ease understanding and adoption of 5G. It is also specifically designed to be easily expanded and updated, ensuring its sustainability and evolution moving forward.

Its main aims are:

- Classifying, illustrating and analysing experimental vertical use cases funded as research and innovation actions in the 5G PPP.
- Offering a harmonised high-level visualisation of all experimental activities and impacts across 5G PPP projects, including results from completed experiments. Diverse formats can also be added, such as dedicated fliers and videos (*See Section 5*).
- Highlighting the participation of stakeholders from diverse vertical sectors in the public and private sectors, as well as supply side partners and European SMEs.
- Extending Global5G.org coverage of vertical industries beyond the four sectors (automotive, energy, healthcare and industry/factories of the future) analysed in D2.1.
- Boosting stakeholder outreach across 5G verticals through collaboration between Global5G.org and the Verticals Task Force, 3GPP market representation partnerships and

[10] https://5g-ppp.eu/5g-ppp-phase-2-projects/.

key stakeholders within the 5G PPP projects. For example, building on the Verticals Workshop at EuCNC 2018, which was co-hosted with Ericsson, Samsung, Sony and Chalmers University. The workshop covered several verticals and phase 2 projects, such as to be added.

- Generating updated content for the website with close links to the Verticals Cartography as well as the forthcoming Standards Tracker in terms of coverage of 5G for vertical industries.
- Pinpointing opportunities to support cross-WG activities, outlined in the next section.

3 The EU Context

3.1 EU 5G Action Plan and National Programmes

Europe is keen to spearhead the development of 5G. To, this end, in September 2016, the European Commission launched its **European Action Plan** (5GAP). The 5GAP sets initial targets including 1) early 5G launches in selected areas in 2018; 2) commercial launches of 5G services in at least one major city in all EU member states by 2020; 3) uninterrupted coverage in all urban areas and along main transport paths in 2025. In the 5G PPP context, the AP also calls for preliminary trials from 2017 onwards, and pre-commercial trials with a clear EU cross-border dimension from 2018.

The 5GAP thus sets out the framework conditions for 5G deployment in Europe. Notably, it highlights spectrum and regulatory issues while defining initial targets for 5G deployments. At the highest level, 5G is an opportunity for policy makers to empower citizens and businesses, by playing a key role in transforming cities into smart cities delivering socio-economic benefits through an advanced, data-intensive, digital economy. Thus, smart cities are seen as important test grounds for 5G through the gradual rollout of smart city applications and services, in settings that will increasing see a myriad of vertical industry coverage.

Also stressed in the 5GAP, is the role of spectrum as a fundamental building block for launching 5G for both testing and commercial launch. The bands 3.4-3.6 GHz (band 42), 3.6-3.8 GHz (band 43), 700 MHz and 6 GHz (the upper part of the 26 GHz band) were identified for the first deployments of 5G in EU. Focusing to the bands 42 and 43, designated as pioneers and mainly supported by network and mobile equipment at the 5G launch, several significant allocations have been awarded in 2018 in Italy (3.6-3.8 GHz, 700 MHz and 26 GHz in October 2018), Finland (3.4-3.6 GHz, 3.6-3.8 GHz in October 2018), Spain (3.6-3.8 GHz in July 2018) and in UK (3.4-3.6 GHz in March 2018). With Ireland, Czechia and Latvia in 2017, 7 EU countries have now seen part of the band 42 and 43 allocated for 5G deployment. In addition to the recent bands 42 and 43 awards, 10 EU countries have already forecast auctions between end of 2018 and 2020 for 5G spectrum.
Many EU cities are already strongly engaged in 5G development, trials and pilots and first commercial deployment already demonstrated or starting in specific EU cities in 2019. For example, leading

member states include Austria, Denmark, France, Germany, Italy, Luxembourg, Malta, Poland, Spain, Sweden, Netherlands and UK with 5G roadmaps or strategy documents already in place, with many that have already received funding and up and running.

Key to successful 5G is the ability to drive coordinated rollouts of 5G compared with the staggered approaches of 4G. As highlighted in the GSMA Mobile Economy Europe 2018 report[11],

"*We expect Europe to reach 203 million 5G connections by the end of 2025, accounting for 29% of total connections in the region. The largest advanced mobile markets, such as the EU, will drive much of the take-up*". In addition, as also highlighted in this GSMA report "*more coordinated rollouts of 5G services, compared to the staggered approaches of 4G, will result in coverage and adoption levels increasing at a faster pace in Europe in the first few years after launch than with the previous technology generation*".

3.2 The 5G PPP Programme and Funded Projects

The 5G PPP is a multi-thronged, 7-year partnership leading to the introduction of 5G infrastructure and the rollout of 5G services in Europe from 2020. The Public-Private Partnership was created by a contractual agreement between the European ICT Industry, represented by the 5G-Infrastructure Association and the European Commission.

- Phase 1 (started 2015): 18 collaborative projects with most completing their work by mid-2017[12].
- Phase 2 (started 2017): 21 running projects that are contributing to prototyping, experimenting and trialling 5G technologies and components for specific 5G technologies, including use-cases with vertical stakeholders[13]. This phase is the initial focus for the Verticals Cartography, and assessed in detailed in this document.
- Phase 3 (started 2018): a multi-faceted approach to 5G testing and validation on a large scale[14].

6-9 projects funded via ICT-19 will be Vertical Pilots. Starting in June 2019, these projects will target large-scale trials and pilots, including complete end-to-end 5G systems and leveraging the test platforms. This last round of projects will start in June 2019. It is expected that other 5G test corridor projects will be launched in the context of Phase 3. In addition, the current definition of EC Connecting Europe Facility (CEF2) programme (2021-2027) includes a specific focus on 5G corridor deployments[15].

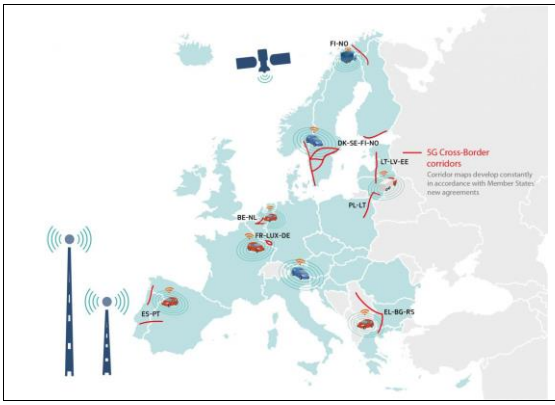
[11] https://www.gsmaintelligence.com/research/?file=884c77f3bc0a405b2d5fd356689be340&download.
[12] https://5g-ppp.eu/5g-ppp-phase-1-projects/.
[13] https://5g-ppp.eu/5g-ppp-phase-2-projects/.
[14] https://5g-ppp.eu/5g-ppp-phase-3-projects/.
[15] https://ec.europa.eu/commission/sites/beta-political/files/budget-may2018-cef-regulation-annex_en.pdf.

- **ICT-17**: End-to-end test facilities: 5G-EVE, 5GENESIS, 5G-VINNI. These pan-EU end-to-end facilities bring 20 nodes/platforms.
- **ICT-18**: Test corridor projects: 5GCARMEN, 5GCROCO, 5G-MOBIX.
- **ICT-19**: 5G!DRONES, 5GROWTH, 5G HEART, 5G SMART, 5G SOLUTIONS, 5G TOURS, 5G VICTORI, officially launched at EuCNC2019 (June). These research and innovation actions will target large-scale trials and pilots, including complete end-to-end 5G systems and leveraging the test platforms.

These phase 3 projects are the focus on the extended Verticals Cartography through an updated Blueprint and collection of inputs starting in July 2019.

It is expected that other 5G test corridor projects will be launched in the context of Phase 3. In addition, the current definition of EC Connecting Europe Facility (CEF2) programme (2021-2027) includes a specific focus on 5G corridor deployments[16].

Connected and Automated Driving (CAD) is an EU 5G flagship use case, whereby pan-EU corridors are made available to relevant stakeholders to test and validate 5G with further incentives coming from on-going and future investments. Such 5G CAD projects involve diverse stakeholders, spanning network operators, manufacturers/vendors, chipset providers, car makers and road administration. Phase 3 projects support the early test projects, with key countries and cities showed in the figure below.



EU Corridors

- Metz-Merzig-Luxembourg (FR-DE-LU).
- Rotterdam-Antwerpen-Eindhoven (NL-BE-NL).
- Porto-Vigo and Evora-Merida (PT-ES).
- Tromso-Kolari, E8 "Aurora Borealis": (NO-FI) Helsinki-Turku-Stockholm-Gothenburg-Oslo-Copenhagen Nordic Way2 (FI-SE-NO-DK).
- Innsbruck-Modena - Brenner Corridor (DE-AT-IT).
- Thessaloniki-Sofia-Belgrade (EL-BG-RS)
- Tallinn-Riga-Kaunas - Via Baltica (E67) – Lithuanian/Polish border (EE-LV-LT).
- Kaunas-Warsaw - Via Baltica (LT-PL).

Figure 1: Map and List of EU Corridors

[16] https://ec.europa.eu/commission/sites/beta-political/files/budget-may2018-cef-regulation-annex_en.pdf.

3.3 Global5G.org in the EU Context

The tools designed and developed within Global5G.org, namely the Verticals Cartography, the Standards Tracker and the Performance KPI tracker, shed light on what 5G capabilities are being rolled out and when, what contributions to standardisation are led by or involve EU players, as well as the coverage and intensity of ambitious performance indicators.

3.3.1 Working Groups and Task Forces

The tools complement the work undertaken within the 5G Infrastructure Association and the 5G EU observatory. From this respect, a key selling point for the Verticals Cartography is its relevance to many of the activities taking place within Working Groups and Task Forces coordinated at various programme levels (5G-IA, 5G PPP, NetWorld2020). The figure below shows all such working groups, except for the Verticals Task Force and the Strategic Deployment Agenda. The coloured circles show the groups that Global5G.org contributes to.

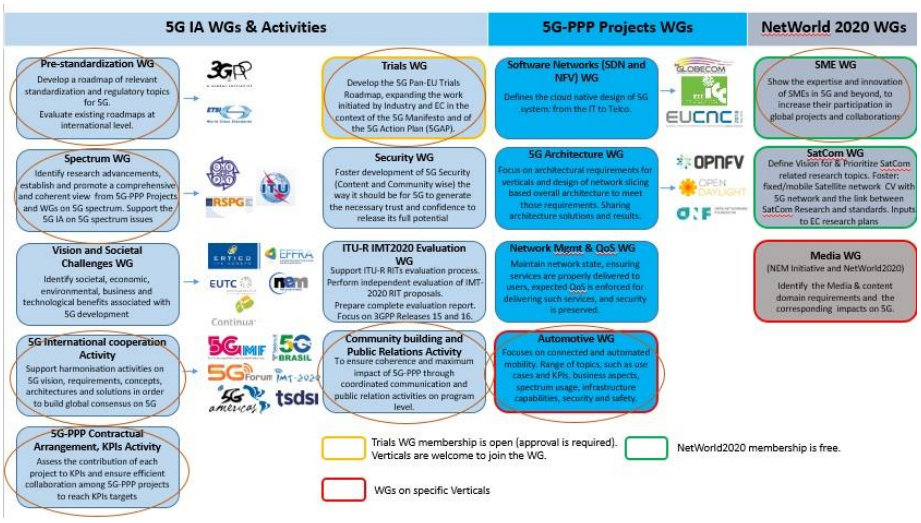


Figure 2: 5G Working Groups

We summarise below the main relevance of each group in relation to the Verticals Cartography:

- **Trials WG (5G-IA)**: contributing to future iterations of the Roadmap, including updates on the Verticals Cartography and the identification of additional vertical use cases to position the ones covered in the Verticals Cartography in terms of expected impacts, rollout, investment and business cases.

- **Pre-Standardization WG (5G-IA)**: further analyzing data collected on targeted standards organizations to develop the Global5G.org online tracker and guidelines, mostly targeting vertical industry stakeholders. A showcase of best practices within the 5G PPP is also being developed.
- **Ad-hoc Performance KPIs WG (5G-IA)**: the on-going analysis into performance KPIs across 5G technologies and applications complements the Global5G.org assessment of vertical use cases in terms of technology and market readiness levels, as well as emerging business models.
- **Automotive WG (5G PPP)**: complements the Vertical Cartography in terms of emerging business models in this vertical. Automotive is also one of the vertical markets analyzed by IDC.
- **Architecture WG (5G PPP)**: investigates and assesses 5G architectures from the perspective of phase 2 projects, building on its work in phase 1. Cross-WG activities include the collaboration between the Architecture WG and the Pre-Standardization WG on the recent white paper, entitled 5G PPP 5G Architecture White Paper Revision 3.0 (June 2019)[17]. The paper presents a consolidated European view of architecture design and inputs to relevant standardisation.
- **SMEs WG (NetWorld 2020)**: identifying results from the experiments that SMEs can pick up on, further develop and ultimately take to market. Supporting SME innovations from both a vertical and technological perspective.
- **International Cooperation Stream (5GIA)**: understanding the current impacts of EU cooperation on verticals with countries outside the EU and identifying future collaboration directions.
- **Verticals Task Force (5GIA)**: supporting synergies (e.g. memorandum of understanding) and engagement with key vertical stakeholders to create a strong connected network across vertical industries. Since the 5G-IA is a market representation partner of 3GPP, synergies can also be created through this channel to help reinforce links across the 5G PPP and vertical industries.

3.3.2 Pan-EU trials Roadmap

The Trials WG tracks progress towards 5GAP fulfilment through iterative roadmaps and other monitoring activities. Its main goals are:

- Supporting EU leadership in 5G technology, network deployment and profitable business.

[17] https://5g-ppp.eu/5g-ppp-architecture-public-consultation/.

- Confirming benefits of 5G across vertical sectors, spanning businesses, citizens and the public sector.
- Fostering a clear path towards successful and well-timed rollout.

It thus covers commercial trials and demonstrations across national initiatives, zooming in on EU cities as an excellent test ground for 5G for all citizens and businesses.

These goals are very much aligned with the work in Global5G.org in terms of:

- Showing progress towards the targets set for the 5G PPP across phases 2 and 3 through the Verticals Cartography and the on-going development of the Performance KPIs.
- Tracking engagement and involvement of vertical industries in 5G and standardisation through several activities:
    - The Verticals Task Force (5G-IA) driving engagement with verticals and collaboration through MoUs.
    - The Task Force established with the 3GPP Market Representation Partners, including 5G-IA, 5GAA, 5G-ACIA and PSCE, driving engagement and standardisation through a workshop series.
    - Networks such as LinkedIn, including both Global5G.org and 5G-ENSURE, as well as membership to several Groups on both verticals and standards.
- Contributing inputs to the road-mapping activities, such as 5G in national programmes and updates from the continuous analysis of the Verticals Cartography.

The latest version of the Roadmap significantly builds on **V3.0**, which presents the overall time plan and relevant standardisation, regulatory and ecosystems; gives an overview of private trials, including trials and pilots publicly announced in member states; makes an initial analysis of 5G for verticals developed through R&I.

Pan-EU Trials Roadmap V4.0[18] (November 2018)**.** The Roadmap highlights the key EU cities targeted for 5G early deployments, on-going/completed pre-commercial and commercial trials and pilots, 5G R&I trials and pilots, 5G R&I platforms. Several national programmes are also described, e.g. Germany, Greece, Finland, France, Italy, Netherlands, Spain and the UK, bringing additional vertical use cases for analysis. This version of the roadmap illustrates the status of the online cartography tool, detailed in Section 6.

3.3.3 EU 5G Observatory

Launched in September 2018, the EU 5G Observatory is an online platform[19] that provides independent monitoring of market rollouts and 5G trials in a global context, as well as actions taken by

[18] https://5g-ppp.eu/wp-content/uploads/2018/11/5GInfraPPP_TrialsWG_Roadmap_Version4.0.pdf.
[19] http://5gobservatory.eu/

member states and industry stakeholders on market introduction in Europe and internationally. Its primary focus is thus on developments across the EU and major international developments that could have an impact on the EU market. Tracking such activities allows for a continuous progress check in relation to the European 5G Action Plan and actions taken/needed for its full implementation.

Global5G.org engages with the 5G Observatory in several ways:

- Through the Trials WG, including the imminent launch of a new competition targeting 5G PPP phase 2 projects on their use-case experiments. The aim of the competition is to select the top ten experiments for inclusion in the 5G Observatory. iDATE and Global5G.org are both in the Evaluation Committee, helping to consolidate the collaboration moving forward.
- Through the new online Mapping Tool developed by Global5G.org (INNO with some data sources from IDC). The Tool draws on and complements the 5G Observatory, also as another mechanism to boost collaboration.

4. Blueprint development for the Verticals Cartography

4.1 Key Definitions and Clustering

4.1.2 Cartography Definition and Evolution

The term *cartography*[20] refers to the science or art of making or drawing maps. Traditional cartographic research methods imply the use of geographic maps to analyse, identify and/or predict different geographical phenomena, their interdependencies and evolution [Griffin2017]. However, these approaches of 'mapping' phenomena, activities or other entities have been widely adopted beyond conventional geographical sciences, such as risk analysis[21], curriculum development[22] and financial modelling[23], among others.

In the context of the Verticals Cartography, it was decided to have the vertical clustering as the key focus, also as an easy and effective way for the vertical industries themselves to find sectors of interest to them. The other chosen search items selected are: the locations of the use-case experiments by country and the targeted ITU functionalities.

The design of the online tool stems from the collaborative development of a Blueprint via the TB and thereafter the Trials WG to validate the approach and collect inputs from phase 2 projects. The blueprint focused on mapping the use case experiments across diverse vertical clusters to analyse

[20] https://dictionary.cambridge.org/dictionary/english/cartography.
[21] https://www.forensic-architecture.org/file/cartography-of-risk/.
[22] https://www.slideshare.net/charbooth/strategic-cartography-identifying-il-intersections-across-the-curriculum.
[23] https://www.jbs.cam.ac.uk/fileadmin/user_upload/research/centres/risk/downloads/2015risksummit-

major trends and expected maturity levels within 5G PPP phase 2 projects. The blueprint therefore includes columns on key data collection points to ensure ease of use by projects giving information, clarifications and updates. These data points have evolved during the development of the blueprint, including synchronisation on vertical clustering with new clustering also added to cover multiple vertical scenarios.

4.1.1 Vertical Clustering

The classification or clustering of vertical industries has been harmonised at the 5G PPP programme level to overcome inconsistencies across projects, working groups, and task forces. The clustering adopted in the Verticals Cartography is based on this harmonised approach, which is derived from the 5G PPP Phase 3 Pre-Structuring Model.

These clusters are illustrated in the figure below.

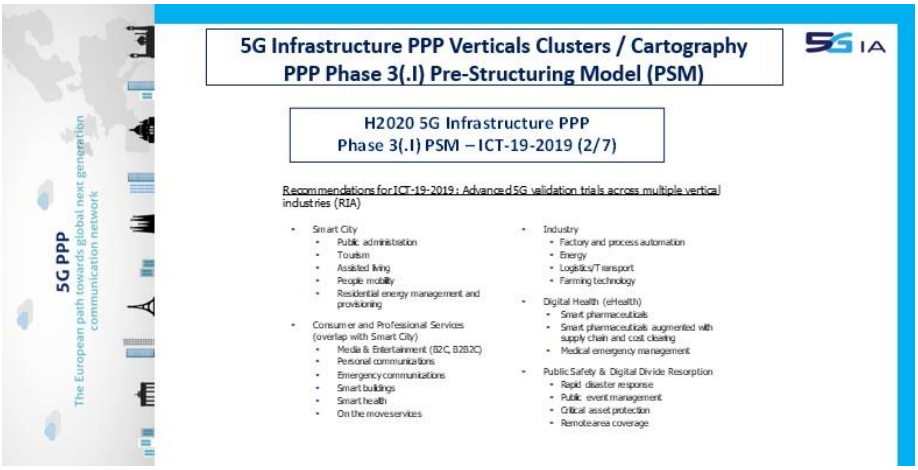


Figure 3: PSM Vertical Clusters

It is important to note that the clustering in the figure is an excellent instrument for a harmonised approach on the one hand. However, on the other hand, it does not cater for multiple vertical scenarios as not all the use-case experiments fit neatly into the categories. Rather new 5G technological advances target scenarios in dense urban areas while others cut across several verticals, including use cases targeting underserved areas.

Thus, a second analysis was performed drawing on discussions and inputs for the Golden Nuggets 2019 through the TB and the Annual Report 2019, as well as interactions with the TSG Chairs of 3GPP as part of the Task Force on standards and verticals. The analysis brings to light several cases that

risktesting-slides-soramaki.pdf.

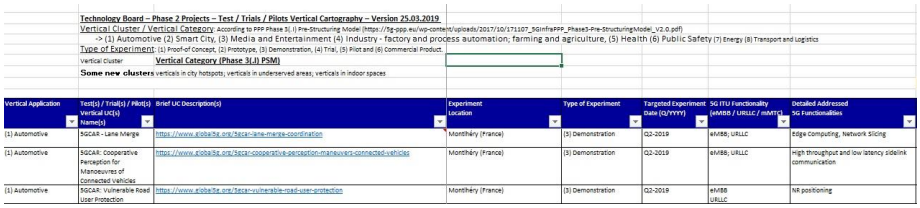
target multiple verticals, as discussed in detail below, including relevant standardisation activities (e.g. for asset tracking). As 5G continues to evolve, it may well be that other use cases with multi-verticals are targeted.
The sections that follow track the development of the Blueprint, its structure and the processes used to collect and update the online tool.

4.1.3 Blueprint Snapshot

The blueprint is structured to collect specific data points on the use-case experiments. These include:

- Project (in alphabetical order).
- Project name + use-case experiment title.
- Overview of the use case.
- Location (city + country): helping to map locations across EU countries.
- Expected dates, expressed as Q1/2/3/4-YEAR, with more testing dates also expected in 2019: knowing when an experiment is taking place and further mapping across targeted functionalities and experiment types.
- The involvement of vertical partners. Ideally, end-user organizations will be involved in the experiments, e.g. port authorities for transport and logistics, city councils for smart cities, car manufacturers for automotive. This element therefore helps to map the level of verticals directly involved, while analyzing cases with no vertical partners to see if any major differences exist. Their involvement in standardization is also being tracked in the 5GIA Pre-Standardization WG.
    - References to the same organisation vary considerably in the early versions of the Blueprint. However, updates have made these references consistent on the online tool.
    - Country references were also inconsistent in the early version. These have also been harmonised with the online tool using the full country name.
- The involvement of other partners: offering insights into the type of know-how needed for specific types of experiments, e.g. network infrastructure, software, measurement tools etc., as well as other support and/or contributions, e.g. from early design to final validation.
- The targeted standards organisations for verification and analysis in the 5GIA Pre-Standardization WG.

The Blueprint collects data on 63 use-case experiments, all of which feature on the online tool. The image below shows a snapshot of the Blueprint and its entry points. Checklists have been added to show when updates occur, whether directly by Global5G.org or from the projects.



Technology Board – Phase 2 Projects – Test / Trials / Pilots Vertical Cartography – Version 25.03.2019

Vertical Cluster / Vertical Category: According to PPP Phase 3(i) Pre-Structuring Model (https://5g-ppp.eu/wp-content/uploads/2017/10/171107_5GInfraPPP_Phase3-Pre-StructuringModel_V2.0.pdf)
-> (1) Automotive (2) Smart City, (3) Media and Entertainment (4) Industry - factory and process automation; farming and agriculture, (5) Health (6) Public Safety (7) Energy (8) Transport and Logistics

Type of Experiment: (1) Proof-of-Concept, (2) Prototype, (3) Demonstration, (4) Trial, (5) Pilot and (6) Commercial Product

Vertical Cluster | Vertical Category (Phase 3(J) PSM)

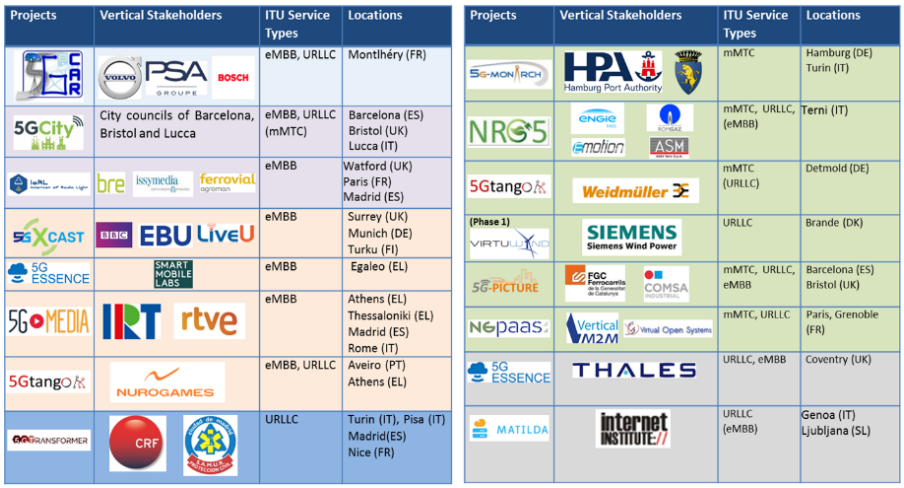
Some new clusters verticals in city hotspots, verticals in underserved areas, verticals in indoor spaces

Vertical Application	Test(s) / Trial(s) / Pilot(s) Vertical UC(s) Name(s)	Brief UC Description(s)	Experiment Location	Type of Experiment	Targeted Experiment Date (Q/YYYY)	5G ITU Functionality (eMBB / URLLC / mMTC)	Detailed Addressed 5G Functionalities
(1) Automotive	5GCAR - Lane Merge	https://www.globalsg.org/5gcar-lane-merge-coordination	Montlhéry (France)	(3) Demonstration	Q2-2019	eMBB; URLLC	Edge Computing, Network Slicing
(1) Automotive	5GCAR: Cooperative Perception for Manoeuvres of Connected Vehicles	https://www.globalsg.org/5gcar-cooperative-perception-manoeuvers-connected-vehicles	Montlhéry (France)	(3) Demonstration	Q2-2019	eMBB; URLLC	High throughput and low latency sidelink communication
(1) Automotive	5GCAR: Vulnerable Road User Protection	https://www.globalsg.org/5gcar-vulnerable-road-user-protection	Montlhéry (France)	(3) Demonstration	Q2-2019	eMBB URLLC	NR positioning

Figure 4: Snapshot of the Blueprint

4.1.4 Evolution from Pan-EU Trials Roadmap V3.0

The Blueprint marks a clear evolution from version 3.0 of the Pan-EU Trials Roadmap in terms of grouping and categorising a core set of elements for the portfolio analysis. The figure below shows a first grouping of elements related to projects, vertical stakeholders, targeted 5G functionalities and locations for the experiments featuring in the Roadmap V3.0.



Projects	Vertical Stakeholders	ITU Service Types	Locations
5G CAR	VOLVO PSA GROUPE BOSCH	eMBB, URLLC	Montlhéry (FR)
5GCity	City councils of Barcelona, Bristol and Lucca	eMBB, URLLC (mMTC)	Barcelona (ES) Bristol (UK) Lucca (IT)
	bre issymedia ferrovial agroman	eMBB	Watford (UK) Paris (FR) Madrid (ES)
5GXCAST	BBC EBU LiveU	eMBB	Surrey (UK) Munich (DE) Turku (FI)
5G ESSENCE	SMART MOBILE LABS	eMBB	Egaleo (EL)
5GMEDIA	IRT rtve	eMBB	Athens (EL) Thessaloniki (EL) Madrid (ES) Rome (IT)
5GtangoK	NUROGAMES	eMBB, URLLC	Aveiro (PT) Athens (EL)
5GTRANSFORMER	CRF	URLLC	Turin (IT), Pisa (IT) Madrid(ES) Nice (FR)

Projects	Vertical Stakeholders	ITU Service Types	Locations
5G-MONARCH	HPA Hamburg Port Authority	mMTC	Hamburg (DE) Turin (IT)
NRG5	ENGIE EMOTION ACCIONA ASM	mMTC, URLLC, (eMBB)	Terni (IT)
5GtangoK	Weidmüller	mMTC (URLLC)	Detmold (DE)
(Phase 1) VIRTUWIND	SIEMENS Siemens Wind Power	URLLC	Brande (DK)
5G-PICTURE	FGC Ferrocarrils de la Generalitat de Catalunya COMSA	mMTC, URLLC, eMBB	Barcelona (ES) Bristol (UK)
NEPAAS	Vertical M2M Virtual Open Systems	mMTC, URLLC	Paris, Grenoble (FR)
5G ESSENCE	THALES	URLLC, eMBB	Coventry (UK)
MATILDA	internet INSTITUTE	URLLC (eMBB)	Genoa (IT) Ljubljana (SL)

Figure 5: Pan-EU Trials Roadmap V3.0 - Initial classifications

4.2 Data Collection and Harmonization

4.2.1 Collecting data on core elements

The blueprint spreadsheet allows each project in Phase 2 to give data and updates on the core elements through participation in the Technology Board. This approach is an improvement on the earlier approach of collecting data through a simple word document as it allows filtering of the

elements for the Portfolio Analysis along with a check-list column to note requests for information and updated information received, ensuring more efficient data handling collected data grew in terms of both type and quantity. This approach also allows the harmonization of data, e.g. country references and partner names.

The blueprint spreadsheet thus eases the iterative process needed to keep up to speed on project developments, data refinement and error checks before using the data in the analysis of the cartography.

Updates can now also be done through the online tool, including videos, communications and dissemination material while using the spreadsheet to update the portfolio analysis. Periodic requests for updates are made and noted in the check list.

The figure below shows the overall workflow for gathering, correcting and updating the data as the basis for further analysis and multi-dimensional representations of the use case experiments. This workflow therefore remains valid for on-going updates of the Cartography in terms of the analysis on key parameters and also for updating and enriching the online tool and analysis.

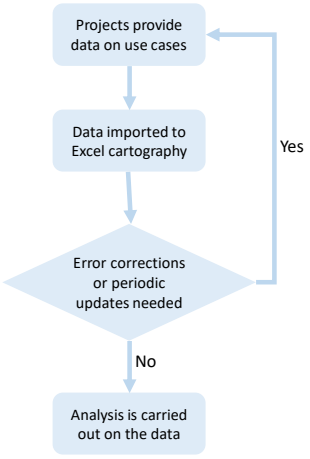


Figure 6: Workflow for data gathering

4.2.2 Experiments and Maturity Levels

Validation of the use cases is grouped into “experiments” showing various levels of maturity as specified within the 5G PPP. The six categories of experiments range from proof of concept (least mature) to commercial products (most mature). The table below defines each the six categories.

Type of Experiment	Description

Type of Experiment	Description
1. Proof-of-Concept (PoC)	Lowest level of maturity where a "theoretical" concept is implemented to prove that a concept has merits.
2. Prototype	Second level where the proved concept is an embedded functionality in a component or system.
3. Demonstration	Level where a system is complete from a certain perspective and can showcase a scenario or use case.
4. Trial	The fourth level consists in conducting tests outside the lab to verify the functionality of a system or parts of it, that is, when correct functioning is the primary interest.
5. Pilot	The fifth level involves conducting a trial that also exemplifies an added value for the end user of a product or service based on underlying business assumptions.
6. Commercial Product	Commercial system or technology available for consumers.

Table 3: Experiments and Maturity Levels

Commentato [A1]: Compare with the roadmap.

The Verticals Cartography maps each experiment to one type of experiment at any given time. If the experiment evolves over time to a higher level, it will be mapped according to this new maturity level, for example, an experiment may be a prototype in Q4-2018 but a demonstrator in Q3-2019.

For analytical purposes, lab-based experiments are grouped 1-3 as they take place in a tightly controlled environment while this is not usually the case for more mature experiments, which are grouped types 4-5 (and 6).

In the Phase 2 projects there are no examples of commercial products though the Trials WG is looking at these kinds of experiments using a distinct set of categories for 5G testing. The Pan-EU Trials Roadmap V4.0 defines the following classifications for technological trials: FUT level (Friendly User Trial), FUT level cities, and 5G cities pre-deployment, describing typical size, end-user type and estimated timeline (e.g. early 2017 to mid-2019/2020). Such a classification is helpful for assessing vertical use cases beyond the 5G PPP, including 5G standard-compliant trials, where EU industry occupies a forefront position with an aggregated presence of 51% globally.

Other elements that can be tracked for assessing maturity levels include:

- The contractual nature of trials or pilots.
- Involvement of partners and number.
- Number of deployed radio sites, where the growing number of sites reflects the closeness to commercial deployments.
- Involvement of real customers or not. A full-scale test with real customers shows good technology maturity and confidence in the solution.

Several steps have already been taken in the 5G-IA Ad-Hoc WG on Performance KPIs, under Global5G.org WP4.

- Comparison of maturity levels in the Cartography with the coverage of the programme-level performance KPIs.
    - A first analysis has been performed through the Ad-hoc Performance WG, looking at both KPI coverage and intensity across each phase 2 project, drawing on the Blueprint developed by this WG.
    - The WG has also produced a comprehensive analysis of each KPI, along with definitions and methodology used, as well as an in-depth look at 5G capabilities like latency. This can be used in the future steps.

Future Steps

- Update and validate the first analysis.
- Develop an online tracker for the Performance KPIs along the lines of the Verticals Cartography.

4.2.3 Comparison between Blueprint and Online Tool

The table below shows the evolution of the blueprint spreadsheet in relation to the online tool of the Verticals Cartography.

Data Point	Data Collection
Vertical Application	In the **blueprint**, this column is based on the synchronized approach used within the 5G IA Trials WG, with 8 vertical clusters now covered in phase 2 projects. In the **online tool**, the vertical clusters are the first-choice users can click on based on their own specific interests.
Project name (acronym) + title of the experiment	For the sake of convenience, only the project acronym is used in the **blueprint** alongside the title of the use case being tested, e.g. **5GCAR – Lane Merge**. **Online tool**: Based on the search items, a specific project appears with its logo alongside the vertical icon and experiment title. In the case of 5G-CAR, the logo appears with the automotive icon. This helps to ensure the cartography is focused on verticals rather than project based.
Brief Description	Each description in the **blueprint** zooms in on the focus of the tested use case, with an overview of its aims (1-2 paragraphs). Hence, the **5GCAR – Lane Merge** outlines how it is dealing with the automated creation of gaps for cars entering a lane, using cellular communication and a centralized lane merge manoeuvre planning. The same text is used in the **online tool** with some editorial

	improvements being made to ensure descriptions have a similar length and layout. Updates and further improvements are part of the on-going enhancement of the tool.
Location of the experiment	The **blueprint** notes the location for the experiment: city/town. The same information is included in the **online tool**, as the second choice for selecting vertical trials. In the case of **5GCAR – Lane Merge** the location is Montlhéry (France). Much work has been done to confirm locations and harmonise country references.
Type of experiment	The **blueprint** shows the type of experiment planned based on the following categories: proof of concept (PoC), Prototype, Demonstrator, Trial, Pilot. The same information is given in the **online tool** as part of the description. The new template allows phase 2 projects to include additional information about the experiment, e.g. results obtained after testing.
Targeted experiment date (Q-YEAR)	The **blueprint** shows the targeted date. Hence Q2 – 2019 refers to April to June 2019, which is the case for **5GCAR – Lane Merge**. The same information is given on the **online tool** as part of the description. More updates will be requested from projects to check for additional tests planned during phase 2 projects.
5G ITU Functionality (eMBB / URLLC / mMTC)	The **blueprint** tracks the targeted functionality for each experiment. In the **online tool**, this is the fourth selection choice with the information given as part of the overall description. A general definition of the functionalities is also included as part of the updates.
Detailed Addressed 5G Functionalities	This section of the blueprint gives projects the opportunity to expand on the targeted functionalities. In the case of **5GCAR – Lane Merge**, the project highlights edge computing and network slicing. The same information is also provided in the online tool, as part of the overview of targeted functionalities.
Potential Addressed Standards Body/Group	The **Blueprint** was useful in collecting initial information about targeted standardization work within the phase 2 projects.

	This information is not included in the online tool as it is subject to on-going analysis for the 5G-IA Pre-standardization WG for the development of the **Standards Tracker**.
Vertical Partners involved	The **blueprint** collects data about which vertical partners are involved. The same information is given in the **online tool** with additional effort spent in harmonising partner references.
Other partners involved	The blueprint collects data that is not always consistent. Global5G.org has assessed each experiment and **harmonised references to partner organisations** in the online tool. All partners are now listed along with the company-type abbreviations.
Further harmonisation and Updates	The first column of the **blueprint** is a check list for tracking requests for clarifications/updated information. It includes the date of the request and the date for the implemented updates. A new template has been created to gather updates from the projects.

Table 4: Cartography Blueprint Data and Inputs for the Online Tool

The new template for collecting updates is aimed at 1) updating the current entry and 2) extending information on concrete benefits for end-users targeted.

- **Benefits for the targeted vertical industry/ies**: perspectives from end-user partners (if applicable). This can be in the form of a quote or short text on how they see the benefits of collaboration on the road to 5G.
- **5G capabilities and functionalities**: some of the most important advances achieved by the project.
- **About [Project X] use-case experiment**: results obtained from testing already performed.

Examples of updated entries are 5GCAR[24] and 5G-MoNArch[25].

5. Portfolio Analysis

5.1 Methodology and Rationale

While portfolio analysis in strategic management depends on the area and purpose, in research programmes it is usually a means for assessing the contributions and complementarities of projects

[24] https://www.global5g.org/5gcar-vulnerable-road-user-protection.
[25] https://www.global5g.org/5g-monarch-5g-smart-sea-port.

towards achieving a common goal [Landree2009], like the 5G PPP programme. The Portfolio Analysis uses a custom methodology to analyze the various elements in the blueprint spreadsheet for multiple perspectives on the 5G PPP Verticals Cartography, considering:

- The specific nature of the 5G PPP programme and collaborations within and across it.
- The possible segmentation of use case experimentation activities (e.g. by vertical cluster).
- The use of the Verticals Cartography as primary input for the analysis.

The figure below shows the overall workflow for the portfolio analysis.

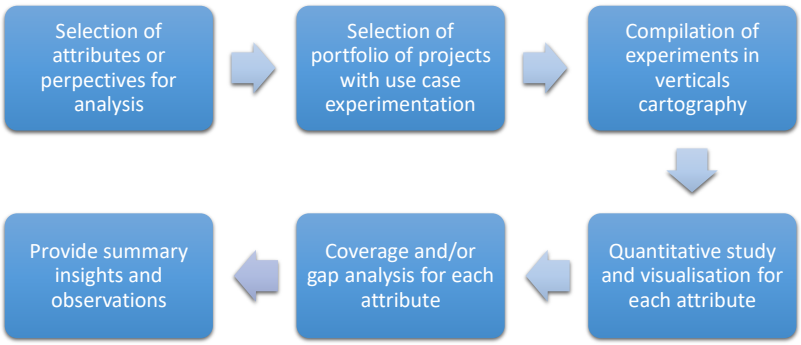


Figure 7: Portfolio Analysis Workflow

Step 1: selecting the attributes or perspectives for inclusion in the analysis, such as the vertical cluster, 5G ITU functionality, location, expected timelines, etc. Each of these perspectives is further disaggregated by vertical clusters and experiment category (aka maturity level). For the sake of simplicity, the experiments are divided into two broad categories:

- Use-case experiments carried out in controlled or lab-based environments, that is, prototypes, PoCs and demonstrations, corresponding to maturity levels 1 to 3.
- Use-case experiments carried out outside the lab environment with no control over certain environmental conditions, that is, trials and pilots, corresponding to maturity levels 4 and 5. This category is of interest as it marks the first interaction with targeted customers while giving insights into how customers may derive value.

As such, the portfolio analysis gives Global5G.org first insights into expected technology and market readiness levels that are investigated under work package 4, along with emerging business models and performance KPIs as defined within the Ad-hoc 5GIA WG.

5.1.1 Research and Innovation Radar for Phase 2 Projects

Before embarking on the analysis of the Vertical Cartography, it is useful to assess the phase 2 projects in terms of their technology focus area(s). This is done through a concise research and technology radar, that draws on the Golden Nuggets, which are tracked through the Technology Board. Specifically, these "Golden Nuggets" (last update in February 2019) define 14 macro groups to cluster the achievements of the phase 2 projects. These 14 groups are:

- **GN1**: 5G Performance Evaluation Framework.
- **GN2**: 5G System, Functional, Logical and Physical Architectures.
- **GN3**: 5G Flexible RAN.
- **GN4**: Novel 5G Radio Systems and Air Interface.
- **GN5**: Technology Enablers for 5G RAN Platforms (HW & SW).
- **GN6**: 5G Fronthaul, Backhaul and Metrohaul.
- **GN7**: 5G Autonomous Network Control and Management.
- **GN8**: 5G Multi-Domains Multi-Tenants Plug & Play Control Plane and Slicing Control.
- **GN9**: 5G Flexible and Agile Service Deployment.
- **GN10**: E2E Orchestration across Optical, Packet, Wireless Virtualized Networks.
- **GN11**: 5G Resilience and Availability.
- **GN12**: 5G Services Platforms and Programming Tools for NetApps.
- **GN13**: 5G Verticals Experimentation, Trials and Pilots.
- **GN14**: 5G Business, Standardization and Regulation.

The tables below map achievements with the vertical use-case experiments along the funding lifecycles, e.g. projects ending in 2019 or 2020, helping to pinpoint technological advances in relation to the rollout phases, showing what types of capabilities will be available, when and for whom in the analysis reported in Section 5. The radar offers a useful basis for verifying progress towards technical goals and targets also for the Standards Tracker and the Performance KPI Tracker, adapting it the specific focus of each tool.

Project	R&I Radar	Use-case experiments and Impacts
5GCAR	5G V2X evaluation framework & Business case calculations for each use case (GN1) 5G V2X system & network architecture (GN2) Technical components for 5G V2X radio links (GN4)	**Vertical cluster**: Automotive • Lane Merge • Cooperative perception manoeuvres of connected vehicles • Protection of vulnerable road users **End date**: May 2019 5G radio access network concepts integrated into overall 5G RAN framework
5G MoNArch	Resource elasticity for flexible RAN, scaling resources to demand and gracefully scaling network operations in cases of insufficient resources (GN3)	**Vertical clusters**: Transport & Logistics; Smart Cities • 5G Smart Sea Port • 5G Touristic City **End date**: June 2019

	Cloud-aware protocol stack with flexibility for specific service requirements (e.g. via node switching) (GN5) 5G telco-cloud resilience and RAN reliability, meeting requirements of resilient slices (GN11)	Very high potential commercial impact, including enhanced products (orchestrators, edge-cloud RAN), novel services (enabled by network slicing), and opportunities for new market players.
5G-Xcast	Content delivery network evaluation for multicast and broadcast in 5G: internal network optimization technology is the best way to exploit multicast and broadcast for linear content. Flexible approach is driven by content popularity (GN2) Implemented the design of a comprehensive and holistic 5G Point to multi-point RAN solution. Supporting both PTM and PTP (point-to-point) transmissions and PTM services with diverse requirements.	**Vertical clusters:** media and entertainment; public safety; 5G spectrum bands • Object-oriented broadcasting • Hybrid broadcast services • Public warning system • 5G spectrum bands **End date**: May 2019 5G-Xcast aims to overcome limitations in existing networks (fixed, mobile, broadcast) key for meeting future demand by leveraging advanced 5G capabilities. Ensure optimized and seamless media user experience. 5G-Xcast is also evaluating 5G spectrum allocation for 5G broadcast network deployments.
NGPaaS	5G platform-based built-to-order design: customising different platforms as a service to meet needs of services supported (GN3) Carrier-grade orchestration and accelerated microservices: new features implemented to overcome shortcomings, with telco-grade enhancements for data plane, intensive telco workloads/VNFs, a.o. (GN5) Dev-for-operations model: improving DevOps paradigm used in IT industries, enabling use of similar approach in a telco-grade environment (GN9)	**Vertical clusters**: energy; public safety • IoT4Energy • Mission-critical push to talk **End date**: May 2019 NGPaaS advances revolve around achieving maximum flexibility while meeting business and technical requirements for diverse 5G use cases, which will demonstrate a sub-set of features like telco-grade Kubernetes, monitoring as a service and new OSS design. NGPaaS adopts cloud-native principles based on service-oriented architecture and new modelling approach based on reusable function block to abstract, decompose and deploy the different PaaSes. NGPaaS aims to enable interaction of many players in a multi-organizational context (e.g. FOSS, 3rd parties, verticals, vendors, operators).
ONE5G	Advanced frameworks for validating and optimising 5G components: system-level	**Vertical clusters:** Industry – factory and automation processes (large industrial areas); smart cities with multiple verticals; media and

	simulations evaluate capacities and benefits. Integration into PoCs confirms performance. Cost evaluation via a techno-economic analysis of the use cases (GN1) E2E-aware performance optimization via advanced management of radio resources and multi-link/multi-node connectivity: developing RAN-based techniques to optimize E2E characteristics via KQIs and context awareness, thus dealing with performance also from a quality of experience (QoE) perspective (GN3)	entertainment; industry – farming and agriculture; automotive • Proof of concept for industrial areas with large factories • Smart Megacity Proof of Concept • Enhanced massive MIMO proof of concept • Underserved areas proof of concept • Automotive proof of concept **End date**: May 2019 ONE5G is investigating and designing technical components covering a variety of deployment types, services and verticals, from very dense and crowded urban environments to remote and scarcely populated areas, use cases, KQIs and KPIs.

Table 5: 5G PPP Projects Ending Q2-2019

The table below shows the projects ending in Q4-2019.

Project	R&I Radar	Use-case experiments and Impacts
5GCity	5GCity NFV orchestration platform for neutral host model (GN8). Allowing city infrastructure owners to manage core, edge, and far-edge network infrastructure to host any entity offering 5G services to end-users. Edge virtualization platform– RAN resource manager (GN9) Software development kit for 3rd-party vertical industries.	**Vertical clusters**: Smart cities; Media & Entertainment (e.g. outdoor live events) • Unauthorised waste dumping prevention • Video acquisition & production with community engagement at live events • UHD video distribution & immersive services • Mobile backpack unit for real-time transmission **End date**: November 2019 Open environment for creating network apps and repository for 3rd-party developers
5G ESSENCE	Automated slice creation in the edge cloud as a critical enabler for responsive, elastic & ultra-reliable edge computing implementation of 5G RAN (GN7) Unikernel-based VNF deployment framework aimed at reducing deployment time and VM footprint (GN9) Next-generation inflight entertainment communications	**Vertical clusters**: Media & Entertainment (sports venues; aircrafts); Public safety • 5G Edge network acceleration for a stadium • Mission-critical applications for public safety • Next-gen integrated in-flight connectivity & entertainment systems **End date**: November 2019 Innovations in network softwarization, virtualization, cognitive network management;

	where the aircraft becomes a self-contained 5G network edge (GN13)	flexible and scalable platform to create a neutral host market with new opportunities for ownership, deployment, operation and amortization.
5G MEDIA	Service virtualization platform (SVP) aimed at optimising media services in terms of latency and throughput (GN10) Service development kit, enabling application developers to finetune functionalities before use in production environment (GN12) 5G Application and Service Catalogue supporting the 3 use cases (GN12)	**Vertical cluster**: Media and entertainment • Immersive applications and Virtual Reality • Remote and smart production in broadcasting • Dynamic and flexible UHD over 5G CDNs **End date**: November 2019 Open innovation: platform for 3rd parties to develop, combine, verify, deploy and validate media apps using SDK and service platform.
5G PICTURE	Providing more efficient support to demanding requirements of transport in converged fronthaul and backhaul environments (GN6) Using 5G operating system to abstract complexities in the underlying 5G infrastructure, offering common functionalities required for efficient and flexible service and slice management and orchestration (GN10) Use-case experiments form part of an open 5G infrastructure capable of instantiating and co-hosting diverse vertical sectors (GN13)	**Vertical clusters**: smart cities (new city services; media services in stadium); transport and logistics (rail) • 5G city testbed • 5G-railway testbed • 5G-stadium testbed 5G PICTURE aims at reducing significant installation, operational and administrative costs of services with very high bandwidth and low latency requirements currently supported through multiple application-specific platforms. Using the DA-RAN concept to form any service under a common programmable open infrastructure with significant performance cost and energy efficiency benefits expected.
5GTANGO	Providing a service platform that is highly modular and that supports multiple providers and infrastructures (GN9) Supporting and automating functional and performance testing, validation and verification of VNFs and entire network services (GN11) Easing the life of developers of	**Vertical clusters**: industry – factory and process automation; media and entertainment • Smart manufacturing • Immersive Media • Communications Suite **End date**: November 2019 5GTANGO showcases aim to illustrate added value of service programmability, service validation and orchestration. 5GTANGO service platform with its modular orchestration

	network functions, descriptors and tests with lightweight tools that can be used on their own or together (GN12)	framework is aimed at alleviating pain points for communication service providers related to NFV transition. The Store for Verification and Validation expertise (V&V store) is designed as an experimental innovation environment enabling collaboration across verticals to enrich service portfolios.
5G-Transformer	Mobile transport and computing platform: managing the underlying infrastructure of 5G integrated transport networks (GN6). Service orchestrator: an end-to-end platform for service and resource orchestration in single and multi-domain 5G virtualised networks (GN10) Vertical slicer: serving as the vertical front-end and common entry point for all verticals (GN12)	**Vertical clusters:** Industry – factory and process automation; health; public safety; automotive; media and entertainment • Cloud robotics for industrial automation • Emergency health service • Emergency services • Intersection collision avoidance • Live streaming **End date**: November 2019 5G-Transformer is developing an SDN/NFV based mobile transport and computing platform (MTP), bringing network slicing into mobile transport networks. The twofold aim is to enable vertical industries to meet service requirements; aggregate and federate the transport networking and computing fabric, from the edge all the way to the core and cloud.
MATILDA	Networking and computing slice deployment platform: supporting the creation and management of end-to-end network slices for hosting vertical application needs (GN9) Vertical application slicer: providing a set of intelligent orchestration mechanisms and interfaces for interaction with northbound APIs from communication service providers via their OSS/BSS systems (GN10) Development kit for 5g-ready applications: implementing tools to design and deploy 5G-ready applications based on cloud-native/microservice development principles (GN12)	Vertical Clusters: public safety; media & entertainment; smart cities (lighting systems); automotive; industry – factories and process automation • 5G emergency infrastructure & service orchestration with SLA reinforcement • High-resolution media on demand • Smart city intelligent lighting • Remote control and monitoring of automobile electrical systems • Industry 4.0 Smart Factory **End date:** November 2019 MATILDA is aimed at enabling the shift towards stronger integration of cloud and multi-access edge computing environments via interfaces for multi-site management of cloud/edge and IoT resources, supported by a multi-site virtualized infrastructure manager.

NRG-5	MAPE-K (hierarchical monitoring analysis planning and acting) with optimization in loop: meeting stringent requirements in terms of quality, latency, reliability, availability, resiliency, operation cost and efficiency (GN7) Extended MANO with multi-domain capabilities and application-specific components and functions: integration and interoperability with 5G PPP reference architecture (GN10) MEC extensions, including VNFs for smart energy services: aimed at meeting smart energy as a service requirements (GN13)	**Vertical Clusters:** Energy • Decentralised, trusted lock-in-free Plug & Play • Aerial predictive maintenance for utility infrastructures • Resilience and high availability in dispatchable demand response **End date**: November 2019 NRG-5 will help transform the energy landscape into an open, multi-owned, decentralized ecosystem by overcoming considerable functional and non-functional challenges. NRG-5 thus aims to bring value add to the energy sector, where automatic and prompt mechanisms are mandatory for dealing with critical resources and services.
SAT5G	Integration of satellite in the 5G system: Demonstration of indirect mixed 3GPP NTN access architecture option to showcase efficient edge content delivery (EuCNC 2018). Further validations with 5G testbed are planned, including integration of orchestration and satellite service provider OSS and integration with 5G NR (GN2) Two technical reports approved within 3GPP, laying the foundations for seamless integration of satellite in 5G. New study items in 3GPP SA2, RAN 1/2/3 and work item in SA1 paving way to accomplish the specification of enablers for seamless integration of satellite in 5G. Four satellite use cases for 5G eMBB defined and adopted in ITU and 3GPP contexts. (GN14)	**Vertical clusters:** media and entertainment; verticals in underserved areas; transport and logistics. • Edge delivery & offload via satellite multicast • 5G cellular backhauling in rural areas • 5G in homes and offices in rural areas • 5G on board commercial airplanes • 5G NR over satellite link **End date:** November 2019 SAT5G is developing enablers for a converged 5G-satcom virtual and physical resource orchestration and service management. Development of link aggregation scheme for small cell connectivity mitigating QoS and latency imbalance between satellite and cellular access. SAT5G has analyzed architecture in several technical reports (e.g. ETSI, SES). It has also produced draft business models with benefits of broker role between MNOs and satellite network operators, including initial calculations showing viable ARPU.

Table 6: Phase 2 Projects ending Q4-2019

The last table on phase 2 covers those projects ending in Q2 and Q3-2020.

Project	R&I Radar	Use-case experiments and Impacts
5G-PHOS	New fronthaul architecture (C-RAN) to increase scalability, manageability, and flexibility of mobile systems (fibre and wireless), supporting ultra-high bandwidth in the V-region, ultra low latency and dense coverage (GN2) Flexible scaling of network resources according to traffic demand so telecom operators and network owners can exploit novel services, applications and markets (GN3) Innovative analogue optical transceivers, overcoming limitations of current spectrally inefficient and technology-limited digital techniques (GN5)	**Vertical cluster**: smart cities • Hot-spot city Area • Ultra-dense city area **End date**: August 2020 Shaping new network concepts validated via the use-case experiments (lab and field trials) and turning them into tangible market outcomes. Use cases are tailored to serve 5G network requirements in terms of performance, business models and economic viability. Cost-effective, energy-efficient 5G network solutions for high-density use cases. 5G-PHOS is capitalising on novelties in InP transceivers, Triplex optical beamformers and multi-bitrate optical communications for migration to integrated Fibre-Wireless packetized C-RAN fronthaul supporting mmWave massive MIMO communications.
Bluespace	Space division multiplexing in RAN: applications with ultra-large capacity needs and resource allocation and network optimisation for a combined wavelength and spatially multiplexed RAN (GN2) ARoF fronthaul and optical beamforming: using ARoF fronthaul transceivers to optimize optical bandwidth usage and maximize centralization of signal processing functions (GN5) NFV service platform and orchestrator for network slices and NFV network services across computing and networking domains, exploiting the mix of advanced capabilities provided by MEC resources and SDM/WDM optical fronthaul networks in 5G infrastructures (GN7)	Vertical clusters: smart cities - crowded and indoor spaces • Broadband access in crowded spaces • Indoor ultra-high broadband access • Co-existence with PON **End date**: May 2020 Bluespace combines three technology enablers (ARoF, SDN and optical beamforming). By doing so, it will show a viable alternative for ultra-high capacity, densely deployed mmWave RANs seamlessly supporting multi-beam transmission. Bluespace will enable the provisioning of network slices customized to service requests from verticals, delivering eMBB, mMTC OR URLLC slices that share the network infrastructure controlled via SDN technologies. Optical beamforming maximizes the available RF bandwidth and allows multi-beam transmission from a single antenna with narrow beams, minimizing interference and increasing potential frequency reuse.
IoRL	5G building network architecture: updates to the IoRL architecture are on-going based on practical	**Vertical clusters**: verticals in indoor spaces. Only services for domestic settings feature in the Cartography R1.0. Others to be integrated include

	experiences from the integration process. Architecture features include: multi-component VLC; mmWave 5G compatible transmission system (GN4) 5G Building network: demonstrating broadband services in the home via iterative integration steps and testing (GN12)	public spaces (e.g. museums, shopping malls and metro stations). • Video streaming • Video communications and location-based services **End date**: May 2020 IoRL aims to overcome limitations of current wireless networks in buildings, such as congestion, interference, security and safety concerns, restricted propagation and poor indoor location accuracy, thereby unleashing incentives for building construction companies and landlords.
Metro-Haul	High-capacity and metro-optical network with edge computing: providing a dynamic data plane with intelligent control plane involving multiple network segments and layers, spanning multiple datacentre geographic locations and tackling resource heterogeneity for optical transport (GN6) Real-time performance monitoring and analytics: real-time view of network performance, improving service configuration, ensuring reliable operations and enabling pro-active detection of issues (GN7) Open multi-layer disaggregated network: model-driven development for the SDN control of multi-layered disaggregated and open transport networks (GN10)	**Vertical clusters**: Media & entertainment; public safety • Crowdsourced video broadcast • Real-time object tracking **End date**: May 2020 Metro-Haul aims to improve the efficiency of network resource allocation via data and control plane architectures, including optical transport capacity across metro and core networks, and edge datacentre resources (e.g. compute and storage). Machine learning within the decision engine allows this new metro-haul technology to continue to learn and improve as real network data is collected. The analytics framework will enable the monitoring of applications as they travel through the network using telemetry probes, modifying path and resources as network conditions change. Metro-Haul will also allow flexibility in deployment choices, extensibility for integrating new technologies and agility in migration processes without vendor lock-in.
SLICENET	Multi-domain multi-tenant network slicing: defining business models based on cooperation of players involved, e.g. peer-to-peer negotiation across administrative domains along an E2E path and orchestration (GN8)	**Vertical clusters**: energy; health; smart cities • 5G Smart Grid Self-Healing Use Case • 5G Smart Health / Connected Ambulance • Smart City SmaLI-5G Use Case **End date**: May 2019 SLICENET will give network operators an E2E multi-domain network management paradigm

	SLICENET Plug & Play control framework: key enabler for advanced slice customization with novel combination of tailored content functions, APIs and tools for vertical businesses so they can plug their own control logic based on needs and on demand (GN8)	with integrated fault, configuration, accounting, performance and security (FCAPS). SLICENET will give service providers significantly higher service quality through intelligent QoE-driven design and vertical businesses the ability to use 5G services more quickly and efficiently via a one-stop-shop approach.

Table 7: Phase 2 projects ending in 2020

5.2 Main findings from Portfolio Analysis

In this section, we report on the main findings of the Portfolio Analysis for the Verticals Cartography across all key data fields. We also zoom in on the insights emerging from the updated findings, drawing on the analytical tables in section 5.1.1. Updates to the online tool are described in section 6.

Such an analysis enables the 5G PPP to pinpoint current gaps within the 5G PPP programme. The planned inclusion of phase 3 projects will add vital information about large-scale vertical pilots on the test platforms and trials for automotive through the cross-border corridors.

5.2.1 Vertical cluster perspectives

In terms of vertical cluster coverage, the Global5G.org analysis shows that the peak of experiments occurs with **media and entertainment** (21 out of 63 experiments; 40%) with a strong focus on enhanced mobile broadband as the first service supported in 5G. **Smart cities** are another important vertical in the cartography (10 out of 63; 17%), followed by **public safety** (8 out of 63; 16%), showing that many experiments directly or indirectly contribute to the smart city ecosystem.

Energy is targeted both a utility key for the European economy but also in terms of

The figure below shows the distribution of experiments across the eight vertical clusters in the 5G PPP Verticals Cartography.

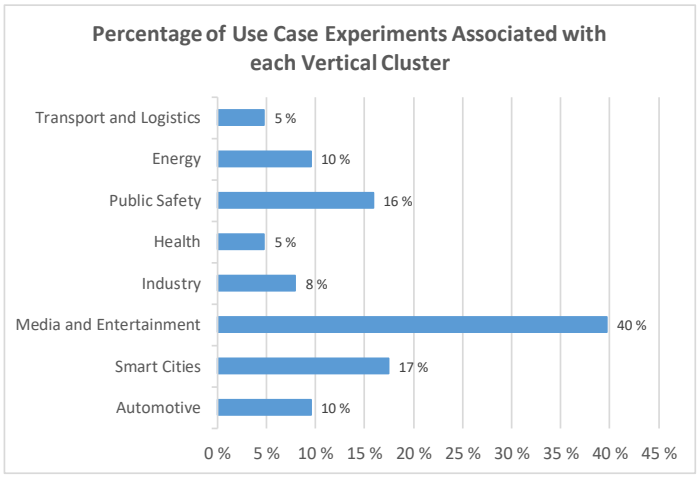


Figure 8: Distribution of Experiments across Vertical Clusters

5.2.2 Perspectives on 5G ITU functionality

Our analysis shows that eMBB is the most targeted ITU 5G functionality. The analysis also confirms its importance for media and entertainment with all 21 experiments targeting this functionality. URLLC is the second most targeted functionality.

Other vertical experiments targeting only eMBB include Bluespace smart cities (co-existence with PONs); MATILDA industry (Smart Factory); NGPaaS public safety (Mission Critical Push to Talk); 5G-PHOS industry (Hot-spot area); SAT5G satellite for 5G (NR over satellite link) and transport and logistics with media and entertainment (5G on board commercial airplanes), satellite integration with media and entertainment (5G in homes and offices in rural areas); SLICENET health (connected ambulance). The table below gives the example for coverage of eMBB for media and entertainment.

Project	Use Case Experiment	Targeted 5G functionalities
5GCity	Media & Entertainment - Video Acquisition and Production with Community media engagement in live events	eMBB and URLLC
	Media & Entertainment - UHD Video Distribution and Immersive Services	eMBB, URLLC, mMTC
	Media & Entertainment - Mobile Backpack Unit for Real-time Transmission	eMBB, URLLC, mMTC
5G ESSENCE	Media & Entertainment - 5G Edge network acceleration for a stadium	eMBB
	Media & Entertainment - Next-Generation integrated in-flight connectivity and entertainment systems	eMBB, URLLC

5G-MEDIA	Media & Entertainment - Immersive Applications and Virtual Reality	eMBB
	Media & Entertainment - Mobile contribution, remote and smart production in broadcasting	eMBB and URLLC
	Media & Entertainment - Dynamic and Flexible UHD Content Distribution over 5G CDNs	eMBB and URLLC
5G-PICTURE	Media & Entertainment - Mega-Event in stadium	eMBB, URLLC, mMTC
5GTANGO	Media & Entertainment - Immersive Media	eMBB/URLLC
	Media & Entertainment - Communications Suite	eMBB/URLLC
5G-XCast	Media & Entertainment - Object oriented broadcasting	eMBB
	Media & Entertainment - Hybrid broadcast service	eMBB
BlueSpace	Media & Entertainment - Broadband Access in crowded areas	eMBB
IoRL	Media & Entertainment - multiple verticals: 5G indoor scenarios in home, museum, railway tunnel and supermarket	eMBB
MATILDA	Media and Entertainment (*) Finance and Retail - High Resolution Media on Demand	eMBB
METRO-HAUL	Media & Entertainment - Crowdsourced video broadcast	eMBB
ONE5G	Media & Entertainment - Smart-Megacity	eMBB/URLLC/mMTC
	Media & Entertainment - Enhanced massive MIMO	eMBB
SaT5G	Media & Entertainment - Edge delivery & offload via satellite multicast	eMBB

Table 8: 5G Functionality Distribution across Media and Entertainment

The figure below shows the overall distribution of 5G functionalities across the phase 2 projects.

eMBB is also often targeted in smart city experiments (64%), public safety and digital divide resorption and health, though coverage of the health vertical is much less intense. URLLC is most often targeted in energy though with less intense coverage of this vertical, industry experiments (both factory and process automation and farming and agriculture). Experiments on transport and logistics is quite evenly distributed across all three functionalities.

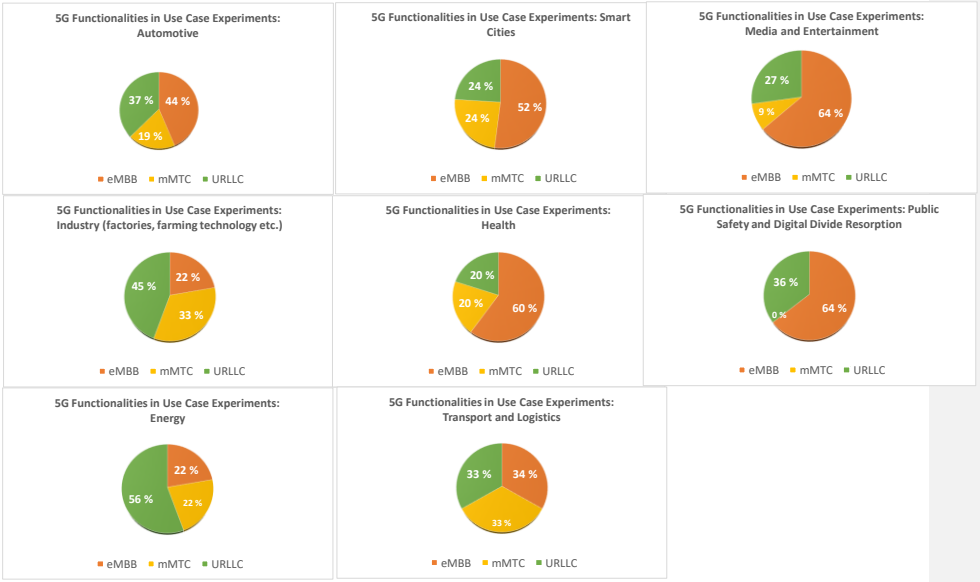


Figure 9: Occurrence of 5G functionalities across Experiment Verticals

5.2.3 Experiment type and maturity perspectives

According to our analysis, most of the experiments fall under types 1-3 with a total of 61 taking place between 2018 and 2020, and peaking in 2018-2019. 27 experiments are targeting experiment types 4-5, peaking in 2019. Some projects are evolving their experiments over time, e.g. the experiments in 5GCity are being tested across several maturity levels, four of which are across types 3-4-5 (from demonstration through to trial and pilot) and one for types 3-4 (from demonstration to trial). Other examples include 5GMEDIA, with three experiments moving across 3-4-5 types and two across 2-3-4. Some projects only target one type of experiment, e.g. ONE5G and BlueSpace (1 – proof of concept); 5GCAR (3 – demonstration). The figure below shows the overall focus on experiment types across the 2018-2020 timeframe.

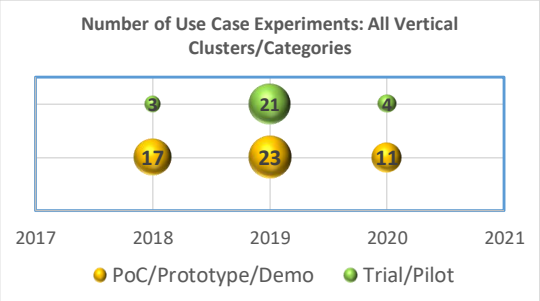


Figure 10: Distribution of Experiment Types 2018-2020

The figure below shows the distribution of use case experiments across all verticals in the same time frame.

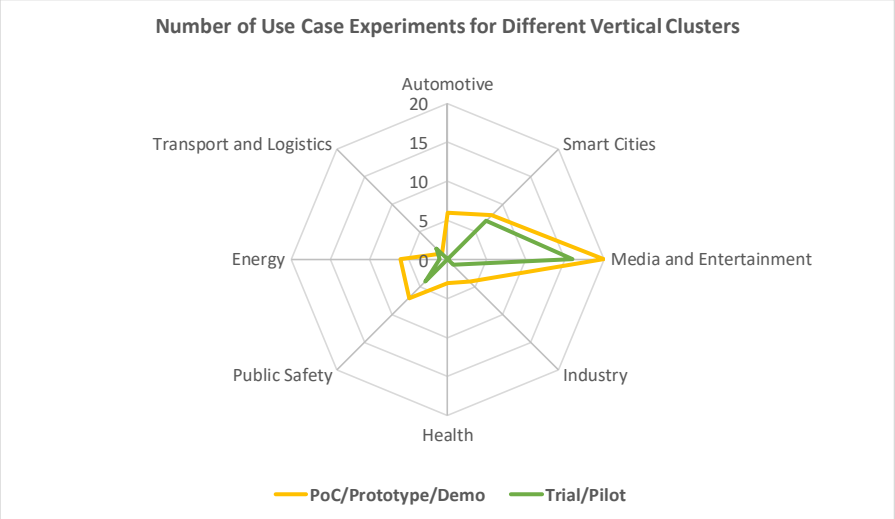


Figure 11: Distribution of Experiments across Vertical Clusters

The figure below shows the intensity of 5G functionality distribution across the five types of experiments, confirming high frequency of experiment types 1-3 across all three of the 5G functionalities but with relative high focus on URLLC for types 4-5. This finding reflects also the evolution across experiment types in some of the projects.

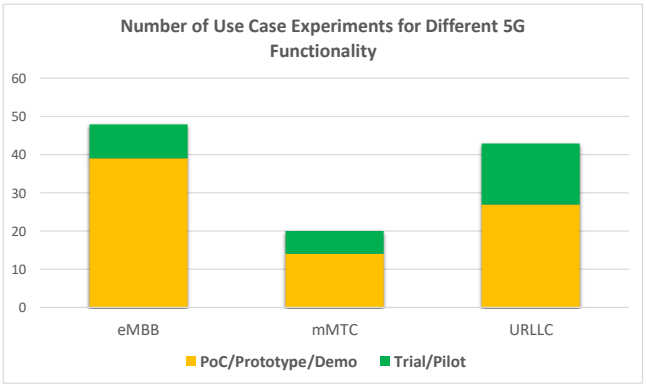


Figure 12: Distribution of Experiments across 5G Functionalities

The figure below gives further details about distribution and intensity across 5G functionalities and experiment types.

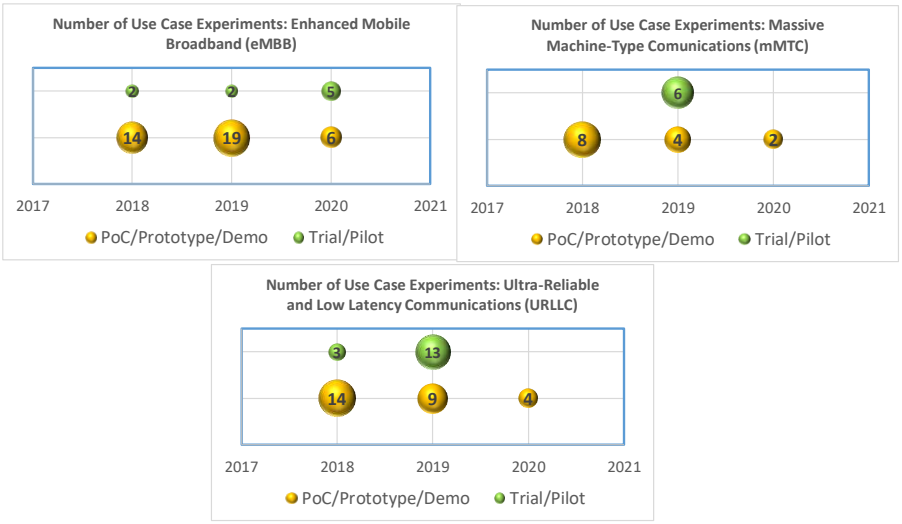


Figure 13: Distribution and Intensity of 5G Functionalities across Experiment Types

5.2.4 Vertical Participation Perspectives

The Blueprint is the first step towards analysing vertical participation in the experiments based on the following EC classification (EC Recommendation 2003/361 [EC2003]).

Type of Vertical Partner	Defining Characteristics
Small and Medium Enterprise	Private enterprise with staff headcount < 250 Turnover ≤ € 50 m or balance sheet total ≤ € 43 m
Large Enterprises (private sector)	Private enterprise with staff headcount ≥ 250 Turnover > € 50 m or balance sheet total > € 43 m
Government and Public Sector	Local government, government agencies, central government, public enterprises, public services etc.

Table 9: EC definition of organisational types

From here, we can see the distribution of vertical stakeholders in the experiments. 62% of the experiments involve 1 or more vertical stakeholder compared with 38% having no vertical partners involved/in the consortium. More specifically, 41% have only 1 vertical stakeholder, 18% have 2 and only 3% have 3 or more. Examples of vertical stakeholder involvement include 5GCAR (PSA Groupe, Volvo, Bosch); 5GCity (City Councils of Lucca, Bristol and Barcelona; RAI); 5GMEDIA (IRT, RTVE); 5G-Xcast (BBC, LiveU); IoRL (Building Research Establishment, Ledpcom, Ferrovial, Issy Media).

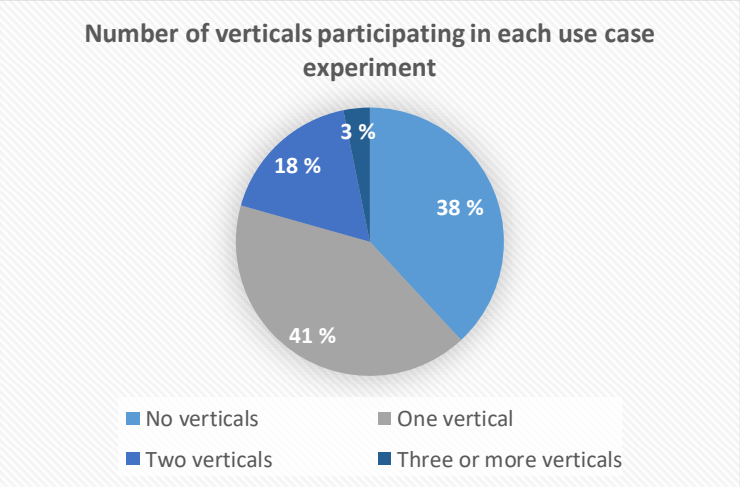


Figure 14: Breakdown of Vertical Stakeholder Participation

While most of the vertical stakeholders come from public-sector organisations (32%), large enterprises (27%) and SMEs (20%) also make an important contribution. The figure below shows the breakdown of participation.

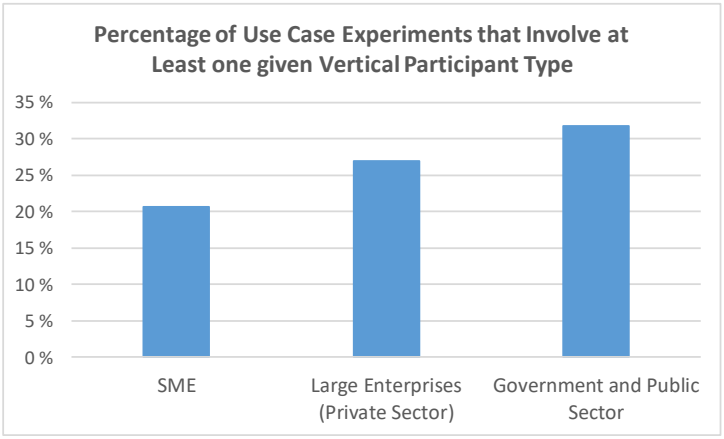


Figure 15: Breakdown of Organisation Types

Organisations belonging to the government and public sector are typically end-users, including neutral hosts (e.g. 5GCity). Large enterprises can be both supply side stakeholders and end-users, e.g. 5GCAR with PSA Groupe on the end-user side and Ericsson, Nokia and Orange on the supply side.

By contrast, SMEs typically belong to the supply side that have mastered the key technologies and services enabling new business models to emerge, not only in the telecommunications ecosystem but also across verticals. As such, they may well be the ultimate winner when it comes to opportunities coming from 5G rollouts. From a vertical perspective, SMEs contribute in sectors like media and entertainment.

Global5G.org has made a first assessment of emerging business models emerging from 5G in D4.4 – Emerging Business Models for 5G Verticals, 1st Report (April 2019) with a final report due in December 2019. The topic has also been explored in a workshop at EuCNC 2019 (June): *Emerging 5G Business Models: Opportunities for SMEs and large companies – Lessons from 5G PPP*, with an online report covering the main discussion points and take-away messages[26].

[26] https://www.global5g.org/news/report-eucnc-2019-business-models-workshop.

5.2.5 Vertical cluster perspectives

The figure below shows the distribution of organisation types across the vertical clusters.

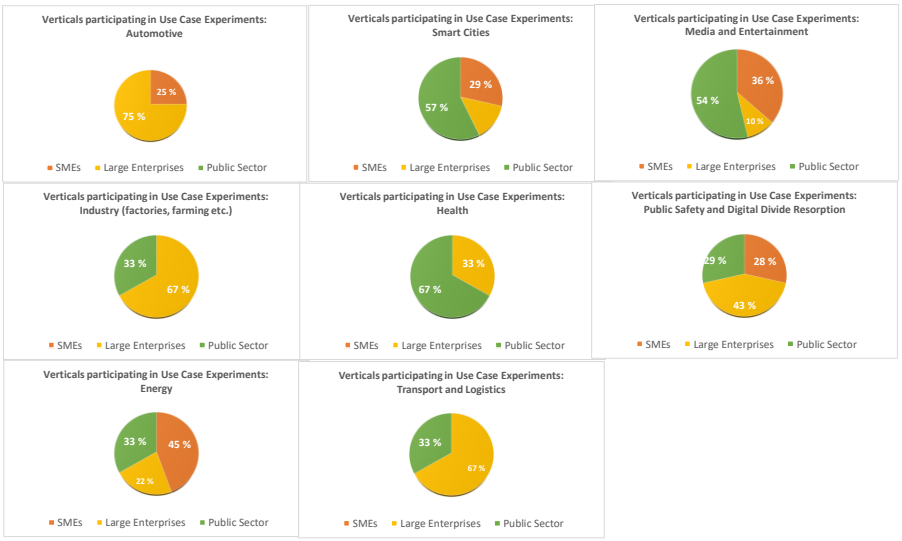


Figure 16: Distribution of Vertical Stakeholders across Vertical Clusters

Not surprisingly, it shows that large enterprises are more common in verticals like automotive, industry, transport and logistics, and public safety. Public-sector organisations are more common in experiments on smart cities, media and entertainment and health but play smaller roles in energy and industry. SMEs are more common in energy, media and entertainment, smart cities, and public safety.

5.2.6 Experiment Type and Maturity Perspectives

The Blueprint also helps analyse the distribution of the three organisational types across the diverse types of experiment. The government and public sector is equally distributed across types 1-3 and 4-5, and a similar picture applies also to large enterprises. However, SMEs are slightly more involved in types 1-3, and therefore at the forefront of technological advances and merging technologies.

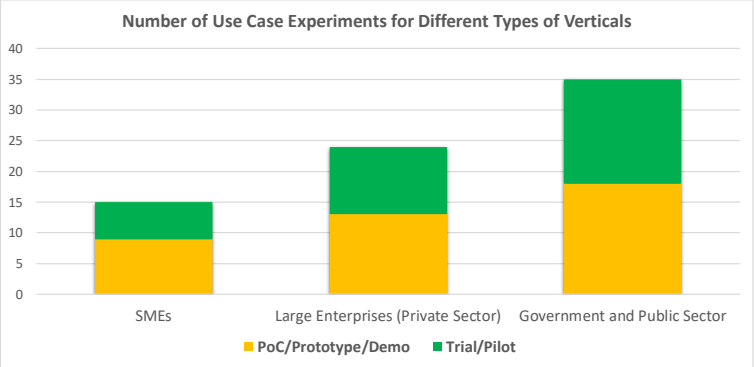


Figure 17: Stakeholder Involvement by Experiment Type

In the next figure, we show how these organisation types contribute to experiment types 1-3, showing SMEs on 45%, large enterprises on 33% and public sector on 22%.

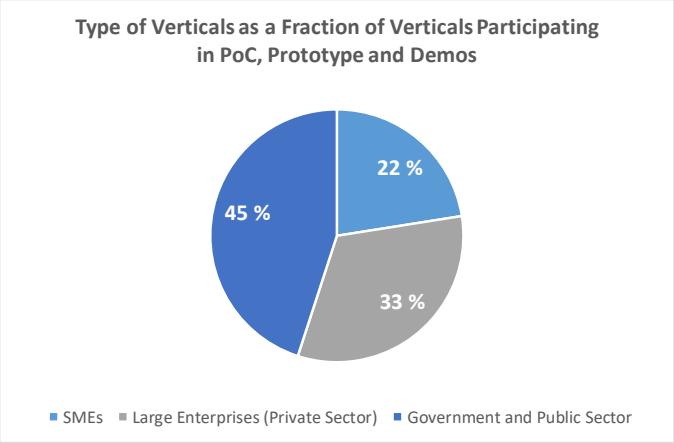


Figure 18: Distribution of Vertical Stakeholders in Experiment Types 1-3

The next figure shows distribution across types 4-5, showing higher participation of government/public sector (50%), large enterprises in second place (32%), with SME participation standing at 18%. This confirms that SMEs generally play a bigger role in early experiments.

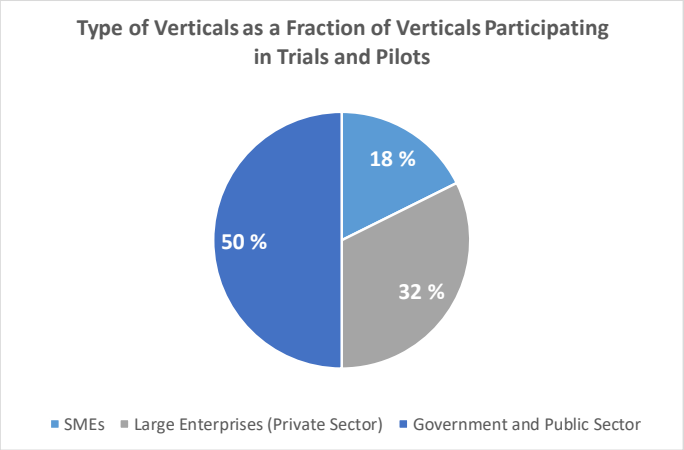


Figure 19: Distribution of Vertical Stakeholders in Experiment Types 4-5

5.2.7 Multiple Vertical Perspectives

A closer analysis of several projects defying a neat fit with the phase 3 clustering reveals multiple vertical scenarios, which have been incorporated into the online updates. It also reveals a wide of end-user stakeholders, directly and indirectly targeted.

Most importantly, it shows key differences between single applications or services versus experiments covering a myriad of verticals, thereby extending the range of end-users that can benefit from 5G.

- Smart Cities: multiple verticals, e.g. 5G-PHOS and Bluespace with a focus on city hot spots[27], ultra-dense urban areas[28] (5G-PHOS) and crowded areas[29] (Bluespace).
- Indoor spaces: multiple verticals, e.g. Bluespace[30] and IoRL[31] covering indoor ultra-high broadband access (Bluespace) and video streaming, video communications and location-based services across verticals such as domestic settings, museums, railway spaces/tunnels, supermarkets (IoRL).
- Satellite for 5G: multiple verticals and underserved areas, e.g. SAT5G with use-case experiments in homes and offices in rural areas[32]; edge delivery offload with satellite

[27] https://www.global5g.org/5g-phos-hot-spot-area.
[28] https://www.global5g.org/5g-phos-ultra-dense-city-area.
[29] https://www.global5g.org/bluespace-broadband-access-crowded-areas.
[30] https://www.global5g.org/bluespace-indoor-ultra-high-broadband-access.
[31] https://www.global5g.org/iorl-video-streaming-video-communications-and-location-based-services.
[32] https://www.global5g.org/sat5g-5g-homes-and-offices-rural-areas.

multicast[33]; 5G New radio over satellite link[34]. SAT5G also has a use-case experiment that covers both transportation (aviation) and 5G-enabled onboard entertainment, where Lufthansa are the carrying out the demonstration in Germany[35].

The integration of satellite in 5G is also confirmed from a standardisation perspective, such as asset tracking in 3GPP, which covers multiple environments and verticals as goods travel from departure point to destination[36]. More details are given in *D3.3 - Report on 5G Standardization and Verticals* (June 2019).

The image below shows the distribution of these use cases.

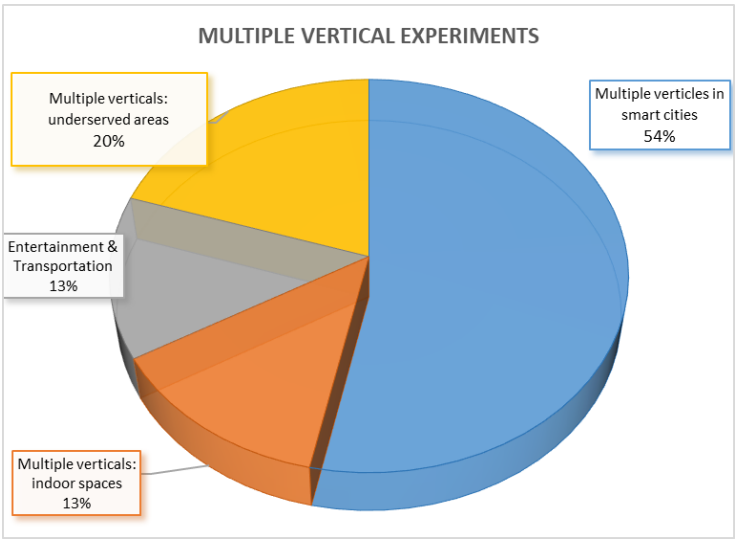


Figure 20: Phase 2 Multiple Vertical Experiments

By contrast, there are other use-case experiments that focus on a single application or service. In many cases, these applications and services can be replicated across other cities etc. A good example is 5GCity, with its unauthorised waste dumping prevention in the Italian city of Lucca, which is specifically designed for large events (e.g. Summer Festivals and Comics and Games), which are annual events taking place around the city[37]. This is also a good example of a city council (Lucca) working with

[33] https://www.global5g.org/sat5g-edge-delivery-offload-satellite-multicast.
[34] https://www.global5g.org/sat5g-5g-new-radio-over-satellite-link.
[35] https://www.global5g.org/sat5g-5g-board-commercial-air-planes.
[36] https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3525.
[37] https://www.global5g.org/5gcity-unauthorised-waste-dumping-prevention.

an SME specialised in the required technologies (Nextworks srl), leading the demonstration, trials and pilot.

6. Web Implementation Updates and Dissemination

6.1 Design and Rollout of the Online Tool

The design of the Verticals Cartography (Trust-IT) translates into an online tool that visualises the 63 use-case experiments in terms verticals, countries, type of experiment and 5G functionalities targeted. The online tool allows users to filter across four key categories:

1. Vertical Cluster, represented by a graphically designed icon.
2. Country where the experiment is taking place.
3. Type of experiment.
4. ITU 5G functionalities.

One or more options for each category can be selected. Once the desired options are selected, users can click on the projects of their choice. The information given for each project experiment includes:

- The project logo.
- Title of the experiment.
- Focus of the experiment.
- Targeted functionalities.
- Location.
- Vertical partners involved.
- Other partners involved.
- The possibility to upload one or more videos. Videos can be replaced to mirror progress over time.
- The possibility to generate informative fliers on specific verticals or countries (see example below).

So far, two releases of the online tool have been launched. The two releases have the same navigation but improvements have been made in V2.0 to ease visualisation of the experiments, with a short blurb about them. The second release therefore offers an enhanced user experience.

The two images below show how the online tool has evolved.

The first image shows the main entry point with filtered searches for smart cities and industry – factory and automation processes.

The second image shows the new layout entry point and filtered searches for public safety and multi-vertical scenarios with the three new icons.

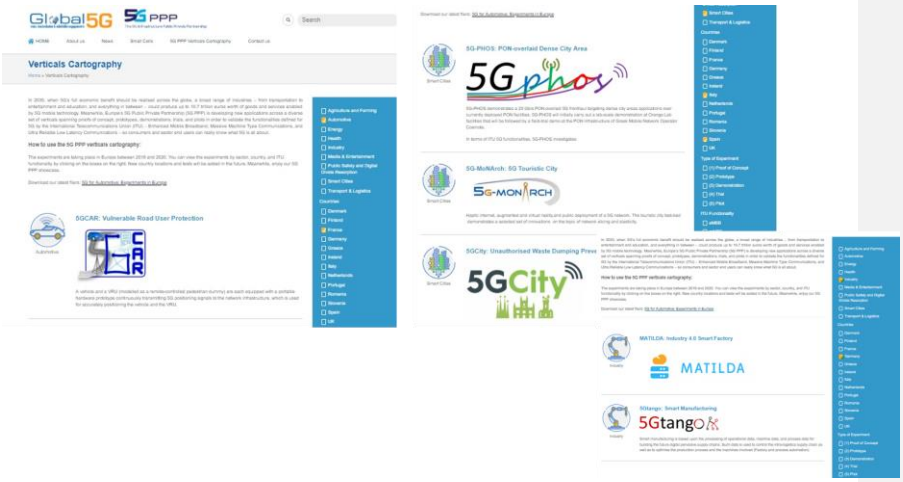


Figure 21: Verticals Cartography Online Tool Release 1.0

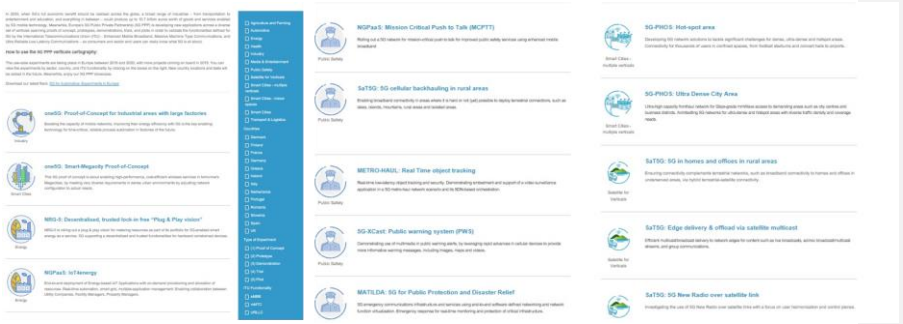


Figure 22: Release 2 of the Online Tool

Three new icons (Trust-IT) visually conceptualise the results of the updated analysis.

Figure 23: Icons for Multiple Vertical Experiments

The updates for release 2.0 clearly show that the online tool can be continuously enriched with updated/additional content in diverse formats, using the Blueprint checklist to track changes. This is key as we move towards on-boarding all phase projects (ICT-17-18-19).

The various search options are also practical in terms of producing tailored, downloadable fliers that can be used for events, both physical events and webinars. These fliers can also be tailored to diverse audiences, from newcomers to 5G to sector specific domain experts and national policy makers.
The figure below shows a sample of the fliers produced so far by Global5G.org. The first flier is an example of a national perspective created for the International Robotics Festival (Pisa, September 2018) and the webinar on automotive.

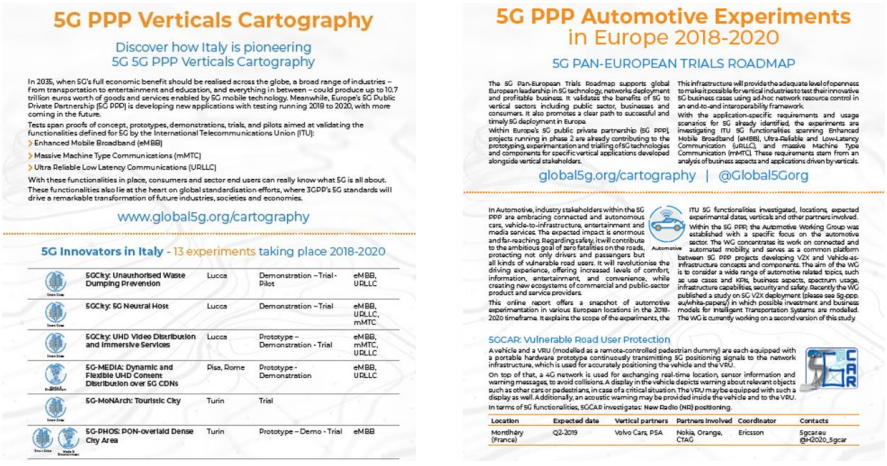


Figure 24: sample of fliers generated from the cartography

6.2 Official Launch of the Online Tool

The online tool was officially launched at the ICT-19 Info Day on 14 September in Brussels. The goal

was to give prospective proposal consortia an online tool and analysis to help build on the current portfolio of experiments.

The presentation was made by Dr Didier Bourse, Chair of the Technology Board and Trials Working Group, who concisely presented the brief history of the Cartography through the Pan-EU Trials Roadmap v3.0. The presentation also featured the launch of the online tool along with the first analysis made using the Blueprint.

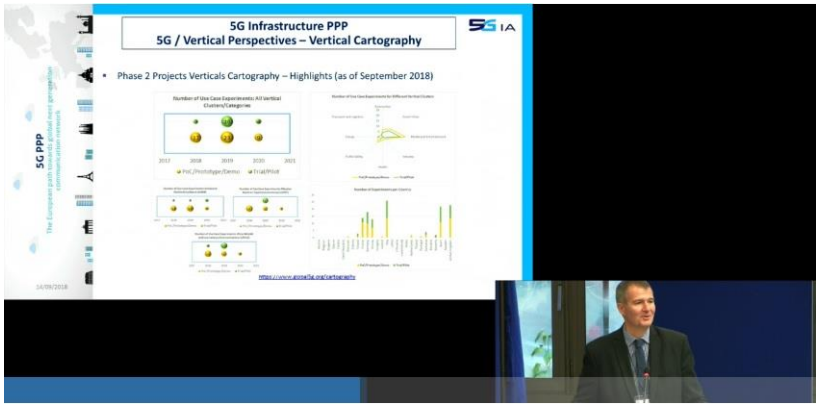


Figure 25: Launch of the Online Verticals Tool at Info Day ICT-19

6.3 The Cartography in the Pan-EU Trials Roadmap v4.0

As a member of the 5G-IA Trials WG, Global5G.org (Trust-IT) has had the opportunity to contribute to the Pan-EU Trials Roadmap 4.0 (November 2018). Contributions include:

- A high-level overview of the Online Tool, in terms of geographic and vertical coverage. It is important to note that the definition of 5G trials, pilots, pre-commercial and commercial deployments does not tally with the definition of "experiments" for the Verticals Cartography, which covers lower levels of maturity for use cases that need significant R&D.
- A cityscape image mapping the phase 2 experiments along two axes: coverage of EU cities at the selected locations (vertical axis with points highlighted on the map of the EU) and coverage of the 8 vertical clusters (horizontal axis with representative icons).
- A high-level overview of selected national 5G programmes/roadmaps. Global5G.org gave 4 country analyses: **Germany**, **Greece**, **Italy** and the **UK**. Other countries selected include: Finland, France, Netherlands and Spain. This overview helps source 1) further examples of vertical trials and pilots and 2) potential case studies on the deployment of small cells

along with several examples of implementations of 3GPP technical specifications, both within national trials and the 5G PPP phase 3 platforms.

The Roadmap summarises the scope of the Online Cartography in terms of what it tracks, alongside a synopsis of the main findings represented in **four quadrants**: vertical coverage showing high frequency of experiments on media and entertainment; coverage of 5G functionalities across the smart city experiments, where eMBB represents 52%; the timeline for the experiments, where most of them are taking place in 2019-2020; smart city and public sector involvement, where public-sector organisations represent 57% (the others being SMEs and large companies).

The figure below shows the four quadrants resulting from the analysis of Verticals Cartography featured in the Roadmap 4.0.

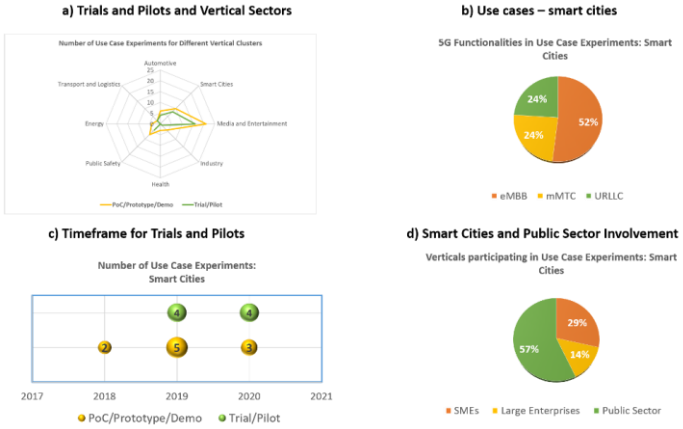


Figure 26: Four Quadrants in the Pan-EU Trials Roadmap V4.0

i. Impacts from Dissemination of the Verticals Cartography and Roadmap V4.0

The figure below shows the cityscape analysis for the Verticals Cartography featured in the Roadmap V4.0, with 63 experiments taking place in 38 cities across 13 EU countries. The image was specifically created for the Roadmap.

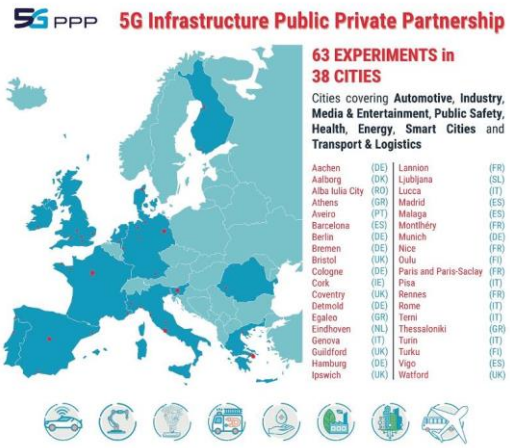


Figure 27: Vertical Cartography Cityscape in the Pan-EU Trials Roadmap V4.0

Impacts include visibility via social media channels. The image below shows a sample of the launch via Twitter, resulting in Top Tweet for September 2018.

Figure 28: Top Tweet - Launch of the Online Tool

The Roadmap 4.0 was officially launched at the 6th Global 5G event in Rio (November 2018)[38] with a presentation from Dr Didier Bourse (TB and Trials WG Chair):

- Presentation: "The 5G Infrastructure Association 5G Pan-European Trials Roadmap[39].
- Video recording of the presentation: session on 5G Trials and Pre-commercial Launches[40].

Promotion of the Roadmap also led to good visibility in the telecoms media via Twitter. The example in the figure below shows the importance of the various online tools and planned phase 3 launches in the Roadmap. The Tweet reads: "This update on 5G trials has been produced in time for this week's Global 5G event in Rio. Well worth a read. Lots in there. One aside is that there's a useful looking 5G test bed inventory development".

More details on the dissemination of the Roadmap and Verticals Cartography are given in *D4.3 - Communication, Stakeholder Engagement, and Coordination Plan 2nd Report*.

Figure 29: Press coverage of Roadmap V4.0

Promotion of the online tool at launch also included selected use-cases. The figure below shows one

[38] http://6thglobal5geventbrazil.org.br/en/home/.

[39] http://6thglobal5geventbrazil.org.br/wp-content/uploads/2018/11/Panel7-Didier-Bourse_5GInfraPPP_TrialsRoadmapVersion4.0_Rio.pdf.

[40] https://www.youtube.com/watch?v=5oJq1dBxFt8&index=11&list=PLgkqAXrulK-LlvS9P6Q5ZlBmBfaHn7ieK.

example.

Figure 30: Phase 2 Showcase on Twitter

In view of the updates for Release 2.0 of the tool, Global5G.org has also produced a new version of this image, adding another city (Weissling, Germany – SAT5G on-board entertainment) and the three new icons.

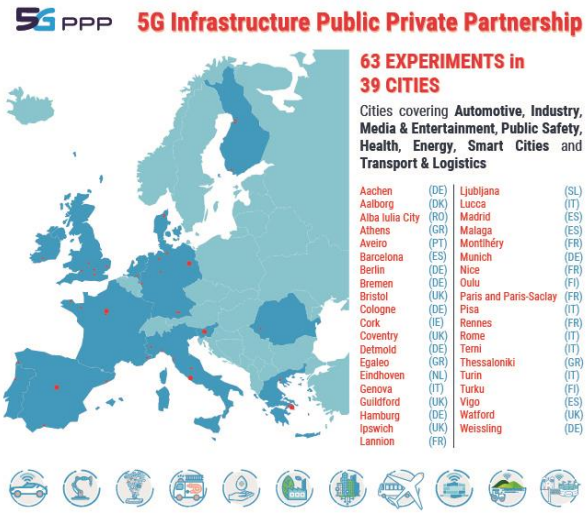


Figure 31: Updated Vertical and Cityscape

EuCNC 2019 was the chosen venue for promoting the updates. The Tweet is top media Tweet for June

2019.

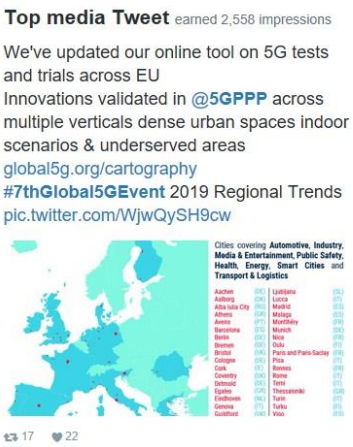


Figure 32: Top Tweet - Updated Online Tool

6.4 Future developments

The design of the Online Tool is intended to be flexible enough to easily add other data fields over time. Such an approach not only enables updates from phase 2 projects on their results but will also extend to projects from ICT-17, -18 and 19. The Verticals Cartography is therefore sustainable over time, and potentially beyond Horizon 2020, for example, by re-working the design and data fields accordingly.

Development Plan and Timelines

Below we show the actions already taken in Q1 and Q2 2019, with plans for Q3- and Q4 2019.

- **March-April 2019**: new layout to ease user experience with the production of introductory statements on each of the 36 experiments. Global5G.org analysed also the Golden Nuggets and project websites to help define these statements. Visualisation now shows the introductory statement rather than the project logo. The texts were also updated and re-structured, with inclusion also of all partners.
- **May 2019 (on-going)**: creation of a new template to capture results, especially from phase 2 projects ending between Q2 and Q4-2019. Uploading the updates.
- **March-May 2019**: new analysis was triggered through discussions with the Technology Board in relation to the Golden Nuggets, Annual Report 2019 and, also with the Technical Specification Group Chairs of 3GPP in relation to satellite (non-terrestrial networks). This has resulted in:

- **June 2019**: updated verticals cartography image with the inclusion of 39 cities and 3 new icons showing multi-vertical scenarios (vs. 38 cities and 8 verticals in the image published in the Roadmap V4.0; See D2.2 – Verticals Cartography, 1st Report). Impacts of the SMART-campaign for EuCNC 2019 are given in Section 6.
- **June 2019**: updated analysis to explain the scenarios with multi-vertical coverage on top of the first analysis. Examples include the following:
  - Satellite for verticals, e.g. *https://www.global5g.org/sat5g-5g-homes-and-offices-rural-areas*.
  - Smart cities – multiple verticals, e.g. *https://www.global5g.org/5g-phos-hot-spot-area*
  - Smart cities – indoor scenarios, *https://www.global5g.org/one5g-smart-megacity-proof-concept-0*

- **May-June 2019**: co-creation of a template within the Trials WG for a competition to select the top 10 experiments for inclusion in the EU 5G Observatory. Trust-IT is part of the Evaluation Committee.
- **July-September 2019**: on-boarding of Phase 3 projects from calls ICT-17-18 and 19. A new blueprint is being developed to collect project information based on a first overview prepared for EuCNC 2019, where the new ICT-19 projects were officially launched, and ICT-17 and ICT-18 projects were present.
- **May-December 2019**: regular updates to the experiments (phases 2 and 3), with a showcase publication planned for late September 2019, with details being defined in the TB and trials WG. Twitter cards will also be produced for SMART-based campaigns. The examples for 5G-MoNArch (phase 2) are shown in the figure below.

Figure 33: Example for Promotion of Phase 2 Showcase Campaign

7. Summary of Main Findings and Next Steps

Europe has embarked on an ambitious plan to realise full 5G with smart cities and vertical industries as prime examples of the promises of an emerging ecosystem, enabling operators and other stakeholders, including new entrants, to extend into diverse new service-types and markets over coming years. Europe's significant investments aim to place Europe in a leadership position, one that is not about making claims of early 5G rollouts but ensuring the best possible 5G technologies are available through well-timed deployments based on evolved capacities and increased coverage across multiple verticals.

The tools being designed and developed within Global5G.org, namely the Verticals Cartography, the Standards Tracker, the Mapping Tool, and the Performance KPI tracker, shed light on what 5G capabilities are being rolled out and when, what contributions to standardization are led by or involve EU players, as well as the coverage and intensity of ambitious performance indicators.

Specifically, the Verticals Cartography Blueprint and Online Tool tracks the progress of 63 use-case experiments in phase 2 of the 5G PPP with two releases of the Tool already produced.

The main findings from the new analysis and on-going updates are as follows.

Summary of Main Findings

Top coverage: verticals and countries

- Media and entertainment is the most frequent cluster in both mature and less mature use-case experiments.
- Enhanced mobile broadband (eMBB) is the most targeted 5G functionality for media and entertainment.
- Five countries are hosting most of these experiments: UK (16); Italy (14); France (13); Germany (13); Spain (11). High-level overviews of the national 5G programmes are featured in the Pan-EU Trials Roadmap V4.0.

Low coverage: gap analysis

- Low coverage occurs for agriculture and farming; healthcare; transportation and logistics.
- The analysis pinpoint gaps that could be filled by future projects, with the potential to demonstrate compelling innovations

Coverage of multiple verticals

- An updated analysis reveals cases that target multiple verticals, e.g. indoor scenarios, city hotspots, dense and ultra-dense urban areas, and satellite for 5G, including underserved areas to help overcome the digital divide. These findings are confirmed by the Golden Nuggets (February 2019) and the on-going analysis of 3GPP study and work items for Releases 16 and 17, e.g. asset tracking with non-terrestrial networks (Thales Alenia Space). Indeed, non-terrestrial networks are one of the EU priority areas for 5G standardisation.

Vertical stakeholder coverage

- Local and city councils, and other public-sector organisations, are mostly involved in smart cities, but also health, media and entertainment as complementary services. Smart cities targeting multiple verticals also extend the range of stakeholders, e.g. bodies running museums, owners of supermarket chains, metro stations/railway infrastructure and stadiums (live sport events and concerts).
- SMEs are mostly involved on the technology supply side as network-savvy companies that are good candidates for exploiting phase 2 project results. This is also demonstrated in D4.4, our first study on business models, and validated through our jointly hosted workshop on the same topic at EuCNC 2019.
- Not all the use-case experiments directly include end-users. In these cases, large enterprises typically represent the interests of the verticals.

Updates of the phase 2 projects are now on-going while the vertical clustering has been revised to reflect new findings. These findings show that 5G has the potential to deliver important societal impacts both in general and through the rollout of vertical applications, where. Impacts can be direct, related to a specific vertical or cut across several verticals.

Global5G.org is now poised to on-board the phase 3 projects successfully retained for funding through ICT calls 17-18-19, with interactions already under way.

Summary of Next Steps

- **May-June 2019**: Co-creation of a template within the Trials WG for a competition to select the top 10 experiments for inclusion in the EU 5G Observatory. Trust-IT is part of the Evaluation Committee.
    - Joint promotional campaigns with the 5G Observatory post-competition to highlight the experiments of the successful candidates.
    - Cross-referencing to the 5G Observatory from the Online Tool to boost collaboration and visibility.
- **July-September 2019:** on-boarding of Phase 3 projects from calls ICT-17-18 and 19. A new blueprint is being developed to collect project information based on a first overview prepared for EuCNC 2019, where the new ICT-19 projects were officially launched, and ICT-17 and ICT-18 projects were present.
- **May-December 2019**: regular updates to the experiments (phases 2), with a showcase publication planned for late September 2019, with details being defined in the TB and trials WG. Twitter cards will also be produced for SMART-based campaigns.

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