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Master Thesis

5G-Enabled Business Models for Logistics and Smart Ports in collaboration with 5G-LOGINNOV

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Abstract

The purpose of this paper is to investigate innovative business models and new potential actors for the port and logistics industries created in collaboration with 5G-LOGINNOV, a European initiative started in September 2020 and developed within the ICE-ICT for City Logistics and Enterprises laboratory. This project aims to analyze 5G-enabled applications and innovative solutions that will be tested in three living labs to create a beneficial impact for the port ecosystem; it follows a stakeholder-led approach to ensure that proposed innovations are co-created with the 5G consortium partners and ports (Athens (GR), Hamburg (DE) and Koper (SLO)).

Regarding the thesis structure, the preliminary part deals with the current state of the art of 5G, with an in-depth study on critical success factors (CSF) and key performance indicators (KPI), taking into account the 5G features and network requirements, and the applications and use cases (eMBB, URLLC, mMTC) in line with existing standards (ITU, 3GPP, ETSI).

The following section concerns a description of the current political, economic and technological situation in Europe, examining the public and private initiatives and financial resources that participate in developing this disruptive innovation.

After an evaluation of several projects in the field of ports, logistics and transport, and Industry 4.0, the last step relates to the construction of a taxonomy that will be the baseline to generate new business models and promote SMEs and startups, guaranteeing widespread and lasting exploitation of results and managing the transition to the latest technologies in the best possible way.

5G-LOGINNOV-will positively impact the economy and technology and the whole society and environment by strengthening the three main pillars of sustainability: profits, planet, and people.

Summary

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Chapter 1. Introduction to LOGINNOV-Project

5G-LOGINNOV: scope of the project and purpose of the paper

This thesis aims to find new business models for ports and logistics that arise with the introduction of the innovative 5G technology. It is realized in collaboration with LOGINNOV, a project started in September 2020 and developed within the framework of Horizon 2020 that explores the opportunities for ports coming up by the launch of 5G technology. The project is part of the third phase of the 5GPPP initiative, and in this context, it is in line with 3GPP, ITU, ETSI, and other global standards.

5G LOGINNOV-goal is to improve ports and logistics hubs by exploiting novel technologies such as 5G, Internet of Thing, data analytics, next-generation traffic management, Cooperative, Connected and Automated Mobility (CCAM), and the 5G logistics corridor.

In this way, it aims to benefit port areas and port cities and support future challenges in capacity, traffic efficiency, and sustainability protection, minimizing the environmental impact and reducing the urban population's disturbance.

The innovations proposed for the port environment are automation, generation of data on floating trucks and emissions, and automated truck platooning. Their effectiveness will be tested in real operating conditions in three Living Labs linked to Athens (GR), Hamburg (DE), and Koper (SLO) ports, consisting of workshops and demonstrations to involve local and national stakeholders and report to them the functioning and status of developed systems, collecting their feedback and ensuring possible cooperation in future companies. The labs will be focused on eMBB (Enhanced Mobile Broadband), mMTC (Massive Machine-Type Communications), and URLLC (Ultra-reliable low-latency communication) use cases, and also systems for VNF (Virtual Network Functions) and MANO (Management and Network) orchestration capabilities.

The project also focuses on identifying new potential players, such as SMEs and innovative startups, in order to exploit their growth capacities and support the creation of a "leading" marketplace, a single digital market involving heterogeneous sectors.

From the very first phase, 5G-LOGINNOV-follows a stakeholder-driven approach, taking into account ports and the main challenges of port-cities and considering the significant changes brought about by the transition to Industry 4.0. This approach ensures that the proposed innovations will be co-created with the 5G consortium partners and ports, prioritizing its specific requirements and needs.

Moreover, the 5G-LOGINNOV-baseline will focus on the actual work of three significant logistics projects: Aeolix, Selis, and Fenix to conceive new scenarios starting from the results already obtained, and for this reason, it is crucial to know the most common procedures considered by other projects and to compare them and actuate the necessary improvements.

The main objectives expected are:

- 10% higher load factors with a better combination of transport modes.
- Commitment to reduce CO_2 emissions and air pollution improving European citizens' quality of life and achieving the Paris Agreement and the European Green Deal' objectives.
- Traffic control measures in port city areas with the adoption of 5G technology, thus creating high bandwidth and data resolution, accurate positioning, and real-time visual information on vehicles.
- Evolution of ports and logistics operations to optimize costs and enable innovative use cases. In this regard, an example is the implementation of an innovative IoT-5G solution on trucks that will lead to a substantial reduction in CO_2 emissions and noise enabling cleaner transportation modes.
- Support pit stop operations characterized by prompt delivery of information through the design of an innovative solution to maximize data processing.

5G-LOGINNOV-logistics hub will positively impact the economy (increasing operational and maintenance efficiency and reducing costs) and the environment (reducing emissions of CO_2 and NOx). Furthermore, the promotion of SMEs and startups will ensure that the project's impact becomes widespread and lasting and that there will be broad exploitation of the results made possible by good communication and dissemination.

The project will benefit society by following and strengthening the three main sustainability pillars: profits, planet, and people.[9][67]

This elaborate will be based on a description and contribution to the preliminary phases of the project and will address investigations on port and logistics current situation to find efficient improvements in transport, traffic control, and operating systems management in both areas.

After an introductory part concerning 5G, its potential and applicability, and state of the art on the current situation of this technology in Europe, the main focus of the elaborate concerns logistics and port environment, starting also in this context with a general overview.

The second part of the thesis follows step by step the classification of selected 5G European projects in the field of logistics and ports with the construction of a taxonomy: the final purpose is a statistical analysis of the dataset obtained to discover innovative business models, understand market trends and the strengths necessary to create new promising opportunities for new players.

Chapter 2. 5G State Of Art

2.1 General Overview

In a context characterized by daily challenges, companies continuously try to emerge and adapt their strategies to respond to the growing needs of innovation.
An example is the mobile network technology, which is ready to overtake the current 4G LTE by introducing a new generation of mobile networks, known as 5G.
The fifth generation of wireless technology is not just a new way of communicating through smartphones, but it represents the opening of new services and new markets that will change life and work.

2.1.1 G stands for generation

G recalls the word "generation" of mobile technology, which started with the first commercial 1G mobile network in the world launched by Nippon Telephone and Telegraph Company (NTT) in 1979. It was a cellular network with 88 cell sites with base stations covering all Tokyo districts: phone calls between different cell sites were supported, and there was no more need for a human switchboard operator.

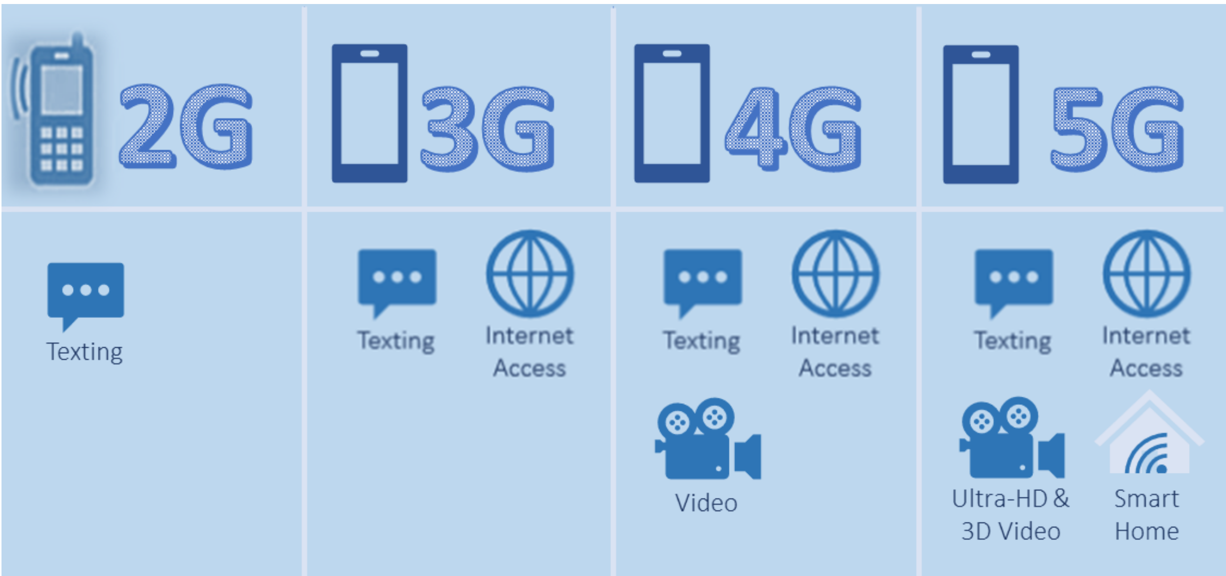


Figure 2.1 - Evolution of Mobile Generations
Source: Personal Elaboration of Gordon More, 5G - The Hype and the Reality, available on: www.idsapp.com/5g-the-hype-and-the-reality, 2020

However, most of the mobile phones in the 1G era were heavy and only destined for corporate and executive use, the coverage was limited with an inefficient use of the electromagnetic spectrum, and different 1G systems were incompatible due to frequency ranges.

With the deployment of 2G in 1991, voice transmissions were digitized, and it was possible to send and receive text messages.
In 1998 the 3G was launched; this generation provided the first internet connection, even if the data speed was only 2 Mbps.
Then, since 2008 the world became 4G (also known as LTE), and this provided data speeds of 10 to 100 Mbps and introduced video transmissions.
Only ten years later, 5G was born, and today it is the subject of the digital transformation. It is considered the last radical evolution of the network since the upgrades will only become software replacement and research for the low-cost supply of raw material components.
If over the years, things were continually enhanced by orders of magnitude, the data rate always multiplied by 10 or 100, the number of devices connected increased, and critical communications improved, prospects for 5G anticipate that it will follow the same trends, but it won't be limited to this. [81]

2.1.2 Small comparison among 4G and 5G

The high-level performance indicators representative of the significant improvements deriving from 5G can support innovative business models and are briefly summarized in the chart.

Parameter	4G	5G (expectations in 2020)
Peak Data Rate	[0,5 - 1 Gbps]	[10 - 20 Gbps]
User Experienced Data Rate	10 Mbps	100 Mbps
Peak Spectral Efficiency	[6,75 - 15 bps/Hz]	[15 - 30 bps/Hz]
Mobility	350 km/h	500 km/h
User Plane Latency	10 ms	250 µs - 1 ms
Connection Density	1.000 devices/km²	1.000.000 devices/km²
Energy Consumption	1 (normalized)	1/10x 4G consumption
Mobile Data Volume	0.01 Tb/s/km²	10 Tb/s/km²

Table 2.1 - KPIs comparison among 4G and 5G
Source: Mischa Dohler, 5G Technical Guide With Overview Details Specifications, available online on: www.techbylight.com/

It is noticeable that the user-experienced data rate average in 4G is about ten megabits per second, while in 5G, it is ten times the previous achievement.
The user plane latency is very low in 5G: if in 4G it was ten milliseconds, in 5G, it will be only one millisecond.

The reduction in latency time can be simplified with the metaphor of fireworks: if in 4G the explosion was witnessed first and then heard loudly, 5G promises to eliminate this lag by making sure that the user sees and hears the explosion meanwhile.
Another expectation regards the speed improvement: it will be achieved mobile and fixed Internet access at a broadband speed of the order of 10 Gbps, about one hundred times faster than the speed theoretically possible with the current technology, LTE.
In terms of connection density, if with 4G, it was possible to connect one thousand devices per square kilometer, upping the game by several orders of magnitude, 5G sustains the connection of millions of devices.
Therefore, as a result of the comparison, this radical innovation is not mere progress from the previous generation of 4G. It is destined to revolutionize the industry and society both from a technological and a business point of view by merging the mobile phone industry with the Information Technology (IT), and it will support many innovative applications such as the Internet of Thing, the virtual and augmented reality, the artificial intelligence, and the development of scenarios addressing heterogeneous market segments.
If, on the one hand, the 5G technology will have an exponential increase in the data volumes and a growth in the number of devices connected, on the other hand, it will need to support network operators and cope with that considerable data growth.[99]
The mobile network operators (MNOs) have to build a dense network with many nodes to form the 5G infrastructure. Thus, they won't remain only telco operators but become system integrators for the 5G ecosystem, constituted of a single network flexible enough to handle various use cases.
5G brings the necessity of a review of actual market players' business models, from mobile operators to those working in vertical sectors.[107][94][95]
Moreover, it will be the enabling technology allowing not only the connection of people but also objects, platforms, and infrastructures, leading to the creation of ecosystems.
The fifth-generation technology must be interpreted as an element at the service of citizens and businesses that will make greater efficiency achievable in various areas, such as autonomous vehicles, smart cities, and smart buildings, telemedicine, agriculture, areas not covered by the network, and all types of intelligent connected devices.
The most significant impact will be on Industry 4.0, offering the best performances for latency and high reliability and increasing the availability of connection densities even in a specific industrial area or district.

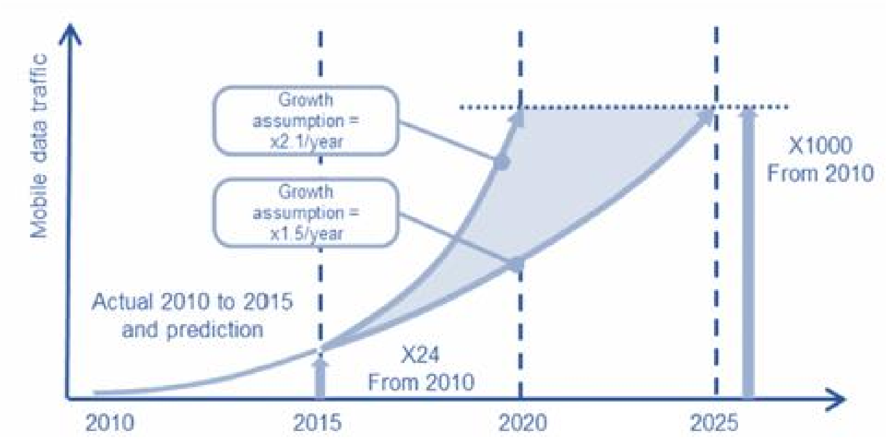


Figure 2.2 - Projected Growth of Mobile Data
Source: ARIB 2020 and Beyond Ad Hoc Group White Paper, 2014

The following chart concerning the data growth projections shows a forecast of the timeline between 2020 and 2025 at the launch of 5G, and it is noticeable that mobile data traffic grows 1000 times more than 2010, known as the starting year of 4G.

If wireless communication technology was already making headlines before the crisis, wireless networks' value has become incredibly intense as part of the global response to the Covid19 pandemic, where millions worldwide are staying at home. In fact, with social distancing and restrictions, digital activity has reached an unprecedented spike, and media streaming services and video calling technologies have become fundamental means to maintain contact with friends, family, and at work. This next-generation technology empowers the further step in the communication revolution, overcoming today's goal of connecting everyone to reach a new world where everything and everywhere can be connected.

2.2 5G Features and Network Requirements

As anticipated, 5G will be a crucial element in achieving digital transformation.
5G network is expected to create optimized environments in support of various business verticals, specific industries, or markets focused on different niches. After introducing the 5G KPIs and comparing 4G, below the main features that distinguish 5G from the previous generations are introduced and a scheme of its network requirements.

2.2.1 Main Features

The fifth generation of mobile data will be so fast to make possible the implementation of IoT in a situation where all the objects of our daily lives will be connected to the internet and communicate among themselves. All this will be made possible by some specific innovations on which 5G will be based:

Massive MIMO

The first is the Massive MIMO, simply an upgrade of the 4G towers that are in use today. The current buildings are equipped with only a dozen antennas that manage all the incoming and outgoing data traffic, while 5G repeaters, furnished with massive MIMO, will support up to a hundred antennas, exponentially increasing their traffic management capacity.

MIMO systems require a combination of antennas and complex algorithms. With its MIMO algorithms that control how data is mapped in antennas and where energy is concentrated in space, MIMO was already adopted in wireless communications to improve connectivity and deliver better speed, user experiences, and close coordination between devices.

With the design of new networks, MIMO becomes "massive" and crucial for 5G NR deployments.

Massive MIMO, an extension of MIMO, expands beyond legacy systems by adding so many antennas on the base station. The "huge" number of antennas helps concentrate energy and allows drastic enhancements in performance and efficiency. Along with the increase in the number of antennas, both the network and mobile devices implement more complex designs to coordinate MIMO operations and achieve performance

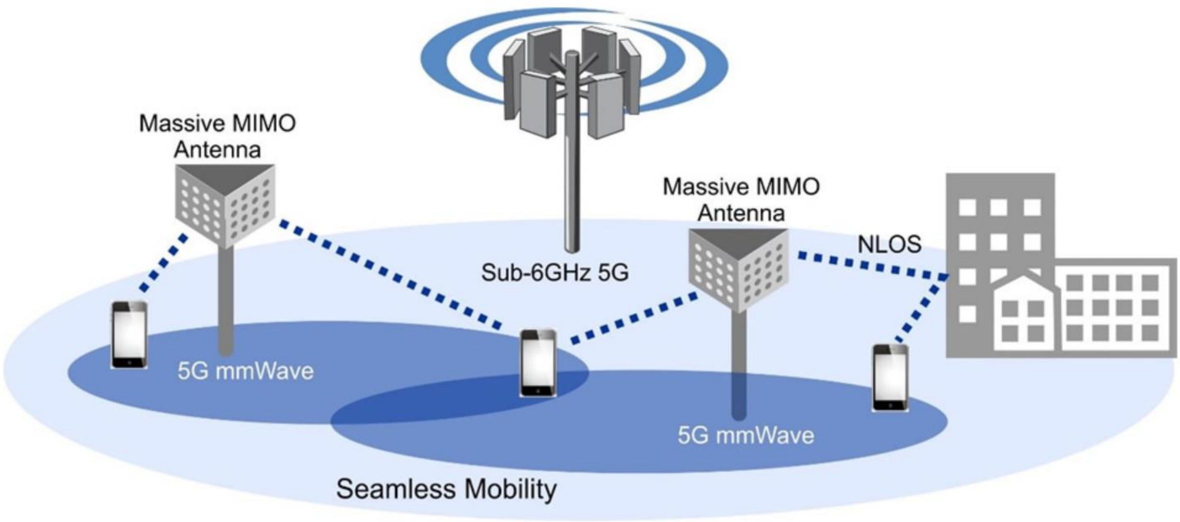


Figure 2.3 - Massive MIMO antenna and 5G System
Source: www.accton.com/Technology-Brief/the-emergence-of-5g-mmwave

improvements necessary to sustain the 5G experiences consumers anticipate in this new era.

NLOS, in the chart, stands for non-line-of-sight and refers to the possibility of capturing reflected signals and use them to complement the line-of-sight (LOS) signal, increasing channel capacity. It is, therefore, feasible to use reflected signals and maintain a link to a mobile device even when it moves entirely out of the LOS of the transmitter. For this reason, it can be expanded to the role of mmWave for 5G mobile broadband.

Beamforming

As the name suggests, beamforming is used to direct radio waves to a specific recipient, structuring the radio signal to focus it in one particular direction. The technique is based on the use of in-phase antennas and consists of modulating the power of the individual elements of the antenna to generate constructive interference on signals directed towards a given angle and destructive on indications directed towards different angles. It increases the signal quality and the data transfer rate in the selected direction. In 4G, each antenna transmitted its signal in all directions, often creating interference or confusion in the data traffic. With beamforming instead, each antenna will be able to direct a specific data flow towards a particular device, minimizing interference and making it easy and manageable to connect many more users simultaneously.

New Frequencies and Millimeter Wave

The third 5G innovation concerns the radio waves used by the new network. The 5G network will, in fact, also use radio with frequencies higher than those generally used for 4G networks or for home Wi-Fi, including frequencies ranging from 24 to 300 gigahertz, the so-called millimeter waves, which will be able to carry much more data faster and which will permit to reach speeds of one gigabit per second. As a metaphor, if the 4G network, in terms of speed, is a car, the 5G network will be a thermonuclear missile rocket.

The frequency currently used is between 800 MHz and 2.6 GHz, and it is this one only, while 5G will embrace three different frequency bands: 700 MHz, 3.6-3.8 GHz, and 24-28 GHz.

The new radio access networks in wavebands between 24 and 28 GHz, often identified as "millimeter waves," make it possible to take advantage of much wider communication channels than lower frequencies. Also, they can guarantee higher data transfer speeds and lower latency. According to the GSMA, by 2034, the portion of the spectrum ranging from 24 to 86 GHz will increase the global GDP by 565 billion euros. [115][101][106]

However, millimeter waves have a defect: they cannot travel very far and do not have an excellent penetration capacity. Moreover, they are rapidly absorbed and dispersed by solid materials that encounter.

Small Cells

An issue arises from the fact that millimeter waves, compared to the lower frequency ones used by previous communication standards, have more difficulty overcoming obstacles. The low propagation capacity of mmWaves, especially in large cities, is the reason why this other innovation linked to new technology will be needed.

It will be necessary to increase the number of repeaters in the area to ensure stable coverage. This result can be achieved if there is a transition from the current antennas to the most innovative small cells, repeaters covering a radius that can range from a few tens of meters to about 2 kilometers. The small cells are minor repeaters much closer to each other than the 4G towers, and they will be installed in strategic points, creating a grid that will allow bypassing obstacles and always keep the connection to the network constant.

Small cells offer flexibility and increased QoS capabilities at an appealing cost. Moreover, implementing a small cell infrastructure is more sustainable as well.

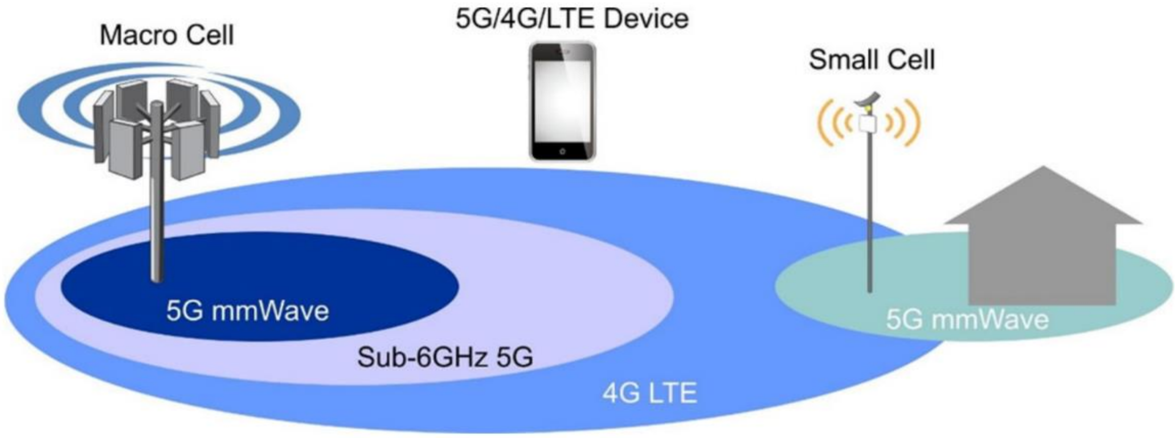


Figure 2.4 - Configuration of a 5G System
Source: www.accton.com/Technology-Brief/the-emergence-of-5g-mmwave

However, it should be considered that small cells present lower performances in propagation compared to the frequency bands already in use, and there are high physical costs for the connections with the referring macro cell, for the installation, and the numerous access rights to urban infrastructure.[115]

The 5G system differs not only because it gives better transmission capacity but also because it becomes a platform enabling new services: with the 5G system, the network virtualization is reached and, therefore, the possibility of using the 5G system as an evolutionary platform for provision of services to verticals. If the virtual machines are put inside the cloud, it is possible to create different service types.

However, if the previous characteristics were inherited from the 4G system, the full virtualization is the pure innovation of the 5G system, and it permits to perform the slicing of the network, so the selection of resources based on users or services requirements of a particular type.

Network Slicing and SDN

Network Slicing is a network architecture and refers to the ability to define a set of logical or virtual networks on the same physical infrastructure, independent one each other, and capable of operating simultaneously, at total efficiency and without interference as if each had a physical network dedicated to the software process.

Each "slice" of the network is a complete network specifically tailored to meet all the requirements of a particular application.

Partitioning the network makes it possible to use different security levels from multiple virtual networks on a single physical infrastructure. This technology plays a central role in 5G mobile networks intended to effectively support many services with very different Service Level Requirements (SLRs).

Slices can differ in functionality (such as priority, policy control, and security), in performance of requirements (latency, availability, reliability, and data speed), or they can only serve specific users (for example, public safety users, corporate customers, or industrial users). Each network slicing is administered by a mobile virtual network operator (MVNO) from a business model perspective. The infrastructure manager rents physical resources from virtual operators who share the same physical network and, depending on the availability of allocated resources, each MVNO can, in turn, create its own "network slices" customized to the various applications required by its customers.

If network slicing has proved to be a key technology for effectively managing this new market model in which all the various applications, even very different ones, rely on the same infrastructure, space must be dedicated to Software-Defined Networking (SDN), and virtualization of network functions.

The SDN is what allows real-time partitioning of the network at the base of network slicing, to manage each slice as if it were an independent network and to dynamically and automatically coordinate the overall distribution of resources between the portions, for example, by allocating bandwidth where and when it is needed based on the characteristics and temporary requests of the service. Software-Defined Networking (SDN) will enable the control of network resources to be opened to third parties.

Virtualization (VNF)

Therefore, another innovation in the 5G network sphere will be that the network functions that typically run on hardware will be virtualized, functioning as software.

In this way, the 5G network can be used to all intents and purposes as an internet service provider on mobile infrastructure and provide assistance information to enable the network and select the correct network segments. Then, the network operator checks which sections should be available for a specific device and offers the associated subscription.

VNF indicates that entire network node functions are virtualized as building blocks that can be interconnected to implement communication services through IT technologies.

Concerning network virtualization, it will be functional to this management model and reduce infrastructure costs and integrate more sophisticated services based on solutions running on software instead of hardware.[106][91]

Cloud and Edge computing

Cloud computing and its benefits are already well known in the business world. The Covid-19 crisis has concretely demonstrated its value by allowing millions of companies to operate seamlessly, even remotely. To date, 85% of companies believe that cloud adoption is necessary for innovation. On the other hand, as regards edge computing, it is a more innovative concept that is even advantageous in some cases of use compared to the traditional centralized cloud infrastructure. However, using one technology does not necessarily exclude the need to use the other: both play an essential and distinctive role within an IT ecosystem.

In comparing edge and cloud computing, the main difference is where the data processing takes place. In the cloud, data is stored and processed in a central data center, while with edge computing, data processing takes place closer to the device.

The user will receive content after recognizing, interpreting, and reasoning on extensive data information collected through various sensors in the coming years.

For this reason, the use of mobile edge computing will be a convenient solution to reduce network delay and maximize efficiency by providing a prompt and timely response also in the case of any disaster; it can be helpful also for intelligent cars, innovative health care, industrial automobiles, augmented reality and gaming, and to offset climate change and industrial accidents.

Data processing at the edge reduces the operational constraints of the cloud. Combined with data centers, edge computing can address more localized data processing, freeing the cloud for more general business needs and helping applications run faster.

Besides, edge computing helps to avoid the criticality of delay due to latency by moving data processing closer to the device that processes the information.

Finally, with the increase in the number of people working remotely, cybercriminals have a greater chance of accessing corporate data and misusing this information. By reducing sensitive data transfers between devices and the cloud, security is significantly strengthened.

SA and Non-SA infrastructure

In the short term, the 5G network is not intended to replace existing systems but will work in conjunction with existing 4G networks. New frequencies will be activated, close to those currently in use for mobile devices, and an additional spectrum at lower and higher frequencies.

However, before 5G networks reach their full potential and become self-sufficient, existing 4G with the LTE RAN radio access networks that will be strengthened with some new antennas will still be widespread. In this way, the offer of improved services will begin, and, in the meantime, the new physical infrastructure will be built.

There are two infrastructure alternatives for a 5G network, the non-autonomous and the autonomous infrastructure. A non-autonomous (or non-stand-alone) infrastructure is partly based on the existing 4G LTE framework and puts together some new technologies such as 5G New Radio (NR). The autonomous distribution option is instead composed of the RAN, which includes the NR and the 5G core network, and it is expected to have lower cost, better efficiency, and assist the development of new use cases. The 5G core network relies on the service-based architecture framework with virtualized network functions (VNF) described before.

5G NR is the new radio access technology foreseen in the latest generation mobile communications standard, which is significantly different from LTE: it is characterized by the new frequency bands below and above 6 GHz and offers broad flexibility in the choice of physical radio parameters, such as channel bandwidth, distance and signal duration.

These characteristics substantially impact signal propagation and, consequently, increase the need for accurate coverage measurements to verify the 5G NR network and related base stations' correct planning.

Cell towers represent a crucial cellular communication element and cover medium and large geographic areas in 5G networks. 5G RAN focuses on mid-range and lower-range radio frequencies such as frequencies below 6 GHz which can cover a larger space but carry fewer data. This part of the 5G infrastructure will be used more often for less populated areas where there is less network congestion, allowing faster speeds with a more dispersed infrastructure.

In short, the 5G system will provide a flexible technology framework where networks, devices, and applications can be co-optimized to meet the wide variety of requirements by operating across multiple spectrum bands, ranging from radio frequency bands to millimeter waves.[116]

Private 5G Network

In conclusion, the concept of Private 5G Network is described.
First of all, it must be considered that both network slicing and private networks will be important for next-generation mobile networks, but they will have different applications. This new generation of private 5G networks is emerging right now to meet critical wireless communication requirements in public safety, infrastructure, and industry.
It is in the first phase of experimentation and its application today appears only in some of the most recent projects, and tests and trials on it are expected for the following years in order to have an emerging design by 2030.
These scenarios include public safety, but also manufacturing, airports and ports, financial institutions, logistics, hospitals, etc.
The emergence of Private LTE and Private 5G has shown that many companies do not want to share hardware or software infrastructure with other companies, especially with their competitors. Indeed, private networks will require connectivity platforms and dedicated core networks to provide businesses with complete network isolation, offering greater control, reliability, and deterministic quality not shared with other customers.

2.2.2 KPIs and Core Network Requirements

Below are the performance indicators that allow measuring the achievements of 5G processes and the core networks' requirements, which can be used as guidelines for standardization, implementation, and diffusion of this innovative ecosystem.[116]

The KPIs are briefly described in the following chart:

Technical Requirements	Description
High data speed	○ Provide tens of Gbps peak data rate ○ Provide up to 1 Gbps user experienced data rate ○ Provide areal capacity of 10 Mbps per square meter
Ultra-low latency	○ Provide less than 1ms latency over radio interface
Reliability	○ Provide 99.999% service availability even in an extreme situation ○ Guarantee a single packet transmission failure per 10,000 or 100,000 transmissions
Mobility, Security and Flexibility	○ Guarantee seamless connectivity to moving terminal at speed of 500 km/h
Efficiency	○ Improvement of 100 times energy efficiency per bit, in both network and device sides ○ Energy harvesting capabilities can be applied to sensors
Cost Effectiveness	○ Improve cost effectiveness in network side even handing huge volume of traffic ○ Reduction of devices' cost especially in sensors
Massive connection density	○ Identify all devices (maximum of one trillion devices) over the world ○ Provide services to a million terminals per square kilometre

Table 2.2 - 5G Technical Requirements
Source: Personal Elaboration of Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

These indicators characterize 5G and allow it to improve or enable many different applications that weren't available only with the previous technologies.
Instead, as regards the core network requirements of the system, they are divided into three subgroups in support of various 5G services:

- Functional requirements (F)
- Architectural requirements (A)
- Operational requirements (O)

and they are briefly described in the table below:

Core-Network Requirement	Subgroup	Brief Description
Seamless mobility	F1	Shall support seamless mobility regardless of the cell types and RATs where the macro-cell BSs, small-cell BSs, WLAN APs, and relay stations are mixed and overlapped
Wired/wireless terminal switching	F2	Shall support terminal and/or session mobility to provide fast handover between wireless and wired terminals
Context-aware best connection	F3	Shall utilize the various context information (device, user, environment, network) to provide always best connection/service
Single ID for multiple access	F4	Shall recognize a mobile terminal as a single entity regardless of its access network
Distributed architecture	A1	Shall support the distributed network architecture to accommodate anticipated 1000 times of traffic
Lightweight signaling	A2	Shall have lightweight signaling to support a variety of terminals such as massive MTC terminal
Multiple RAT interworking	A3	Shall have architecture to support 'Flow over Multi-RAT' to provide the high volume service with low cost and guarantee the service continuity in spite of the bandwidth deficiency in a wireless access
Fine-grained location tracking	A4	Shall have function to trace the mobile terminal location in a fine granularity in order to provide advanced location based service
Flexible reconfiguration and upgrade	01	Shall provide virtualization environment and support to reconfigure and upgrade the core network at low cost without changing the physical network infrastructure
Network on-demand	02	Shall be able to build the network based on the QoS/QoE, charging and service characteristics

Table 2.3 - 5G Core-Network Requirements
Source: Personal Elaboration of Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

2.3 5G Standards

2.3.1 Global Initiatives

In the world of 5G standards, different global initiatives try to categorize 5G services. The minimal rules to define the technical characteristics of 5G are described in the document "Minimum requirements related to technical performance for IMT-2020 radio interface(s)" redacted by ITU in 2017. ITU is the "International Communication Union" or the ONU agency establishing international radio spectrum policies.
However, as will be seen later, some additional features have been added to these requirements by 3GPP.
Here there is a schematic presentation of the predominant initiatives in the world of 5G standards that will be described later:

Figure 2.5 - Global Standards for 5G
Source: Personal Elaboration

To start, it is fundamental to remark the principal role of 3GPP (Third Generation Partnership Project). It represents the operating engine for the entire telecommunications industry, and it is the primary organization for creating standards in mobile communications. In simple terms, it is the body that allows making a phone call wherever the user is situated, standardizing the process.
Its current 5G standardization time plan concerns the span between 2015 and 2021 and aims to gradually realize the full 5G capabilities in four consecutive releases. Indeed, 3GPP has concluded that it is unrealistic to implement all functionalities for 5G in a single release; thus, new features and improvements of previous versions have been implemented in the various releases, as described above.[1]
There follows a short description of the releases, including the first one relevant to the introduction of 5G, started in 2015, and the last one still in the phase of deployment:

- Release 15 concerns the first phase of the technology's standardized commercialization and is the new generation of wireless standards' technical foundation. It includes an autonomous capability for RAN, the first specification for mmWave communication, and a focus on commercializing the EMBB part of 5G. However, it is only an initial work, and it will be necessary to add ideas and improvements to it. There is a lack of mmWave space mobility features, a lot of work on IoT requirements, and improvements in system capacity and energy efficiency.

- Release 16 aims to find improvements for dynamic spectrum sharing and to distribute it across production networks. There is the introduction of the concept of Industrial IoT and the applications related.
- Release 17 regards the expansion of mmWave with an extension up to 71 GHz. More than one sim will be supported in a single device, and the focus will be on enhancing the concept of Industrial IoT introduced with the previous release. Further implementations for access and backhaul and spectrum sharing via MNOs should also be mentioned.
- Release 18 main objective is the Massive IoT. It is about a category driven by scale rather than speed. In fact, massive IoT deployments can include hundreds to billions of connected devices. The main goal of these applications is to efficiently transmit and consume small amounts of data from a large number of devices. Moreover, this release includes further improvements to NR positioning and location-based services and a few other features, but it is still in the preliminary phases.

The timeline of 3GPP and its releases can be observed in the timeline based on the roadmap inserted below:

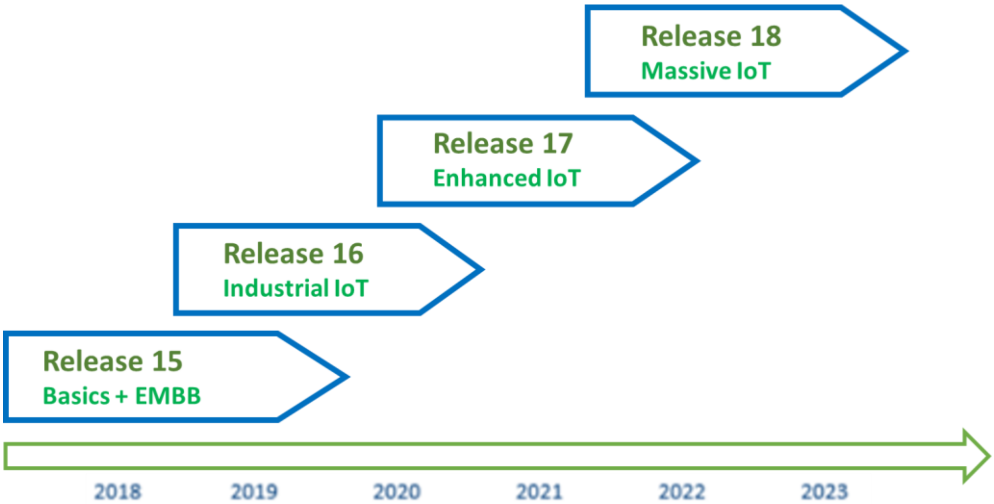


Figure 2.6 - Timeline of 3GPP Releases
Source: Personal Elaboration

Other initiatives are the GSM and NGM, fully operator-led initiatives in which they set requirements on what nearly drives 3GPP and the type of ITU standards development previously anticipated.

Subsequently, IEEE, the Institute of Electrical and Electronics Engineers, is the largest professional association in the world dedicated to advancing technological innovation and excellence for humanity's benefit. It covers technical areas ranging from aerospace systems, computers, and telecommunications to biomedical engineering, electrical power, and consumer electronics. It pays particular attention to the wired part between the radio station at the antenna, the Remote Radio Head (RRH), and the unit in baseband, the Base Band Unit (BBU), to connect to the mobile network and to define a new ethernet format on the network architecture capable of transporting data more efficiently and according to the functional subdivisions defined by 3GPP. Finally, the IEEE working groups are also collaborating on synchronization standards for multiple networks to ensure that the radio unit's network time is kept at the level required by the type of traffic being carried.

Then, there is ETSI, the European Telecommunications Standards Institute, which produces globally applicable ICT standards. Here, a specific group for Network Functions Virtualization (ETSI ISG NFV) plays the leading role in standardizing the infrastructure aspects of 5G networks as they become virtualized and softwarized.

Another standard is the Internet Engineering Task Force (IETF), a large open international community of network designers, operators, suppliers, and researchers interested in the evolution of the Internet architecture and the smooth functioning of the Internet. All participants and managers are volunteers, although their employers or sponsors usually fund their work. While the Internet Engineering Task Force (IETF) focuses on the short-term issues of engineering and standards creation, the Internet Research Task Force (IRTF) focuses on long-term research issues by promoting research relevant to the evolution of the Internet and creating targeted research groups.

In the end, the International Telecommunication Union (ITU) is the United Nations specialized agency for information and communication technologies (ICT) and coordinates the international standardization of 5G systems. In 2012, ITU established a program on "International Mobile Telecommunications for 2020 and beyond", also known as IMT-2020, providing the framework for 5G research and development worldwide.

Moreover, in 2017, as preannounced in the paragraph introduction, ITU members have defined the framework, and overall objectives of the IMT-2020 standardization process, and a roadmap to guide the entire action of global radio spectrum and satellite orbits will be allocated. [87][1][3]

Subsequently to the ITU IMT-2020 standard, which required a peak speed of 20 Gbit/s in download and 10 Gbit/s in the upload, the 3GPP industry standardization group proposed a contribution to it, present the 5G NR (New Radio) and LTE standards, approved and, in July 2020. This proposal officially entered into force as a reference for the standard 5G, defining a specific new air interface. [94][95]

2.3.2 3GPP Organizational Structure

To better clarify the context and the models through which these initiatives operate, now it is introduced a detailed description of the 3GPP business model and composition, exploring its operation and functioning.

3GPP is a consortium of 700 companies and is the most known of the 5G initiatives.

The 3rd Generation Partnership Project (3GPP) ties together seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), also known as "Organizational Partners" and offer a stable location to define 3GPP technologies.

First of all, it is made up of 3 groups:

- PCG, a project coordination group, which is responsible for the direction of the activities;
- TSG, a group of specifications that extrapolates the technical characteristics necessary for the elements under analysis;
- WG, a class referring to a specific TSG, for which defines the practical standards of competence.

The 3GPP groups are organized as in the table below:

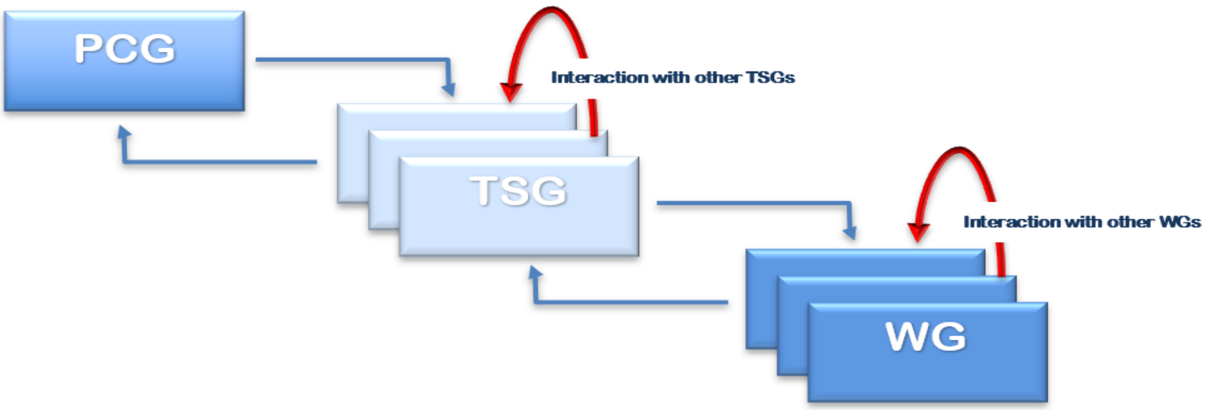


Figure 2.7 - 3GPP Organizational Chart
Source: Personal Elaboration

The PCG is the highest decision-making body in 3GPP. It formally meets every six months to carry out the final adoption of the 3GPP Technical Specification Group's work elements and ratify the election results and the organization's resources. The Project Coordination Group (PCG) is responsible for the overall timing and management of the technical work to guarantee that the 3GPP specifications are produced promptly when required by the market and according to the principles and rules contained in the project resource materials (description of the partnership project, partnership project agreement, partnership project work procedure).

Specifically, the PCG is responsible for:

- Determination of overall time and management of the work progress.
- Final adoption of work items under the agreed 3GPP scope.
- Allocation of human and financial resources budgeted to each TSG as required by the Organizational Partners.
- Election of TSG Chairman and PCG President.

Figure 2.8 - TSG Structure
Source: Personal Elaboration

Concerning the TSG, each column represents a different group:

- Radio Access Network (RAN): this branch represents the radio aspect and its corresponding levels.
- Service and System Aspects (SA): this department defends the service capabilities of systems and the overall architecture.
- Core Network and Terminals (CT): the last division concerns the specifications of the terminal interfaces.

Each TSG is responsible for preparing, approving, and maintaining specifications within its terms of reference. It can organize its work in working groups maintaining contact with other groups if appropriate.

So, each WG refers to a TSG and meets regularly with it (on average five to six times a year) to show its results. The work of WGs in 3GPP is based on the technical contributions of the individual companies.

The activities are divided into SIDs (Study Items) projects, constituted of a feasibility study to evaluate the advantages and disadvantages of new functionality, and WIDs (Work Items) regarding the work on regulations and policies that require the production of technical specifications.

The deliverables of a SID are often Technical Reports TR that have no regulatory value but provide the analysis of a problem and help the group gain greater awareness of its technical aspects and the best solutions.

At this stage of understanding the topic, a WID's approval subsequently allows creating new Technical Specification TS, or functional improvements Change Request CR to existing specifications.
While the technical activity on the SIDs and WIDs is mainly the Working Groups' responsibility, the task of the TSGs is, in the final analysis, to approve the deliverables produced by the WGs as well as the proposals for new SIDs or WIDs.

2.3.3 3GPP Stakeholders

This initiative's success is undoubtedly linked to the wealth of human resources involved. Furthermore, the number of companies participating in 3GPP activities is continuously growing and reached 450 members in 2015, representing 41 countries worldwide. Telecom Italy has contributed to 3GPP since its foundation, remaining for all these years a key interlocutor and acting in the various groups, WG, TSG, and PCG, with its team of around twenty people. It also held positions of responsibility in some cases, currently counting five presidencies and vice-presidencies.[1][95]

2.3.4 Use case Classification Differences among 5G Global Initiatives

The standardization organizations described previously, ITU, NGMN, and 3GPP, offer a framework to support different use cases.
Now it will be described their different approaches to classify the enabled scenarios.
The first categorization analyzed is realized by the ITU, which groups together the 5G services in three categories: eMBB, mMTC, and URLLC.
NGMN proposes 14 categories of services and 24 use cases instead.
Lastly, 3GPP suggests five service categories and 97 use cases for 5G mobile services.
The chart compares the three aggregation methodologies adopted by the three initiatives and enhancing the existing relationships established by the common technical requirements. [116]

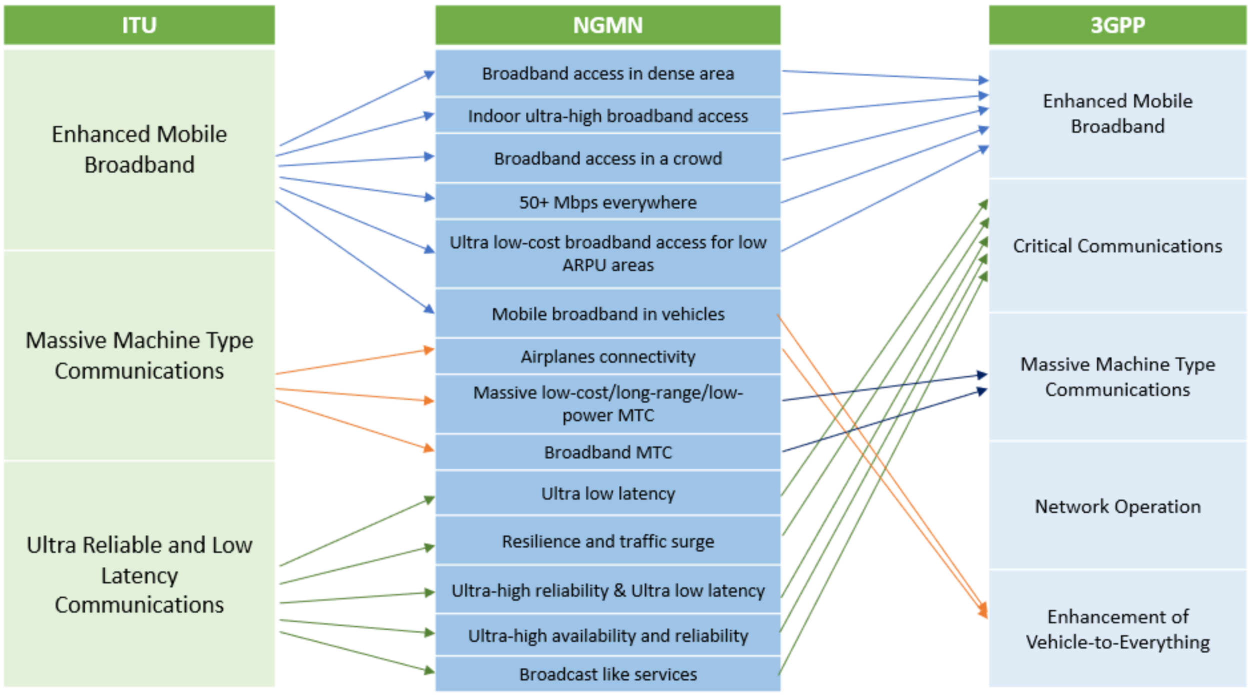


Figure 2.9 - Common Elements Among Different Use case Classifications
Source: Personal Elaboration of Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

ITU Functionalities

In ITU, as anticipated, there are 3 scenarios: eMBB, mMTC, and URLLC.

As can be seen from the chart below, in eMBB the peak data rate, user data transmission rate, spectrum efficiency, mobility, energy efficiency, and area traffic efficiency have great importance. In mMTC service scenarios, the huge number of devices connected in crowded areas need a high and effective connection density to ensure reliable, uninterrupted operations. Then, in URLLC service cases low latency and mobility are the most important elements.

Service Category	Peak Data Rate	User Experienced Data Rate	Spectrum Efficiency	Mobility	Latency	Connection Density	Network Energy Efficiency	Area Traffic Capacity
eMBB	High	High	High	High	Medium	Medium	High	High
mMTC	Low	Low	Low	Low	Low	High	Medium	Low
URLLC	Low	Low	Low	High	High	Low	Low	Low

Table 2.4 - Technical requirements for 5G services in ITU
Source: Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

NGMN Use Cases

	User Experienced Data Rate	End-to-end Latency	Mobility	Device Autonomy	Connection Density	Traffic Density
Broadband access in dense area	DL: 300 Mbps UL: 50 Mbps	10 ms	On demand, 100 km/h	>3 days	2500/km² (Activity factor: 10%)	DL: 750 Gbps/km² UL: 125 Gbps/km²
Indoor ultra-high broadband access	DL: 1 Gbps UL: 500 Mbps	10 ms	Pedestrian	>3 days	75,000/km² (Activity factor: 30%)	DL: 15 Tbps/km² UL: 2 Tbps/km²
Broadband access in a crowd	DL: 25 Mbps UL: 50 Mpbs	10 ms	Pedestrian	>3 days	150,000/km² (Activity factor: 30%)	DL: 3.75 Tbps/km² UL: 7.5 Tbps/km²
50+ Mbps everywhere	DL: 50 Mbps UL: 25 Mpbs	10 ms	120 km/h	>3 days	400/km² in suburban 100/km² in rural	DL: 20/5 Gbps/km² (suburban/rural) UL: 10/2.5 Gbps/km² (suburban/rural)
Ultra low-cost broadband access for low ARPU areas	DL: 10 Mbps UL: 10 Mpbs	50 ms	On demand, 50 km/h	>3 days	16/km² (Activity factor: 10%)	DL: 16 Mbps/km² UL: 16 Mbps/km²
Mobile broadband in vehicles	DL: 50 Mbps UL: 25 Mpbs	10 ms	On demand, up to 500 km/h	>3 days	2000/km² (Activity factor: 10%)	DL: 100 Gbps/km² UL: 50 Gbps/km²
Airplanes connectivity	DL: 15 Mbps UL: 7.5 Mpbs	10 ms	Up to 1000 km	N/A	80 per plane 60 planes/18,000 km²	DL: 1.2 Gbps/plane UL: 600 Mbps/plane
Massive low-cost long-range/low-power MTC	Low (typically 100 kbps)	Seconds to hours	On demand, 500 km/h	Up to 15 years	Up to 200,000/km²	Not critical
Broadband MTC	DL: 300 Mbps UL: 50 Mpbs	10 ms	On demand, 100 km/h	>3 days	2500/km² (Activity factor: 10%)	DL: 750 Gbps/km² UL: 125 Gbps/km²
Ultra low latency	DL: 50 Mbps UL: 25 Mpbs	< 1 ms	Pedestrian	>3 days	Not critical	Potentially high
Resilience and traffic surge	DL: 1 Mbps UL: 1 Mpbs	Not critical	120 km/h	>2 weeks	10,000/km²	Potentially high
Ultra-high reliability & Ultra low latency	DL: 10 Mbps UL: 10 Mpbs	1 ms	On demand, 500 km/h	Not critical	Not critical	Potentially high
Ultra-high availability and reliability	DL: 10 Mbps UL: 10 Mpbs	10 ms	On demand, 500 km/h	>3 days	Not critical	Potentially high
Broadcast like services	DL: Up to 200 Mbps UL: Modest	< 100 ms	On demand, 500 km/h	From days to years	Not relevant	Not relevant

Table 2.5 - Technical requirements for 5G services in NGMN
Source: Personal Elaboration of Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

NGMN has 14 categories of services whose technical requirements (user data rate, end-to-end latency, mobility, device autonomy, connection density, traffic density) can be seen in the table above. The values stated in correspondence with the requirements represent the extreme use cases in the category.[98]

3GPP Use Cases

The 3GPP has recently completed its feasibility study on new services and technology enabling markets (SMARTER). It identifies potential high-level requirements (data rate, latency, reliability, efficiency, traffic and connection density, mobility, location accuracy) for each category of services.

The table shows the technical requirements for 5G in the categories indicated by 3GPP and in the technology enabling markets (SMARTER).

	Data Rate	Latency	Reliability	Communication Efficiency	Traffic Density	Connection Density	Mobility	Position Accuracy
Group eMBB	Very high data rate (e.g., peak rate 10 Gbps)	Very low latency, Low latency for high speed, Reliable low-latency connectivity between aerial objects	-	-	High traffic density	High density for UE (e.g., 2500/km², 50 active Ues simultaneously)	500 km/h	-
Group CriC	-	Real-time low latency (e.g., as low as 1 ms end-to-end)	Ultra high reliability, High availability	-	High density distribution (e.g., 10,000 sensors/10 km²	-	-	Precise position within 10 cm in densely populated areas
Group mioT	-	-	-	Coverage enhancement, Efficient resource and signaling to support low power, Support decives with limited commnications requirements and capabilities	High density massive connections (e.g., 1 million connections/km²)	Low mobility	-	High positioning accuracy in both outdoor and indoor scenarios (e.g., 0.5 m)
Group eV2X	Medium rate (10 of Mbps per device)	Low latency (e.g., 1 ms end-to-end latency)	High reliability (nearly 100%)	-	Medium traffic density	Medium connection density	High mobility (e.g., up to 500 km/h)	High positioning accuracy (e.g., 0.1 m)

Table 2.6 - Technical requirements for 5G services in 3GPP
Source: Personal Elaboration of Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

This feasibility study has been consolidated by grouping the 74 use cases resulting from the first phase of 3GPP in four different Technical Reports, each of them, in turn, related to another class of use cases.

The categories cover improvements in mobile broadband, critical communications, and massive machine-type communications similar to the ITU classification. The main difference is that 3GPP defines an additional class relating to Network Operations. This category does not focus on the requirements for the provision of specific services, but in particular, describes the operational conditions that 5G networks must meet. From these reports, it was obtained a legislative document, named the "Service requirements for next-generation new services and markets."

As a conclusion to this paragraph concerning standards, it is also essential to communicate the existence of other principles imposed, for example, by policy groups: they are policy and compliance requirements, and they will be analyzed deeply in the next chapter relating to policies and missions undertaken in Europe and worldwide.

2.4 Use cases and Applications

After a general overview of 5G in terms of characteristics and technical requirements, the applications that 5G enables as a disruptive technology are introduced.

5G breaks the paradigm of cellular systems until now used for communications between the network and human beings and evolves to accommodate all the services and

applications of the IoT and other existing technologies and contribute to the development of the applications of the future.
In this paragraph, after a general introduction to the IoT and other technologies with which 5G collaborates, such as AI, AR and VR, and Blockchain, some of the most common applications will be seen, following classifications according to two different perspectives. Then, concerning the use cases, the aforementioned ITU classification and the End-User based approach will be presented in detail. While describing the second approach, parallelisms will be made with the first one, and the main applications for each use case will be outlined.
Then, a relationship analysis will be carried out among technical requirements and core network requirements described in the previous paragraph, and the most common applications enabled by the different use cases.

IoT

The Internet of Things represents the network of physical objects, called "things," which are embedded with sensors, software, and technologies to exchange data with other devices and systems, that can be ordinary objects or sophisticated industrial tools on the Internet.
The IoT has become one of the most critical technologies of the 21st century, the era that corresponds with the digitalization and connection of everyday objects to the Internet via embedded devices.
There are various types of sensors: today, human beings are approximately 8 billion on our planet, and there are already twice or three times this number of active sensors. For the next decade, a number from 1000 up to10000 sensors per human being are expected.
The sensors scattered around the territory are intermediated towards the cloud, the distant datacenter described above, through gateways that preprocess the data to transmit only the useful ones. With edge computing, the reduction in latency and significant reliability will be possible through the edge cloud's localization near sensors, eliminating the need for intermediation. So, through the cloud, big data analytics, and mobile technologies, the physical world meets the digital world, and they cooperate.

AI

Artificial Intelligence is the branch of computer science that studies the development of hardware and software systems endowed with the specific abilities of the human being and able to autonomously pursue a defined purpose by making decisions that, until that moment, were usually entrusted to humans. Some examples of activities in which

AI replaces the human being are learning, reasoning, planning skills, and interaction with people, machines, and the environment.
An AI system is based on algorithms that process a massive amount of data, and from these, the system itself must derive its understanding and reasoning skills.

AR and VR

Augmented and Virtual Reality opens up a world of new possibilities for museums, aquariums, science centers, and theme parks and puts the proposed experiences into context like never before.
"Augmented Reality" refers to a technology capable of imposing the digital world on the offline world, "increasing" the user's perception of the latter.
With AR, virtual reality and material reality become a single dimension with infinite possibilities and applications.
Our world is thus enriched by awareness and impressions that would not be possible to experience otherwise.
With Virtual Reality, on the other hand, the referring is to a technology capable of creating an authentic, entirely digital reality. It is a total reconstruction from scratch of a virtual environment, a simulation of facts aimed at the user's complete immersion, who is transported into a sort of "new dimension."
VR requires special viewers capable of showing the user the recreated digital reality.
In addition to the viewers, it is also possible to use gloves, earphones, and other devices that stimulate other senses and interact with Virtual Reality for a major involvement.

Blockchain

The Blockchain is a technology that allows the creation and maintenance of an extensive distributed database for the management of transactions; this bank of data is immutable, cryptographically protected, and uses the so-called proof-of-work to keep the system in harmony.
In other words, the blockchain is a peer-to-peer type network without a central authority that manages the data flow.
Participants, physically made up of each user's servers, called nodes, control the blockchain network in its entirety.
Blockchain immutability means that any transaction within this system is permanently recorded, and anyone who uses it can see and check the recorded data. Each block is an archive for each transaction's entire history; changes can only occur after the approval of the nodes belonging to the network.

All data is decentralized and traceable, and the database cannot be hacked, an advantageous property when dealing with sensitive information.
Thanks to the blockchain, companies involved in a specific supply chain can have a digital database where transactions and goods' movements are updated in real-time. The simplicity of the tool, however, doesn't diminish its potential.
The benefits deriving from its application concern the optimization of processes, greater resilience, a renewal of the business model eliminating problems related to trust between the actors, and greater efficiency thanks to an Agile Supply Chain.
All this is achievable by executing smart contracts, data analytics, and combining the blockchain with other technologies such as 5G, IoT, and Cloud computing.

2.4.1 ITU Use cases Classification

Concerning use cases, the first is the definition of the ITU classification.
It is made the clustering of 5G services following the three different cases:

- URLCC, Ultra-Reliable Low Latency Communication
- mMTC, Massive Machine Type Communication
- eMBB, Enhanced Mobile Broadband

Ultra-Reliable Low Latency Communication (uRLLC)

The 5G outlook promises new applications that will require short latency times together with high reliability, the so-called mission-critical applications, and hence URLCC is expected to change the game.
It is the category dedicated to achieving high reliability and very low latencies in the order of milliseconds. It applies to industrial workflows such as the automation of power distribution in a smart grid, remote control in industrial processes, innovative transportation, V2V and V2X, and wherever there are stringent requirements in terms of reliability and low latency.
With current 4G networks, worst-case latency can last up to a second, which is not a satisfactory result. With 5G, it will be ten times lower.
A concrete case of application is undoubtedly related to self-driving vehicles.
Precisely, a significant reduction in latency time will sometimes prevent fatal accidents: imagine a car traveling on the road at 50 km/h and receiving a signal to avoid hitting an object. The current 4G latency of around 100 milliseconds would still shift approximately 1.2 meters before stopping. If it had a 5G latency of about ten milliseconds, the vehicle would only have covered 12 centimeters. For this reason, a car must be able to send and receive quick alerts to brake in time or change direction in response to traffic signs, hazards, and people crossing the road.

Vehicle technology is rapidly advancing in this direction, and on-board computer systems are reaching very high performance. However, this technology requires many different developments in terms of network speed, data transmission, and machine learning; to this end, 5G can contribute to the future of fully autonomous driving.

In reality, the ultimate goal is a vehicle-to-all communication network (V2X), which allows vehicles to respond directly to objects and changes around their trajectories in less time.

Therefore, connected vehicle technology will enable bi-directional vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2X) communications to enhance safety across transportation systems.

Massive Machine Type Communication (mMTC)

It is dedicated to the connectivity of many sensors and devices used for monitoring purposes in large areas. It is expected to guarantee coverage for hundreds or thousands of devices per square kilometer and contribute to smart cities and factories.

Therefore, this use case concerns the enhancement through 5G in the management of IoT sensors in terms of performance and operation safety to avoid hacking phenomena.

The expansion of connected things (mIoT, which stands literally for massive Internet of Things) brings many new requirements and creates a need for significant resource efficiency improvements in all system components.

This scenario represents the baseline of the connected Industry 4.0 that relies heavily on wireless communication, RFID, NFC, Bluetooth, and other standards. For this reason, 5G is projected to be a massive enabler for entirely new opportunities in the manufacturing areas and to reach the most critical economic advantage related to the connection of plants. In that way, the production process becomes more flexible and individual.

Enhanced Mobile Broadband (eMBB)

It is the most similar use case to the current situation, but it is expected to scale towards transmitting multimedia contents up to the Gigabyte per second. It is intended for entertainment, video social networks, and multimedia communications with higher resolution video channels. It supports the 3D and the Augmented Reality (AR) and Virtual Reality (VR) video applications.

The eMBB is the enabler of immersive services, which require high speed and reliability of transmissions, on the move, with a lower cost per bit than previous generations of cellular systems.

Additionally, mobile broadband (MBB) enhancements refer to high data rates, high user density, significant user mobility, great variability, distribution, and coverage. These are vital features to support immersive AR and VR services that require ever-increasing use of data. If downloading an entire movie takes time, 5G with mobile broadband can do it within seconds.

Moreover, there are enormous opportunities for highly reactive industrial applications. Suppose a technician with a pair of 5G AR glasses: he might see repair instructions shown on the component or receive warnings if something is unsafe to touch.

In the end, concerning the current spread of smart working, thanks to the new technology it will be possible to organize AR meetings remotely, deleting latency and feeling together in the same room even at a distance, transforming boring 2D phone or video calls into a more interactive situation.

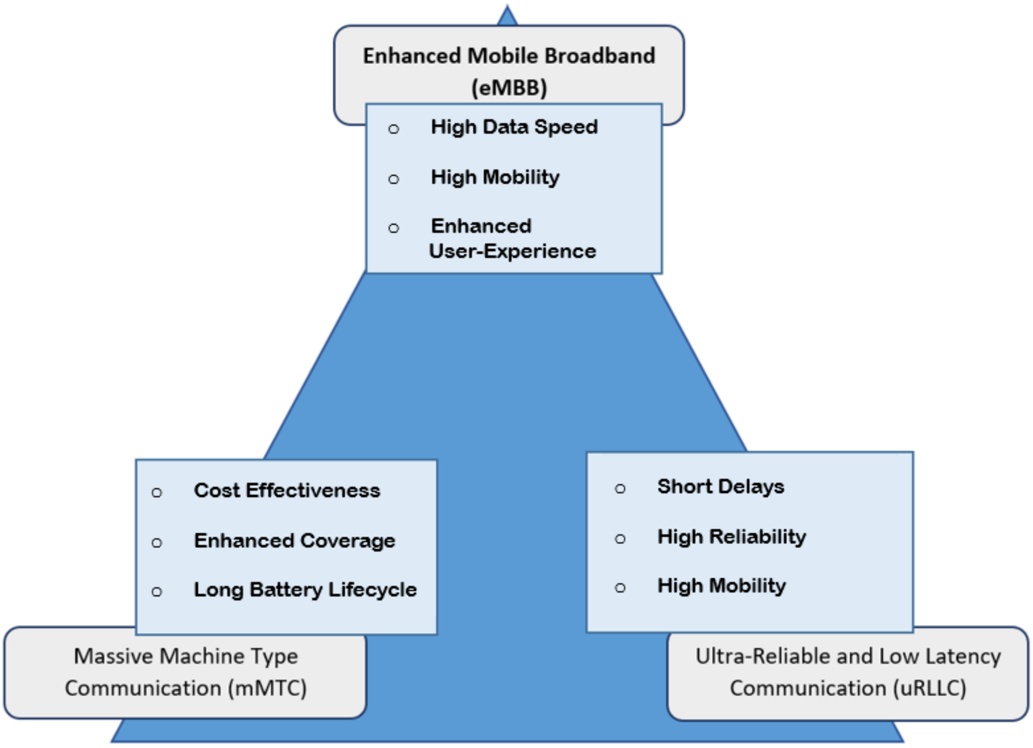


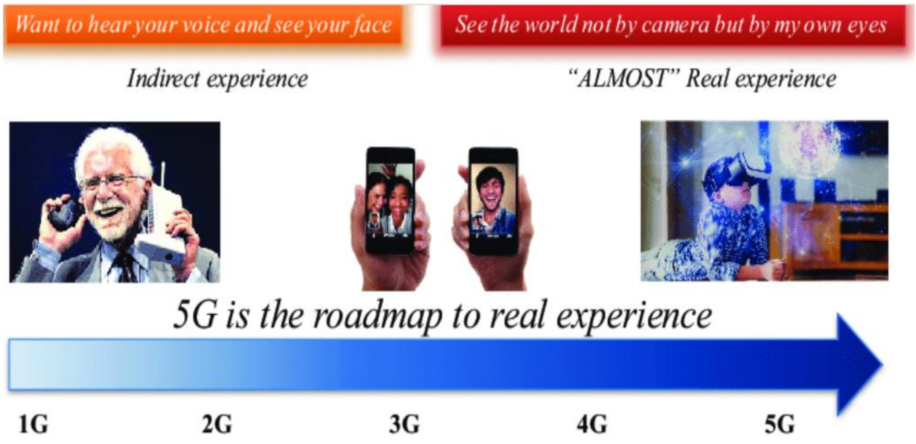
Figure 2.10 - ITU use cases related KPIs
Source: Personal Elaboration

To conclude, it is essential to consider that the services included in one of these categories or more categories combined should realize all use cases and application scenarios in perspective.

2.4.2 End-User Experience Classification

At this stage, 5G services will be classified following the End-User Experience, dividing them into five service categories.

Before examining a specific 5G scenario, it is necessary to investigate its needs, which is why a classification from the end-users point of view is fundamental.



Additionally, it is significant to observe how the evolution from generation to generation of mobile data has led ever closer to an authentic and immersive experience.

Figure 2.11 - 5G as Immersive Experience
Source: Personal Elaboration of Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

Following the analysis of these different categories, there will also be some references to the ITU definitions described above. Therefore, it can be concluded that the difference between the conventional categorization and the one proposed here derives merely from a change in the point of view, but the resulting applications are the same.
The ITU clustering approach is based on a technical perspective, while this one is based on the end-user experience perspective.
The categories to define End-User Experience are five:

- Immersiveness
- Intelligence
- Omnipresence
- Autonomy
- Publicness

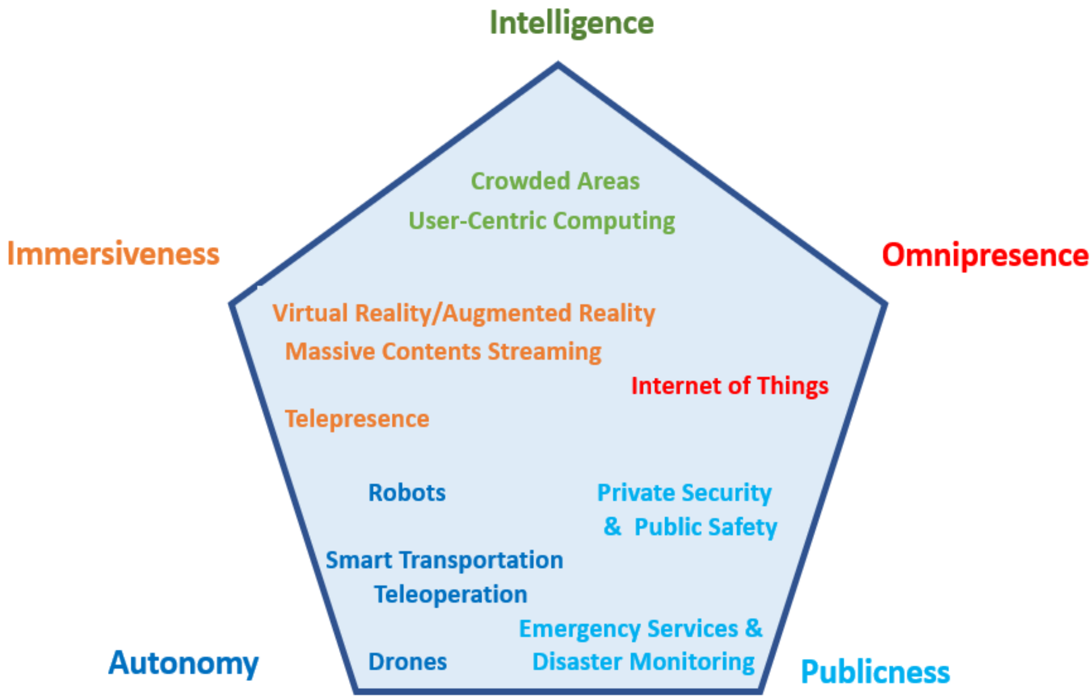


Figure 2.12 - Enabled Applications by End-User Classification
Source: Personal Elaboration of Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

The first two categories, immersive and intelligent 5G services, require high-speed transmission and can be easily compared with eMBB in the technical classification described above.

Immersive 5G Services

Immersive Services include VR and AR functions that will enable the incoming service technology.

As aforementioned, the future is expected to manage a wide variety of entertainment content and guarantee more realistic experiences. In support of this, 5G is anticipated to help the expansion of multimedia services such as interactive 3D and massive content sharing. There will be 4K or 8K resolutions to solve the image quality problem and provide a viewing angle doubled concerning the current one, and there will be cloud computing to fix today's battery and memory capacity issues.

Moreover, 5G networks will offer innovative high bandwidth and low latency, and realistic media in this way will provide information perceivable through the five senses, overcoming the constraints of space and time.

A field in which interesting new applications will be enabled is tourism; 5G will be combined with augmented reality permitting new experiences to travelers.

It would be possible to recreate an ancient reality exploring a historical or a cultural site of the past or imagining to be in a colored Picasso paint.
Although current technology offers high definition video calling services, the user experience is still far from a face-to-face conversation. Therefore, this gap in the user experience is expected to decrease significantly with 5G massive content streaming (MCS) and this can be considered among the most attractive features of 5G technology.

Intelligent 5G services

This concept includes user-centric computing (UCC) and crowded area service (CAS).
A consequence of this digitalization is that future networks are expected to be overcrowded, and an increase in the numbers of devices and data traffic is expected. Crowded areas such as stadiums or concerts in which many users are in the same place but requiring a different service experience can be sources of massive traffic as well.
With the current 4G, this situation may cause network delays and impede connectivity to cloud computing servers. However, to provide wireless connection efficiently, ultra-dense networks are needed.
5G can effectively deliver these services without any interruption by adopting the small-cell concept and mobile edge computing and exploiting, for example, user-location identification to provide location-based services in large areas as shopping malls. Ultra-High Density and 3D multimedia contents replace the current low-volume contents, and the 5G network has to offer an ever-increasing transmission rate.
However, it has to be noticed that these services and the installation of infrastructure are expensive. The result is a trade-off between quality of service and cost.

Omnipresent 5G Services

The applicability of IoT in an industrial context is the most important element in this category. It is also called Industrial IoT (IIoT), and it builds the pilasters for Industry 4.0, the fourth wave of the industrial revolution. With the emergence of edge and cloud computing and related technologies (such as analytics and machine learning), industries can reach a new automation level and create new revenue from innovative business models.
These are some application enhanced by the combination of 5G and IIoT:

- Smart manufacturing
- Preventive and predictive maintenance
- Smart electrical networks
- Smart cities
- Connected and intelligent logistics

- Smart digital supply chains

To the scope of this elaborate, they will be described following the division into three main macro-categories, which are:

- Smart personal networks
- Smart buildings and the environment
- Smart cities

Smart Personal Networks contain smartwatches, smart glasses, various healthcare instruments, and movement-sensitive devices that monitor individual health conditions and suggest exercises or medicines.

Smart Buildings and Environments include different sensors for various uses, such as light and temperature controllers, efficient energy controllers, and crime prevention systems. [116]

The primary case in this category is the smart factory, also known as a factory with a brain: future generations will automatically work in smart factories supported by AI.

Another example is the smart port, with automated operations and data management that improve efficiency and flexibility.

This topic will be treated in more detail in the next chapter as it will then be among the applications taken into consideration in this paper's analyses.

The feasibility of these applications was not possible with the 4G technology.

If nowadays, these industrial automation applications require cables, Wi-Fi does not provide the range, mobility, and quality of service required for industrial control, and the latency of cellular technology is too high, with 5G the industrial automation applications will become completely wireless, enabling more efficient smart factories.

The last application is the Smart City, a well-performing city built on the "smart" combination of endowments and activities of self-decisive, independent, and aware citizens. It is founded on six main features:

- Smart Economy
- Smart Mobility
- Smart Governance
- Smart Living
- Smart People
- Smart Environment

The smart city uses IoT technology to be more sustainable, progressive, and efficient, creating a comfortable and pleasant environment.

The city itself can benefit from using digital technology to make life easier and worth living for citizens.

Moreover, a smart city is also energy efficient. This guarantees significant savings on energy costs as the lights turn on whenever there is movement and turn off or dim in case of quietness.

Here smart traffic lights are an example of a useful resource for the environment. The sensors in the streets and the internal sections help identify and resolve traffic jams and reduce pollution.

Figure 2.13 - IoT Services Categories
Source: Personal Elaboration of Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

Then, it is possible to inform users of the recommended transportation and the estimated arrival time according to traffic conditions.

The other two functional solutions in the smart city dedicated to separate collection and to monitor people flows are smart bins and intelligent gates: the smart container exploits the potential of 5G and artificial intelligence to help people carry out separate collection automatically and quickly. Instead, the intelligent gate combines environmental monitoring and detection of people flow by zones.[100][89]

Autonomous 5G services

Under this category, there are smart transportation, robots, and drone applications.

Smart transportation refers to a transportation system that enables improved safety, higher productivity, and efficiency with a network infrastructure. One of the main enabling technologies for smart transportation systems is artificial intelligence.

The use cases in the automotive domain relevant for 5G include autonomous driving vehicles, vehicle platooning, and traffic safety and control.

Autonomous-driving cars and enhanced V2X communications have the intelligence to recognize, control and avoid accidents caused by human error.

Instead, the concept of vehicle platooning refers to vehicles traveling together by following a lead truck, reducing traffic congestion, and obtaining efficiency improvement.

Moreover, many cities worldwide are already planning to support connected vehicle technology designing intelligent transport systems (ITS), relatively easy to install via current communication methods and valuable to support traffic management.

Localization is another important requirement for autonomous-driving vehicles to acquire accurate information about the environment around. All these elements offer an improved level of safety and control.

However, V2X and some other intelligent transportation systems (ITS) applications require extremely low latency, much lower than the one provided by existing technologies. Current systems cannot support the simultaneous transmission and reception of data at such a high rate and among thousands of cars within a small area. Therefore, 5G technology is essential to provide real-time services and acquire accurate information around the vehicles.

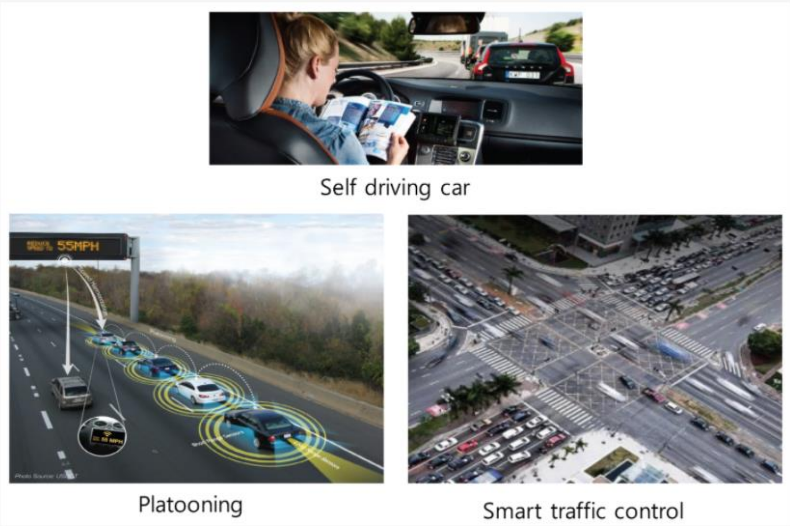


Figure 2.14 - Autonomous 5G services applications
Source: Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

Other applications are Robots and Drones.

Robots are on a high growth trajectory in both the industrial and consumer sectors. 5G will provide the networking functions needed to enable various industries to take advantage of robots' evolution phase. Some robots will be able to move freely, controlled via wireless rather than wired communication links, and leverage the vast computing and data storage resources of the cloud for real-time accuracy.

Besides, use cases for 5G in robots include teleoperation and intelligent industrialization services.

5G technology could be used in telemedicine and remote patient control, raising the so-called "health 4.0".

Another innovative approach in this field is remote surgery, which provides real-time transmission of 3D video data of the surgical site and medical data relating to the patient, controlling the surgical robot based on the data received. In this way, patients will have the opportunity to spend the rehabilitation period at home with their families and not alone in the hospital.

In addition, a cognitive medical tutor is also a solution designed for medical students that would allow them to learn and practice the diagnostic process through a platform born from the collaboration between Humanitas University, Humanitas Hospital, and IBM, and then developed together with Vodafone.
Telemedicine isn't the only area where 5G could be leveraged.
There is a project, the Bari-Matera 5G project, which demonstrates that 5G can also help workers' care, thanks to wearables that monitor and reveal psychophysical stress and posture.
Another example of 5G-enabled robotics, this time in the agricultural sector, is Revitree, a start-up that creates devices to help farmers. In fact, through artificial intelligence algorithms, forecasts on agriculture are made available to everyone; sensors also continuously monitor the fields, letting the farmer know, for example, when they are too dry and therefore when they need irrigation.
Innovative industrialization, therefore, refers to replacing the human workforce with robots that can repeatedly perform the same work, such as assembly processes that use robots. There are several limitations associated with current technologies, such as latency, reliability, and high throughput, for such robotic applications, so once again, 5G seems to be the solution to these issues.
Drones have a large and growing set of use cases beyond today's consumer use for filming and photography. In fact, nowadays, they are limited to line of sight and controller distance: if you cannot see the drone or it is out of range, you cannot see where it is going, and therefore it is impossible to maintain control.
However, with 5G, it will be possible to wear glasses to "see" beyond current limits with low latency and high-resolution video. They can bring new efficiencies to a wide range of industries and businesses and can be used as flying cameras for delivery purposes, public safety, disaster monitoring, infrastructure management, military and agricultural sectors, etc.
For military purposes, drones can collaborate with human-crewed aerial vehicles or ground forces to improve combat efficiency.
Furthermore, to monitor disasters, inspect the state of infrastructure structures and rescue people in the event of an emergency, drones can communicate and share data in real-time with each other, thus increasing the speed and effectiveness of search and rescue missions.
Finally, drones can also play an important role in intelligent transport networks and help spread the Internet in areas without reliable connectivity.[89][88]

Public Safety 5G Services

Public safety (PS) is another field that would appreciate the advent of 5G.

The most important feature of 5G to facilitate such safety and security services is to prioritize data from public safety services. Also, it will be possible to create a unique video surveillance system that integrates data from land, sea, and air stations.

Moreover, in case of disasters (DM), space limits can be overcome using unmanned drones and robots when rescuers cannot easily access the area. These robots will inform rescuers and the command center about emergency status and save and restore the site remotely.

Earthquake prevention (EP) is an example and there is a collaborative project between the University of L'Aquila, ZTE and Wind, concerning the development of some automatic emergency procedures in case of earthquake. The sensors on the walls perceive the first waves and alarm the other buildings and the people inside.

Other sensors can monitor radioactively contaminated mountains, seas, and places and minimize damage in disaster situations by providing a rapid response through interaction with public safety networks.

However, today's networks cannot deliver the desired quality of service (QoS) in terms of coverage, energy efficiency, network reliability, and cost-efficiency. The integration of satellites into future 5G networks will be seen as an essential part of the terrestrial infrastructure to provide strategic solutions for critical and life-saving services, and the network will keep running also in a disaster situation.

Even in the health field, when an accident occurs in a remote location and emergency actions are needed, medical care can be provided through first aid robots. In this case, high-quality videos related to the emergency area and medical data on patients must be sent with high speed and broader network coverage, exploiting reliability and the lowest latency level offered by 5G. [107][101]

2.4.3 Relationship matrices between requirements and user use cases

After seeing several different applications, it should be observed how the possibility of using high bandwidth and extremely low latency in a huge number of devices, along with other innovative features, enable a range of services radically new that permit to realize the paradigm of the connected society and the pervasive digitalization of personal, professional and civil activities.

At this point, it is essential to see the degree of importance that each feature, both KPIs or functional requirements, has in each application, so two relationship matrices have been created.

The first one shows the relationship between 5G applications in the End-User use cases classification on the columns and the KPIs and Enabling Elements on the rows by indicating their different degrees of importance based on this Legenda:

◉ High Level Requirement (9 points relationship)

○ Medium Level Requirement (3 points relationship)

△ Low Level Requirement (1 points relationship)

Relationship Matrix	Immersive 5G		Intelligent 5G		Omni-Present 5G	Autonomous 5G			Public 5G		
	AR/VR	Massive Content Streaming	User-Centric Computing	Crowded Area Service	Industrial IoT	Smart Transportation	Drones	Robots	Disaster Monitoring	Private Safety / Public Security	Earthquake Prevention
High data speed	◉	◉		◉			○	○			
Ultra-low latency				△	◉				○		
Reliability					△	◉	◉	◉	◉	◉	◉
Mobility, Security and Flexibility	◉	○	◉		○	◉	◉	◉		◉	◉
Efficiency						◉	○		○		
Cost Effectiveness					◉		○		◉	◉	△
Massive connection density			◉	◉	◉				△		

Table 2.7 - Relationship Matrix between Technical Requirements and End-User Enabled Applications
Source: Personal Elaboration of Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

For example, massive connection technology can be seen as the most important requirement for the IoT, as it is needed to support the huge number of sensors in a single cell. As most of these sensors can operate at maximum performance for several years with the battery initially equipped, energy efficiency in wireless transmissions is a significant requirement. Furthermore, the cost of implementing such sensors should be minimized. Some of the data provided through intelligent transport networks in smart cities should be transmitted with high reliability and low latency. These first three requirements mentioned are necessary for every IIoT scenario and are therefore included in the first level. The other two remaining conditions are in the second and third rank as their importance is limited to specific systems.
The second relationship matrix between 5G-enabled applications and the required core functionalities described in the previous paragraph is also summarized below. Here it is

not indicated the degree of importance of each requirement, but simply the elements necessary to enable a specific application.

Service Category		F1	F2	F3	F4	A1	A2	A3	A4	01	02
Immersive 5G Service	Virtual Reality and Augmented Reality	✖	✖	✖					✖	✖	✖
	Massive Contents Streaming	✖	✖			✖				✖	✖
Intelligent 5G Service	User Centric Computing		✖	✖						✖	✖
	Crowded Area Service	✖				✖				✖	✖
Omnipresent 5G Service	Industrial Internet of Things		✖	✖		✖	✖			✖	✖
Autonomous 5G Service	Smart Transportation	✖	✖	✖	✖				✖	✖	✖
	Smart Drone	✖		✖					✖	✖	✖
	Smart Robot			✖			✖			✖	✖
Public 5G Service	Disaster Monitoring			✖				✖	✖	✖	✖
	Private Safety and Public Security			✖				✖	✖	✖	✖
	Emergency Prevention	✖		✖				✖	✖	✖	✖

Table 2.8 - Relationship Matrix between Core-Network Requirements and End-User Enabled Applications
Source: Personal Elaboration of Yu, Heejung, Lee, Howon, Jeon, Hongbeom, What Is 5G? Emerging 5G Mobile Services and Network Requirements, 2017

2.5 Safety and 5G impact on health

Another important topic to discuss and which always generates many general issues is the safety of this system. The idea of using very high-frequency waves and the widespread installation of small cell repeaters in our cities has caused significant opposition all over the world by citizens alarmed at the thought that an increase in exposure to dangerous electromagnetic radiations would occur.

In reality, antennas installed almost everywhere in the service of mobile telephony have always been a source of concern for the population: it happened during the transition from 3G to 4G, and it’s the same today situation with the introduction of 5G, although the population is getting used to see antennas everywhere.

As mentioned before, the new radio access networks, previously referred to as "millimeter waves, " will arrange a new type of small cell antennas and advanced antenna technologies installed such as the massive MIMO.

In reality, this technology allows the use of very narrow beams that will follow the user so that the impact and the surrounding exposure level are reduced compared to current systems. In fact, there will be a transition from omnidirectional coverage to adaptive coverage in space and time based on the users served, reducing and increasing capacity if necessary.

Furthermore, the radio emissions and the transmitted signals of the millimeter waves have considerable difficulties in penetrating most materials, and these also include the foliage on trees and the human skin: they only enter about 0.5 millimeters into the skin, and this means that such signals cannot reach internal organs of the body.
Several international scientific bodies have studied the harmful effects on health caused by exposure to radio frequencies such as those used for mobile telephones, whose widespread diffusion has led to a significant increase in the head's exposure level for millions of people. With the increase in the number of antennas, a rise in the risk of developing tumors among young people was expected.
However, the studies concluded that there is no evidence that exposure to electromagnetic fields in the radio frequency range can cause cancer in humans and animals; therefore, they have been classified in risk group 2B (Substances are classified into four groups: if there is sufficient evidence of carcinogenicity in humans the substance is classified in group 1; if there is limited evidence of carcinogenicity in humans, but sufficient evidence in laboratory animals, the substance is classified in group 2A; if there is little evidence of carcinogenicity in both humans and animals, the matter is classified in group 2B; if the evidence is insufficient, it is classified in group 3; if the tests in humans and other animals indicate an absence of carcinogenic activity, the substance is classified in group 4).
In line with this assessment, the fourth edition of the European Code against Cancer clarifies that non-ionizing radiations, including RF electromagnetic fields, are not an established cause of cancer and therefore are not mentioned in the recommendations aimed at reducing the risk of cancer.
To conclude, although these terminals' widespread use could cause some concern, it should be stressed out that the emissions of these antennas are extremely lower than traditional ones. As explained, scientific evidence has confirmed that mmWave are reflected or absorbed only superficially by the skin and therefore do not penetrate the body. Devices and repeaters emit radio waves, and these are all more intense the weaker is the signal from the antennas. Therefore, having good coverage is a way to reduce emissions from devices that, in many cases, are continuously attached to our bodies, such as smartphones or smartwatches.[83][86]

2.6 Cybersecurity and Cryptographical Ciphers

The advent of 5G also requires many adjustments in the security field. In particular, it brings new challenges that will also affect air encryption algorithms:

- Virtualization, as many components of 5G can be virtualized, they include ciphering layers;
- Performance, 5G is expected to operate at a very high speed, at least 20 Gbps;
- Security, 5G is expected to raise the security to a 256-bit level in order to mitigate future advances in cryptanalysis (quantum attacks, for example).

5G is not for smartphones, 5G is designed for machines. With 5G, the mobile network will have the power to manage millions of small devices connected to generate an incredible amount of data to be transferred to cloud analysis centers. Access management, logistics control, and many other aspects will become online services updated in real-time, improving safety and efficiency. But these great promises of 5G are also accompanied by significant challenges. Making everything super-connected increases performance, yields, and control but exposes businesses to hacking risk.

The virtualization and the high performances associated with the 5G network bring the request for new cryptographic ciphers that perform exceptionally well on software. 5G is expected to guarantee a minimum speed of 20 Gbps and a maximum speed of up to 40 or 50-100 Gbps. The ciphers for the future mobile network have to handle those rates, otherwise security risks can become a bottleneck.

Regarding the security level requested, 3GPP has initiated a study on increasing the encryption key sizes from 128-bit keys to 256-bit keys. This change also affects the ciphering algorithms since they must accommodate the increased key size and be strong enough to deliver the corresponding increased security level.

Ericsson Research and Lund University have developed a new cipher called SNOW-V, where V stands for virtualization to respond to all these requests. The authors revised the SNOW 3G architecture to be competitive in such a pure software environment. SNOW-V also has an increased 256-bit security level, compared to the 128-bit security of SNOW 3G. [35]

Chapter 3. Shaping European Digital Future

3.1 5G Commercialization Plan

5G is a new generation of mobile communication technology.

Although it is still in the stage of development, it has enormous market potential.

The construction of 5G networks also poses more significant challenges than previous technologies, and to attain the same network coverage, 5G needs a central station denser than 4G.

However, all 5G devices launched nowadays are set to rely on existing 4G infrastructures, while the "non-standalone" network (NSA) isn't available yet.

2020 is the year that coincides with the launch and commercialization of 5G, and MNOs are entering the main cities in Europe.

However, only early adopters in industry and among the population are approaching 5G technology now, but in few years, the diffusion phase will start, and the proper applicability will be understood. MNOs aim to make 5G available for 2025 in remote areas as well.[19][24]

To briefly resume, the 5G related expectations regard:

- lower energy expenditure for the same number of bits transmitted (which is a sustainable goal);
- greater bandwidth with less latency;
- excellent reliability and fewer emissions.

Therefore, since it is a relevant topic for both the public and private sectors, first of all, policies and regulations concerning the European context are taken into consideration to deeply understand their purposes both at the public and at the private level.

Then, the decision to focus on Europe derives from the fact that the 5G-LOGINNOV project is taking place in Europe, with its living labs and trial cities. Moreover, a contextualization at a geographical level could be essential to obtain critical insights for the definition of future business models and results.[19]

3.1.1 Global Market Developments

5G industrial innovation can be described as a learning process that involves internal and external elements of know-how, and its mastery will bring benefits in terms of time, equipment and costs, and efficiency and real-time data.

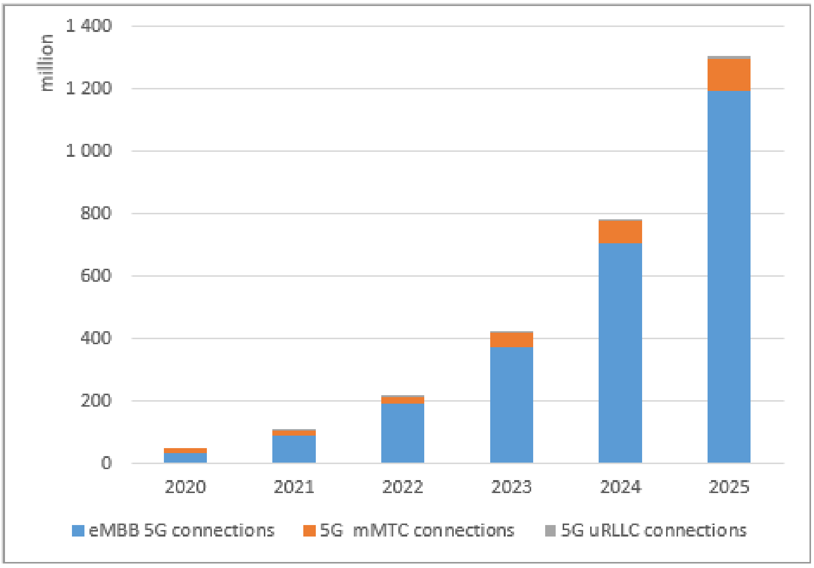


Figure 3.1 - World 5G connection
Source: IDATE Digi World, 2020

2019 was the year of the first 5G launches in developed mobile markets, but a broader appearance on the market came by 2020, including a series of new 5G launches in the world. Below, there is a brief assessment of the percentage of users who have already adopted the service in Europe, and the diffusion phase is in line with the assumptions previously made: it is expected for the following years, precisely for 2025.

3.2 Geography

It is essential to give a geographical perspective precisely because the implementation of 5G can be characterized by differences between the various leading countries and, in particular, between Europe, America, and Asia. Thus, it was decided to focus on Europe, the center of the LOGINNOVbasic project and of most of the initiatives subject to subsequent analyses.

5G is more complicated than previous wireless technologies, and this contextualization helps assessing how Europe is proceeding towards the adoption of 5G and the incentives or slowdowns in specific areas.

5G environment doesn't refer to a short-term race; it should be considered a long-term project to solve technical challenges and develop clear business cases.

Firstly, 5GPPP (5G Private Public Partnership), the EU flagship initiative to accelerate research and innovation in 5G technology, will be presented in detail, describing each phase's composition and the collaboration between companies and governments in support of a unique goal. An entire paragraph is dedicated to explaining its objectives

and organization, and an additional focus is given to stakeholders and their priorities based on the Stakeholders' Glossary.
Other European and Extra-UE initiatives will be introduced, including an overview of the R&D Government policies and private investments.
The public then mentioned the financial instruments and policies responsible for funding research projects and boosting 5G market development. To conclude, a note to cybersecurity policies and regulations is also made as with the increase in the riskiness and exposure to attacks, the protection of the network becomes a crucial point even more. [21]

3.3 5G Public-Private Partnership (5G PPP)

5G Infrastructure Public-Private Partnership is now a 1.4 Billion Euro joint initiative between the European Commission and the European ICT industry (ICT manufacturers, telecommunication operators, service providers, SMEs, and research institutions), architectures, technologies, and standards for next-generation global communications.
It was created by a contractual agreement between the 5G-Infrastructure Association and the European Commission signed at the end of 2013, and its launch inserted Europe clearly in the forefront of the 5G research phase compared to other regions.
The challenge for the 5G PPP is to ensure the European leadership in the areas in which Europe is strong or where there is the potential for creating new businesses such as smart cities, e-health, intelligent transportation, education or entertainment, and media.
In fact, this project will strengthen the European industry to successfully compete in global markets and unlock new advantageous opportunities.
The main challenges for 5G PPP are:

- Reduce the average service creation time cycle drastically providing a thousand times the wireless area capacity and more varied service capabilities
- Reach up to 90% energy savings for service supplied.
- Create a secure, reliable, and trustworthy internet connection
- Facilitate very dense deployments of wireless communication

- Ensure everyone and everywhere the access to a larger board of services and applications at a lower cost

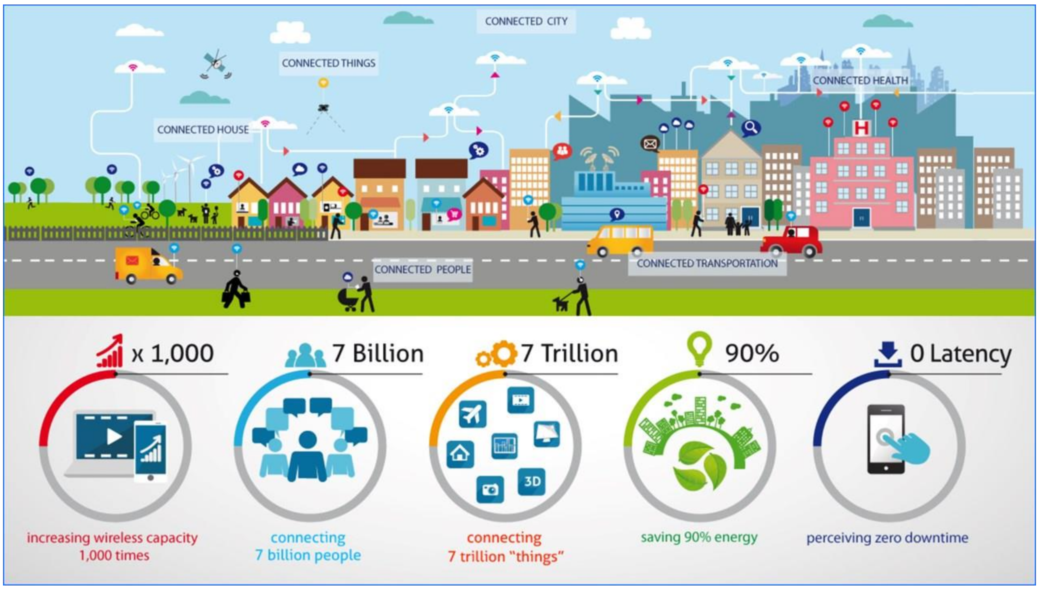


Figure 3.2 - 5GPPP Main Objectives
Source: 5G-PPP Official Website, www.5g-ppp.eu

The goals are based on the expectations derived by 5G as an enabling platform.
5G PPP is constituted by the 5G Infrastructure Association (5G IA), representing its private side and the European Commission that embodies the public side.
The 5G IA sets as objectives the progress of 5G in Europe and the foundation of universal agreements. With this intention, the Association puts together a global industry community of telecoms actors and operators, manufacturers, research institutes, universities, verticals, and SMEs to carry out a wide variety of actions such as standardization, frequency of the spectrum and related partition, R&D projects in collaboration with key vertical industry sectors for the advancement of trials and international cooperation.
The public funding exceeds 700 million euros, while the expected private budget is about 3.5 billion euros. [12][4]

3.3.1 5G PPP Phases

5GPPP includes up to now three Phases, and there is a fourth one planned.
With the launch of this first wave of EU-funded projects, under 5G Public-Private Partnership and the budget of the Horizon 2020 program that will be illustrated later, Europe has a distinct advantage in the race definition of the infrastructure architecture.
They are respectively partitioned towards three different goals:
research (Phase 1), optimization (Phase 2), and large-scale trials (Phase 3).

In the first phase, from July 2015, 18 cooperative projects were consistently chosen, retained from the 83 proposals received by the European Commission in response to the first call of the 5G PPP, and their results came to light constantly, with many of them finished between mid-2017 and mid-2018.
In particular, the projects are related to creating the infrastructure, defining the architecture, and strengthening the network. Concerning the topic of interest of the paper, some of them will be examined in the taxonomy.
This summary shows the key achievements obtained during Phase 1:

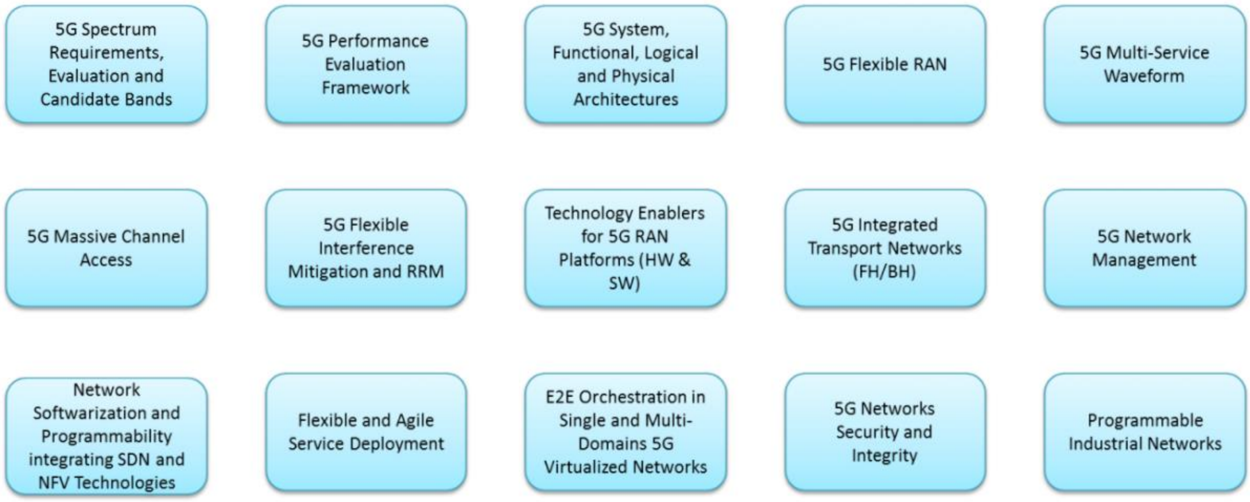


Figure 3.3 - Key Achievements from Phase 1
Source: 5G-PPP Official Website, www.5g-ppp.eu

Phase 2 has initiated on the 1st June 2017, and 21 new 5G PPP projects have been selected, including two complementary international plans strongly related.
This phase focuses specifically on experiments, tests, proofs of concepts regarding vertical sectors where the investments are focused. The central system under analysis is the NFV and network virtualization approach that offers flexibility and reliability with cloud-based services.

It is available the timeline of the Phase 2 projects below and the achievements obtained from their completion[15][16]:

Figure 3.4 - 5GPPP Phase 2 Projects' Time plan
Source: 5G-PPP Official Website, www.5g-ppp.eu

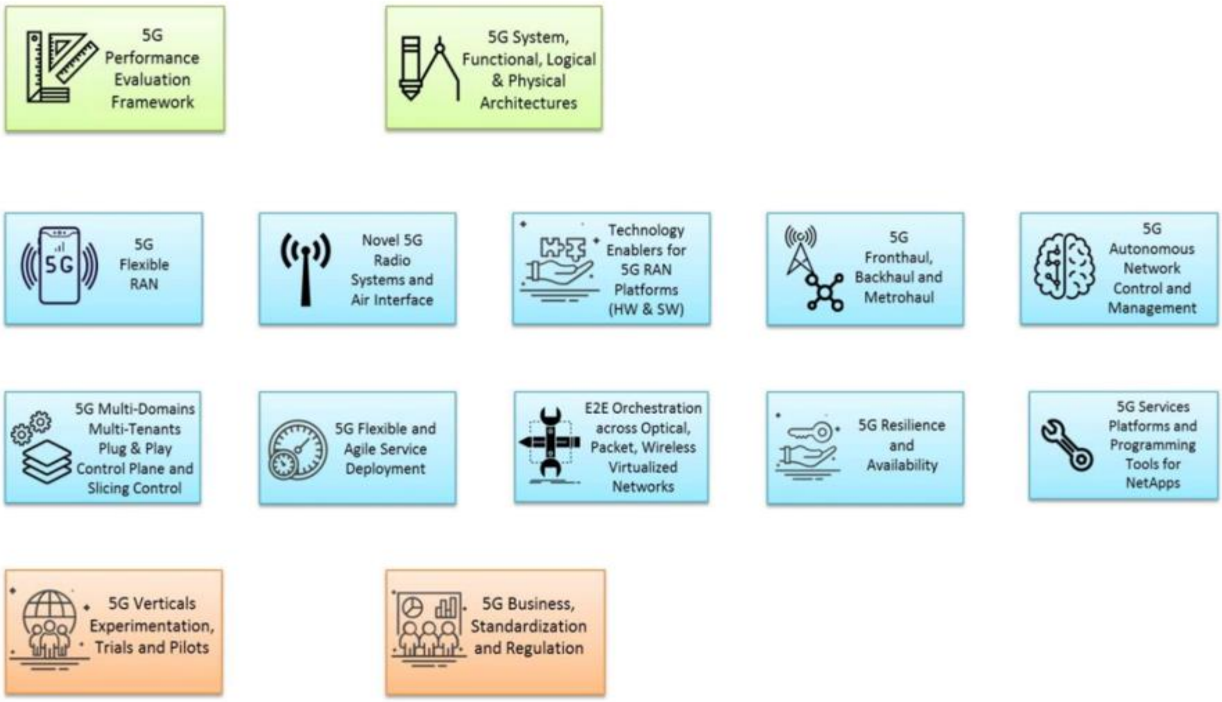


Figure 3.5 - Key Achievements from Phase 2
Source: 5G-PPP Official Website, www.5g-ppp.eu

Ultimately, the third phase, available from shortly before the commercial launch of European 5G networks and still ongoing, was launched together with many new projects in Brussels in June 2018.

There have been many 5G trials in realistic environments regarding its development to exhibit 5G's capabilities and convince stakeholders of its value-added business capability. The advanced 5G provides connectivity and shows its potential to real vertical sectors by overcoming the limitation of the existing 4G network and other long-standing problems.

This phase aims to understand the needs of major industries across Europe and offer a tailored 5G experience to each of them. It carries on the development of projects concerning four different themes:

- Infrastructure Projects
- Automotive Projects
- Advanced 5G validation trials across multiple vertical industries
- 5G Long Term Evolution

Besides, there is complementarity with the other three projects' categories.

In this phase, tests are carried out according to the PPP experience consolidated with the previous steps. In this regard, the 5G Infrastructure Association members have developed the Phase 3 Pre-Structure Model (PSM), which presents features and recommendations to ensure a smooth integration of new projects in the existing coordinated program; thereby, the activities of multiple 5G PPP projects can converge to generate positive synergies.

As a result of this phase, around 80 achievements were reported, and then they were grouped into 11 different categories. Contrary to the critical outcomes of Phase 2, which were mainly related to technological advances, the current list identifies the progress of 5G PPP, according to the plan, as a gradual transition from concepts to trials.

Therefore, as shown in the adjacent figure, most reported results are related to various trials concerning different vertical sectors.

	Technological Areas	Projects
1	Performance Evaluation	Sat5G, 5G VINNI, 5GENESIS, 5GCroCo, 5G-TOURS, 5G-MOBIX
2	Cellular systems, Functional, Logical & Physical Architecture	5G MonArch, Sat5G, IoRL, 5G VINNI, 5GENESIS, 5G-CARMEN, 5GCroCo, 5G-MOBIX, 5G!Drones, 5GROWTH, 5G-TOURS
3	Radio Access Network	blueSPACE, 5G-PHOS, IoRL, 5G VINNI
4	Fronthaul, Backhaul and Metrohhaul	blueSPACE
5	Technology enablers	blueSPACE, 5G-CARMEN
6	Network Management and Orchestration of services	5G-MEDIA, 5G MonArch, blueSPACE, 5G EVE, 5G-CARMEN, 5GROWTH, 5G-SOLUTIONS, 5G-VICTORI
7	Software Networks	5GCity, 5G-PHOS
8	Security, Privacy, Resilience	5G MonArch, NRG5
9	Services Platforms and Programming Tools NetApps	5G-MEDIA, 5G EVE, 5G VINNI, 5GENESIS, 5G-CARMEN, 5G-VICTORI
10	**Verticals Experimentation, Trials and Pilots:**	
10.1	Industry 4.0	One5G, 5G EVE, 5G VINNI, 5GROWTH, 5G-SOLUTIONS, 5G-VICTORI
10.2	Agriculture and Agrifood	5G-HEART
10.3	Automotive	5GCAR, 5G-TRANSFORMER, One5G, 5G EVE, 5G-CARMEN, 5GCroCo, 5G-MOBIX, 5G-HEART
10.4	Transport and Logistics	5G-PICTURE, 5G EVE, 5G VINNI, 5GENESIS, 5G!Drones, 5G-HEART, 5GROWTH, 5G-TOURS, 5G-VICTORI
10.5	Smart Cities and Utilities	5GCity, 5G-PICTURE, One5G, SliceNet, 5G EVE, 5GENESIS, 5G-SOLUTIONS, 5G-TOURS
10.6	Public Safety	5G ESSENCE, 5G VINNI, 5GENESIS, 5G!Drones
10.7	Smart (air)Ports	5G MonArch, 5G-SOLUTIONS, 5G-TOURS
10.8	Energy	SliceNet, 5G EVE, 5G VINNI, 5GROWTH, 5G-SOLUTIONS, 5G-VICTORI
10.9	eHealth & Wellness	5G-TRANSFORMER, SliceNet, 5G-HEART, 5G-TOURS
10.10	Media and Entertainment, Tourism	5G ESSENCE, 5G-MEDIA, 5G MonArch, 5G-PICTURE, 5G-TRANSFORMER, 5G EVE, 5GENESIS, 5G!Drones, 5G-SOLUTIONS, 5G-TOURS, 5G-VICTORI
11	Business, Standardization and Regulation	5GCAR, 5GCity, 5G-MEDIA, 5G Monarch, Sat5G, SliceNet, 5G-CARMEN, 5GCroCo, 5G-MOBIX, 5G!Drones

Figure 3.6 - Key Achievements from Phase 3
Source: 5G-PPP Official Website, www.5g-ppp.eu

However, many projects still focus on 5G architecture, network management, and service orchestration; clearly, these extensions are also functional and necessary to perform the trials. [15] [16]

3.4 5G Target Stakeholders

The last topic of 5GPPP description concerns the Euro 5G project, that in consultation with 18 other 5G PPP projects, produced an overview of the target consumers of the solutions and technologies in question and the domains and sectors most considered with the aim of classifying and defining the different stakeholder groups targeting 5G PPP projects and find synergies and efficiencies in the solutions offered.

The following general diagram graphically shows the different categories of targeted 5G PPP stakeholders, and an attached Glossary offers the priorities assigned to the various stakeholder groups based on a survey of the 5G PPP projects carried out in 2016. Many new projects that span different vertical sectors have been introduced after 2016, so for this reason, this analysis may not be exhaustive.

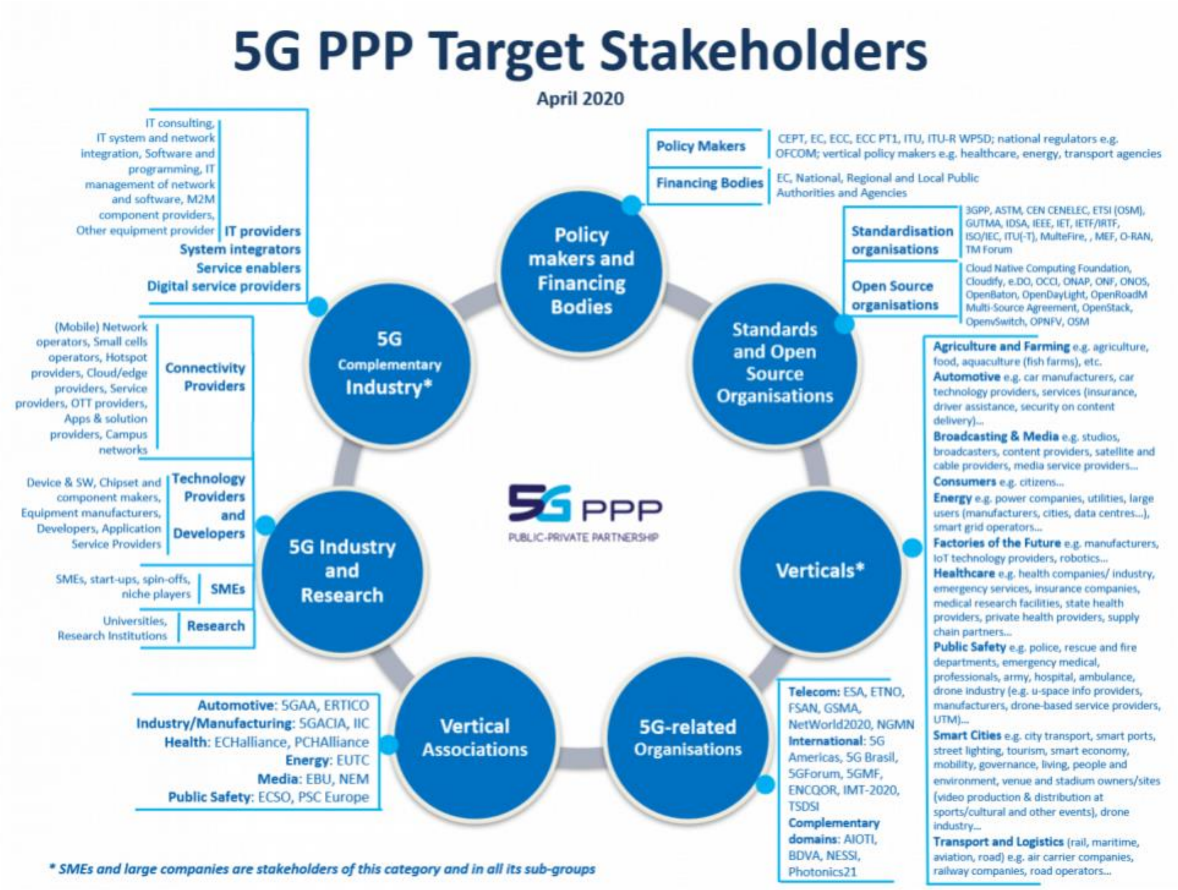


Figure 3.7 - The 5G-PPP Stakeholders Glossary
Source: The 5G PPP Stakeholders Glossary, available on: 5g-ppp.eu/revised-5g-ppp-stakeholders-picture-and-glossary, 2020

The approach towards advanced 5G offers connectivity and shows how to overcome existing 4G network throttling and other long-standing problems to various verticals to understand the needs of major industries across Europe and deliver a tailored 5G experience to each of them.

Furthermore, the reason why trials take place in realistic environments is related to the fact that they want to show the potential of 5G, convincing stakeholders of the added value that their businesses can derive.

According to the diagram, the highest priority is associated with standard organizations, like 3GPP and the others aforementioned.

A standardization organization must be considered a sort of regulator, in fact, it establishes the technical specifications that will be universally followed.

Unlike previous 3GPP systems that sought to build a design suitable for supporting a specific activity, the 5G system should provide optimized support for various services to create its ecosystems. The standards, indeed, define the technologies that, in turn, create the basis for modern businesses and society.

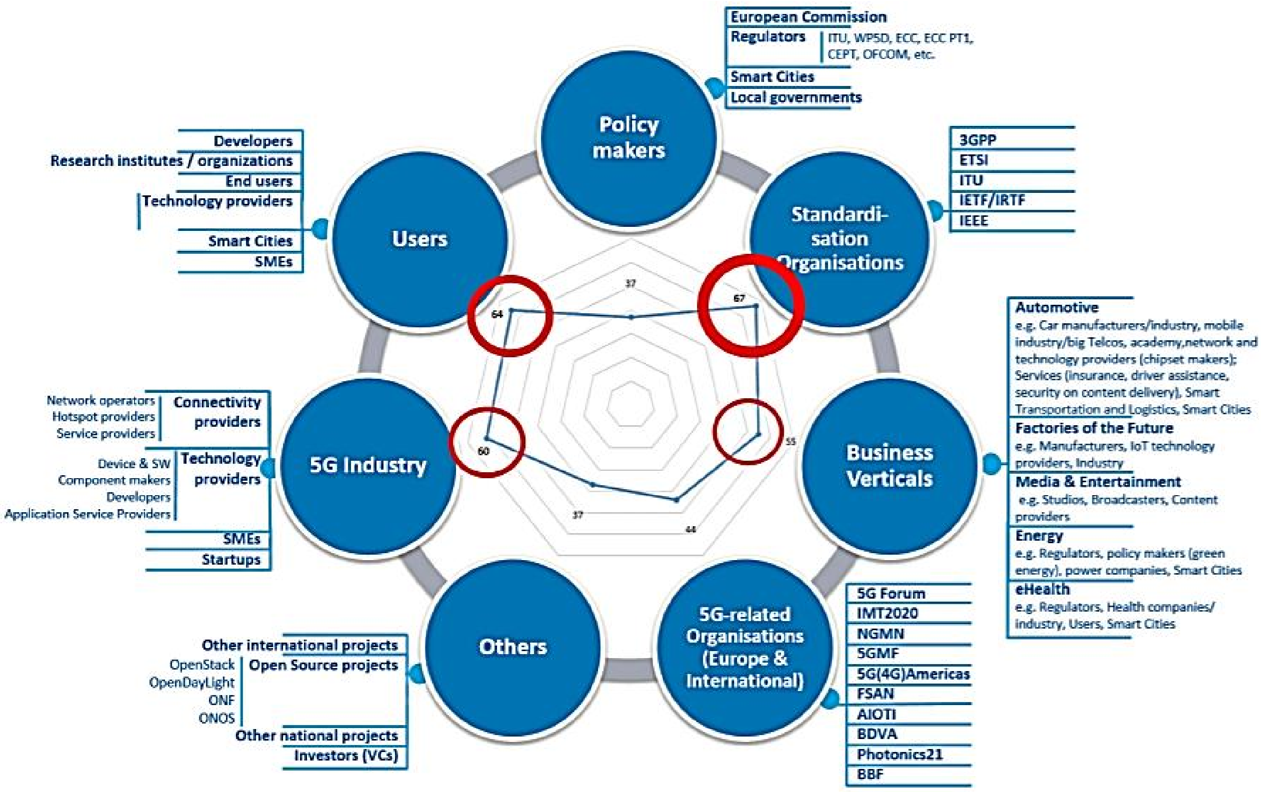


Figure 3.8 - Target Stakeholders' Priority based on 5GPPP Projects Survey 2016
Source: Magen, Lahnalampi, Pastor, Euro5G – Supporting the European 5G Initiative, The 5G PPP Stakeholders Glossary

The second priority level corresponds to the user, an entity with authority to use an application or equipment to obtain an advantage or solve a problem.

The term user here indicates the service's end-user, the application services providers who need specific equipment to offer a service, the media and entertainment providers, the content producers, and the research organizations. Each of these users' categories needs to understand its product-related needs to notice which changes and improvements can be helpfully implemented.

The third in the priority rank is the 5G Industry, which contains any general business or commercial enterprise that uses or is related to fifth-generation (5G) technology. The 5G sector incorporates connectivity providers, service providers, technology providers, SMEs, and start-ups or all those who contribute to the functioning of the 5G network.

Finally, the emphasis is addressed to business verticals and the requirements needed to meet their area's precise demands. [92]

3.5 Other Initiatives in Europe and Extra-UE

3.5.1 Public Initiatives

Countries leading a new generation of mobile communications technology will capture business opportunities in the industry value chain benefitting from the first-mover advantage. Hence, nationally, the emergence of 5G means new economic development opportunities, and governments of many countries have announced their 5G policies to develop the 5G industry.

As for national R&D plans, if in 2018 they were only nine countries in Europe to have one: Finland, Germany, Latvia, Lithuania, Luxembourg, Malta, Slovenia, Sweden, and the UK, nowadays many other have launched a national 5G research and development program or otherwise collaborate on 5G initiatives.

Some national initiative to be mentioned are:

- 5GTNF in Finland, a joint public-private initiative 5G Test Network Finland that coordinates and combines research and technological development activities from 5G infrastructures by receiving funding sources from Tekes, the Finnish financing agency for innovation.
- The overall goal of 5GTNF is to offer Finland one of the best 5G network ecosystems globally, using it for testing business research and development purposes.[17]
- Digital Letzebuerg, in Luxembourg, is a joint public-private initiative that Luxembourg's government has decided to provide in a format that brings together the many public and private enterprises that make up the country's digital economy and society.
- CONNECT in Ireland is a joint initiative co-funded by public bodies and EU CONNECT, the world's leading Irish research center for the future of 5G.
- National Infrastructure Commission in the UK recently released a Commission report on 5G and the UK's approach to maintaining digital leadership and still in the UK, the 5G Innovation Center (5GIC), a public-private initiative at the University of Surrey, the UK's largest academic research center dedicated to developing the next generation of mobile and wireless communications devices. Through this union of academic expertise and key industry partners, 5GIC will help shape the 5G infrastructure that will support the future's society's communication method.

The institution-driven development often plays a more significant role in the process of 5G technology development than market-driven development.

Therefore, as it had happened for the 3G and 4G communication technology markets, in which government policies directly or indirectly had guided the construction and commercialization, it is assumed that a similar scenario will also arise for 5G: the telecommunications industry is mainly a result of the government's efforts to catch up on technology.

Its low-latency and ultra-reliable capabilities, which distinguish it from previous networks, enable vertical industries such as innovative healthcare, smart energy, and autonomous driving, generating a complete paradigm shift for the internet.

3.5.2 Private Initiatives

Instead, concerning Private Initiatives that are taking place, these are the best known:

- 5G for Europe by Ericsson, activated in late 2015, has established a cross-industry 5G research and development (R&D) program which will focus on delivering research, innovation, and industrial pilots that use next-generation 5G networks as an enabler, involving a range of European markets.
- The 5TONIC initiative, by Telefonica and IMDEA Networks, is an Open Research and Innovation laboratory based in Madrid focusing on 5G technologies and aiming to create a global open environment where members from industry and academia collaborate in specific research and innovation projects regarding 5G technologies intending to boost technology and business innovative ventures.[5]

3.5.3 Global 5G actions

The European 5G Infrastructure Association 5GPP cooperates with the following global 5G institutions. A brief description of them is now offered to have a big picture of the 5G situation worldwide.

5G Brasil, based in Rio de Janeiro, is an independent private project launched by Telebrasil, a private association with 65 member institutions to represent Brazil's interests and promote its development, favoring the 5G ecosystem and encouraging its adoption. 5G Brasil has 20 associates, including industries, universities, research centers, telecom operators, and industry associations.

The Forum for the Promotion of Fifth Generation Mobile Communications (5GMF) was founded on 30 September 2014 and conducted research and development on 5G, also devoting itself to analyze its standardization process, coordinating with related organizations, and gathering information on activities that will contribute to the solid development of the 5G eco-society and its implementation from and spread from 2020 onwards.

The 5G Forum was founded by the Ministry of Science, ICT and Future Planning and Mobile Industries in Seoul, Korea, in 2013. The 5G Forum members are made up of public and private sectors, including mobile telecommunication operators, manufacturers, and academic professionals. The aim is to assist in the development of the standard and contribute to its globalization.

5G Americas is headquartered in Bellevue, Washington, and is an industry trade organization leading telecommunication service providers and manufacturers. The organization's mission is to support and promote the advancement and comprehensive capabilities of LTE wireless technology and its evolution beyond 5G across the wireless connected networks, services, applications, and devices of the Americas' ecosystem.

The IMT-2020 (5G) Promotion Group is the leading platform for promoting 5G research and development in China and was established in 2013, with the support of three ministries of China (the Ministry of Industry and Technology of 'Information, the National Commission for Development and Reform and the Ministry of Science and Technology). Its members include leading operators, suppliers, universities, and research institutes in mobile communications. [12]

3.6 Horizon 2020 and Other Financial Instruments

The European Commission has allocated public funding of 700 million euros through the program to support projects related to 5G technological innovation, and this investment should be rewarded up to five times, with a gain of over 3 billion euros.
The European Union's investment will allow to support the expected traffic volumes by 2025 and enhance the networks and Internet architectures such as V2V, V2X, and IoT communication even in areas with an emerging economy.

3.6.1 Horizon 2020

Horizon 2020 is the most extensive EU research and innovation program ever, with almost 80 billion euros of funding available over seven years (2014-2020), plus the private investment these incentives will attract alongside them.
Horizon 2020, in fact, can be considered as the financial tool used to stimulate economic expansion and create jobs and at the same time enjoy the political support of European leaders and members of the European Parliament who, after having implemented the research concept as a future investment, decided to put it at the heart of the EU plan for smart and sustainable growth.
By combining innovation and research, Horizon 2020 is helping to underline world-class scientific excellence, industrial leadership that removes obstacles to innovation and innovative solutions to societal challenges, sparking interest in an integrated public-private contribution.
So, in a nutshell, these measures, in addition to breaking down barriers and creating a true single market for knowledge and research, are the promise of innovative discoveries, bringing great ideas from the laboratory to the market. [114][12][61]

3.6.2 Horizon Europe

In 2018, the Commission proposed this research and innovation program to succeed Horizon 2020, and, following a political agreement in March-April 2019, the Commission launched a strategic planning process.
Having concluded Horizon 2020, Horizon Europe is already planned, which is an ambitious 100 billion euros research and innovation program and appears as a proposal for Europe for the next EU long-term budget and will enter in financial support to all projects analyzed.

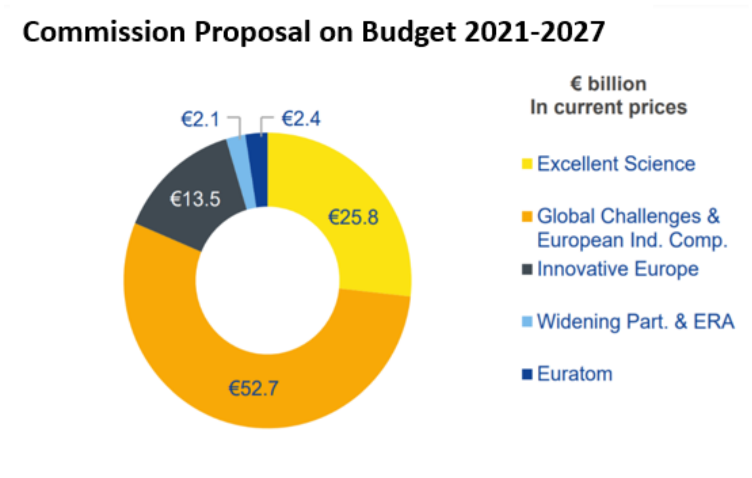


Figure 3.9 - Commission Proposal on Budget 2021-2027
Source: The Commission adopts Implementing Regulation to pave the way for high capacity 5G network infrastructure, available on: EC Official Website www.ec.europa.eu, 2020

The ambitious EU research and innovation framework program, which will begin in 2021 and is scheduled until 2027, aims to boost the European innovation capacity, increase its competitiveness and strengthen the EU's scientific and technological bases with a careful eye also to support a socio-economic model, which helps to obtain a sustainable perspective to tackle climate change.
The outcome of the process will be defined in a multiannual financial framework.
Horizon Europe will incorporate research and innovation missions to increase funding effectiveness by pursuing clearly defined objectives.

Mission areas

Five mission areas have been identified, each with a dedicated board and assembly. The board and assembly help specify, design, and implement the precise missions that will be launched under Horizon Europe in 2021.[114][12]

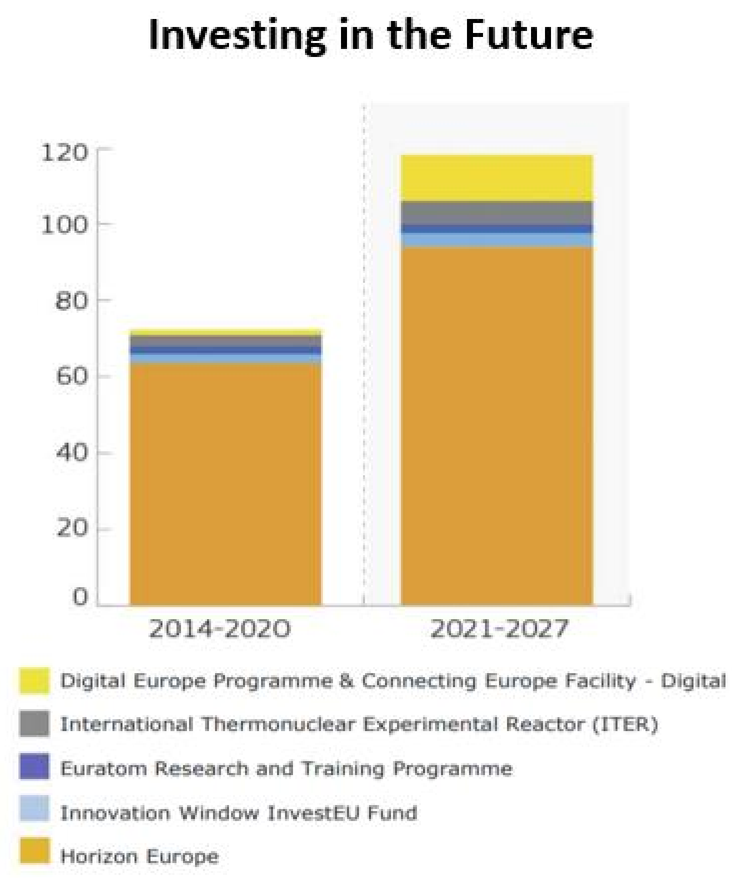


Figure 3.10 - European Investments among 2014 and 2027
Source: The Commission adopts Implementing Regulation to pave the way for high capacity 5G network infrastructure, available on: EC Official Website www.ec.europa.eu, 2020

The Commission even proposes to increase investment in innovation and digital research to reach the share of 114.2 billion euros for the multiannual financial framework considering 100 billion for Horizon Europe. Compared to the previous time horizon, as can be seen from the graph, the investment will increase by about 40%.

Another European-wide initiative that is part of the Horizon Europe program is Next Generation Internet (NGI) which aims to shape the development and evolution of the Internet into an Internet of Humans, an Internet that meets people's basic needs.

The NGI includes an ambitious research and innovation program with an initial EC investment of over 250 million euros between 2018 and 2020. The next generation internet must be designed for humans to meet its full potential for both society and the economy. It aims to shape the future of the Internet as an ecosystem of interoperable platforms that embodies the values Europe cares about: openness, inclusiveness, transparency, privacy, cooperation, and data protection.

The focus is on advanced technologies, like privacy and trust, research and discovery, decentralized architectures, blockchain, Internet of Things, social media, etc.[114]

3.6.3 Other Financial Instruments

The main financing tools for high-speed broadband development projects are revenue-based financing, private capital and financial markets, bank loans, and government-guaranteed bonds in the economic field.

Regarding public funds, the European Commission has proposed a set of telecommunications guidelines covering the objectives and priorities for digital service infrastructures and broadband networks.

As part of the EU's next long-term budget, the Multiannual Financial Framework, the Commission has proposed Digital Europe, a program focused on building the EU's strategic digital capabilities and facilitating digital technologies' wide deployment.
With an overall planned budget of € 8.2 billion, it will also stimulate digital investment and ensure widespread use of digital technologies in the economy and society to improve Europe's competitiveness in the global digital economy and achieve technological sovereignty.
Digital Europe will be integrated into Horizon Europe and other EU programs, such as the Connecting Europe Facility for Digital Infrastructure.
The Connecting Europe Facility (CEF), together with the European Investment Bank (EIB), is specifically dedicated to the Digital Single Market's goals, the Digital Agenda for Europe, and to support strategic plans for the European gigabit society.
Instead, the Connecting Europe Broadband Fund provides capital to small-scale, high-risk broadband projects that do not have sufficient access to finance in underserved suburban and rural areas and supports trans-European networks and infrastructure the transport sectors, telecommunications, and energy.
The FP7, 7th Framework program, aims to explore the available technological options that lead to the future generation of optical and wireless communications. To this end, the European Commission has already launched more than 10 EU projects adding up to over 50 million euros for research on 5G technologies to have distributable systems by 2020.
Besides, the European Commission proposes to create a new recovery tool, Next Generation EU, to ensure that recovery is sustainable, uniform, inclusive, and fair for all Member States. Indeed, the coronavirus has rocked Europe and the world to the core, testing health and care systems, economies, and societies and their lives and works. Complementing national efforts to repair the single market and build a lasting and prosperous recovery, the European Commission proposes exploiting the full potential of the EU budget and targeted reinforcements to the EU budget in the long term to 2021-2027 reach a total EU budget of 1.85 trillion euros. It will be used to fuel a socio-economic recovery, repairing and revitalizing the single market, ensuring a level playing field, and supporting urgent investments explicitly aimed at sustainability and transitions to digital.
European Commission President von der Leyen announced: "The recovery plan transforms the immense challenge we face into an opportunity, not only by supporting recovery but also by investing in our future: the European Green Deal and digitalization will stimulate jobs and growth, the resilience of our societies and the health of our

environment. It is Europe's time. Our willingness to act must rise to the challenges we all face. With Next-Generation EU we are providing an answer ambitious ".
This additional funding will be channeled through EU programs and repaid over a long period during future EU budgets, not before 2028 and not after 2058.
The goal is to strengthen the single market and adapt it to the digital age by investing in better connectivity, especially in the rapid deployment of 5G networks and a stronger industrial and technological presence in strategic sectors.[28][80][79]

3.7 The European Digital Strategy

As the leader in the exports of goods and services globally, the European Union is now exporting its way of managing the digital transformation for everybody's benefit and in line with European values. In this way, as the European model of digital governance inspires more and more countries, European companies benefit from more opportunities to do business and create more jobs for citizens in areas of the economy with high added value.
Therefore, the Commission has adopted a policy since 2016 that sets standardization priorities for the single digital market as part of the "digitalization of European industry" package.
Firstly, it identifies a list of priority building blocks for the market, proposing actions concerning 5G, IoT, cybersecurity, cloud, and big data to achieve complete concrete results within a set time frame.
Secondly, the Commission proposes a high-level policy process to deliver and secure its leadership through standards and foster high-level engagement from a broad base of stakeholders, including industry, policy-setting organizations, standards organizations and the research community, EU institutions, and national administrations.
The EU, therefore, supports an effective and coherent standardization framework, which ensures that high-quality standards are developed promptly.

3.7.1 European Action Plan and 5G Observatory

Europe is shaping a digital future and a single digital market by taking significant steps to drive global developments towards this strategic technology. The actions implemented in 2016 by the Commission include an Action Plan. This strategic initiative concerns all stakeholders, from private to public, from small to large companies, in all Member States, to ensure the rapid spread of the 5G infrastructure in Europe and to make 5G a reality for all citizens and businesses by the end of 2020. Ultra-high-capacity networks such as 5G will be an essential resource for Europe to compete in the global market.

To monitor the progress of the 5G Action Plan, the Commission launched the European 5G Observatory in 2018, a tool to monitor key market developments in Europe in a global context, which also includes references to preparatory actions undertaken by states members such as spectrum auctions and national 5G strategies. 5G Observatory allows the Commission to be updated on all market progresses, including activities undertaken by the private and public sectors, in the field of 5G. It focuses mainly on European events and significant international changes that could impact this market.

Digital Single Market's vision relies on three main strategic objectives expected for 2025:

- Gigabit connectivity for all of the main socio-economic drivers
- Uninterrupted 5G coverage for all urban areas and primary terrestrial transport paths
- Access to connectivity offering at least 100 Mbps for all European households.

It confirms and builds upon the previous broadband objectives for 2020 to supply every European with access to at least 30 Mbps connectivity and provide half of the European households with connectivity rates of 100 Mbps. Furthermore, it calls for 5G connectivity to be available in at least one major city in each Member State by 2020, in line with the technology launch.

3.7.2 EECC and very high capacity networks

In addition to the action plan, the Commission has also initiated several complementary initiatives to help achieve these goals:

The European Electronic Communications Code is in law from 21 December 2020 and is an extension of the previous framework's security provisions, introducing definitions on network and service security and security incidents.

It aims at facilitating the installation and use of very high-capacity networks and stimulate investment in this field across the EU.

The new European Electronic Communications Code and the 5G Action Plan are closely related: both aim to boost industry competitiveness in the single digital market and support the roll-out and take-up of 5G networks.

Moreover, they mainly concern timely allocation and availability of radio spectrum, more favorable conditions for small cell roll-out, or sectoral issues that prevent particular services' deployment.

3.7.3 Trials Cities

The test commercial launch of 5G by 2020 in one of the main cities of each Member State promoted by the Action Plan refers to an initiative called 5G Trials Cities which in 2018 listed 35 Trials Cities, including Turin and Milan in which the technology is applied as a testing proof.

Another related plan is the digital cross-border corridors, including ten facilities that have been set up for live testing of 5G connectivity in real-time in cooperative connected and automated mobility projects.

The diagram on the right shows Europe's readiness to move to 5G.

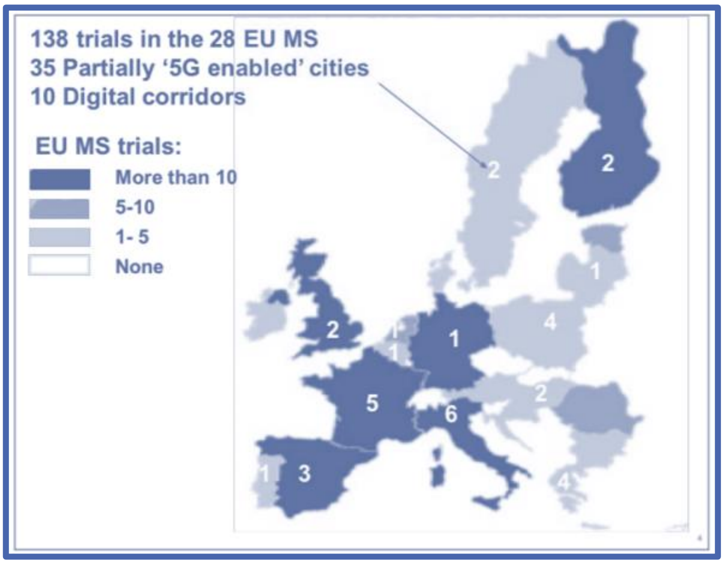


Figure 3.2 - European Readiness towards 5G
Source: European 5G Observatory, 2019

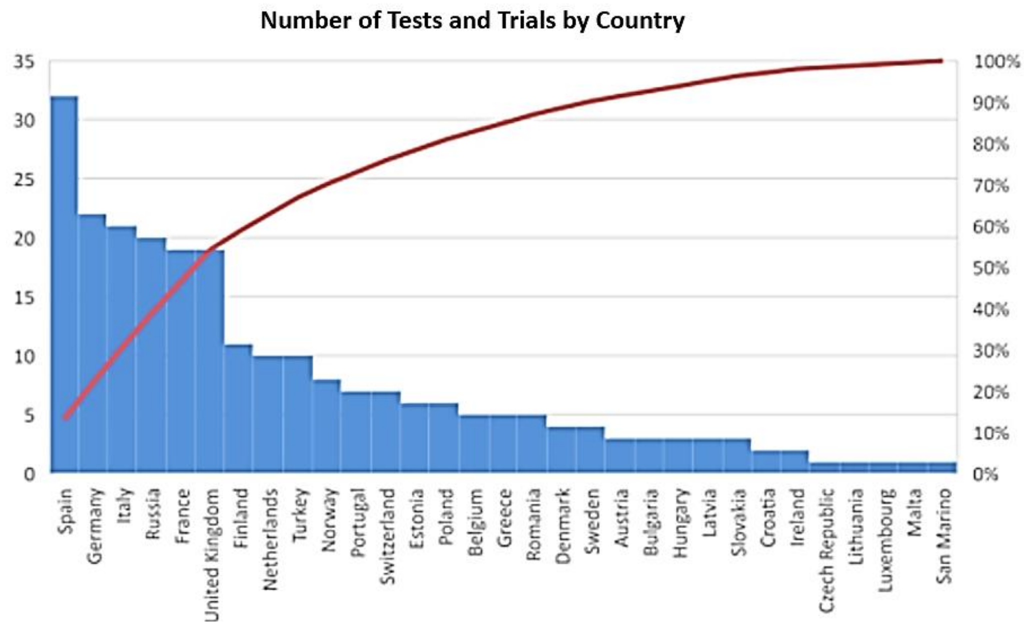


Figure 3.3 - Number of Tests and Trials by Country
Source: IDATE Digi World, 2020

It can be seen from the following graphs containing the distribution of trials among different nations how a clear predominance of some countries, including Spain, Germany, and Italy, emerges.

As for the vertical scope of application, those that attract more focus are media and entertainment, which achieved great importance during the Covid 19 pandemic. Beyond, applications as Transport, Automotive, and Industry 4.0 are listed. [5][114]

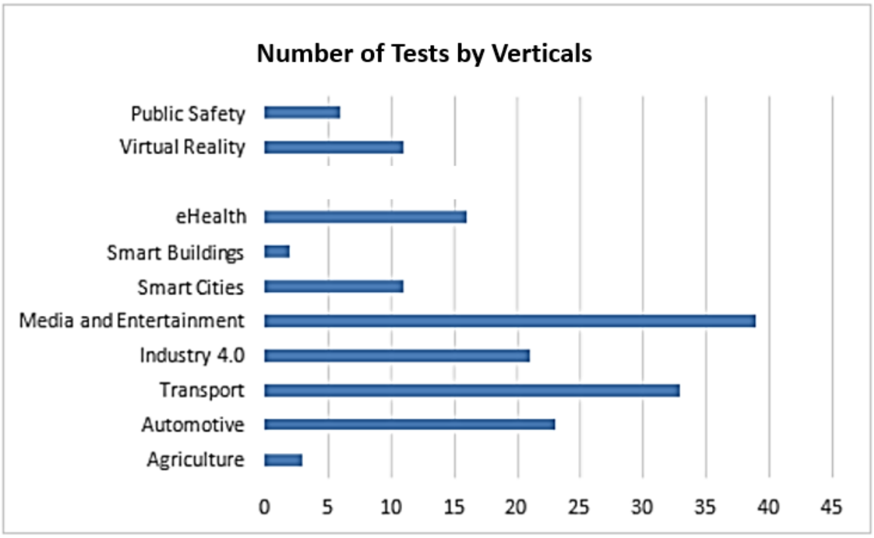


Figure 3.4 - Number of Tests by Verticals
Source: IDATE Digi World, 2020

3.8 EU Investments In Cybersecurity

As already mentioned in the previous chapter, cybersecurity will adopt more effective systems. In fact, thanks to its less centralized architecture and intelligent processing power at the edge, the need for more antennas, and greater software dependency, 5G networks offer more potential entry points for attackers.

Therefore, ensuring the security of future EU 5G networks becomes a crucial point.

If operators are responsible for the safe implementation of 5G and Member States are liable for national security, network security is a critical topic for the entire EU.

A coordinated approach based on trustworthy security measures at a national and European level will help Europe maintain its predominance.

Therefore the EU toolbox on 5G Cybersecurity is introduced. The toolbox identifies and provides risk mitigation plans for each of the nine risk areas identified in the EU coordinated risk assessment report. It consists of technical, strategic measures and possible combinations to reduce the impact of risks or actions that can enable, assist, and improve the strategic and technical measures' effectiveness.

This method also intends to guide in selecting national and European policies that should create a solid framework, ensuring an adequate cybersecurity level of 5G networks.

In 2020, the EU Agency for Cybersecurity published a progress report on project implementation, considering the impact of mitigation measures in the EU Member States.

A further directive concerning this area is the NIS Directive which requires instead that operators of essential services take proper security steps and report severe occurrences to the competent national authority.

Finally, the Cybersecurity Act, which entered into force in 2019, creates a framework for European cybersecurity certification systems for products, processes, and services. Once implemented, certification systems will also allow manufacturers to demonstrate that they have included specific safety features in the early stages of product design and will enable users to determine the level of safety assurance on a European basis.

This framework provides an essential support tool to promote consistent security levels and address users' needs for 5G-related equipment and software.

3.9 Further topics of European interest

To conclude, the Commission adopted the Implementing Regulation on Small Antenna Wireless Access Points, which are critical for the timely deployment of 5G networks providing high capacity and increased coverage while ensuring advanced connection speeds.

The regulation specifies the physical and technical characteristics of small cells for 5G networks and aims to accelerate 5G network deployments while ensuring that national authorities remain in control.

The Commission Implementing Regulation on Small Antenna Wireless Access Points defines the physical and technical characteristics of small cells and guarantees the protection of public health from the exposure to electromagnetic fields adhering to the strict EU exposure limits that impose an impact of small cells 50 times lower than the potential level affecting health.

Another initiative addresses to bring free access to WiFi connectivity (WiFi4EU) in public spaces such as parks, libraries, and squares, the Connecting Europe Broadband Fund and supports the financing of broadband network infrastructure.

To conclude, the last crucial issue will be the alignment between the transition process to 5G and the European Green Deal, a set of political initiatives carried out by the European Commission to achieve climate neutrality in Europe by 2050. The purpose is to make the EU environment sustainable and promote the efficient use of resources by moving to a circular and clean economy, restoring biodiversity, and reducing pollution. [114]

Chapter 4. Logistics and Port Logistics

4.1 General Introduction to Logistics in Industry and Port Logistics

After examining the state of the art of 5G and the current European situation, to complete the general contextualization preliminary to taxonomy, in this chapter, the concept of logistics and the traditional and port industries will be illustrated, starting from a historical context and going through their evolution over the years and the expected developments deriving from the introduction of 5G.

4.1.1 Brief Historical Overview about Logistics

The term "logistics" is of Greek origin and comes from "logistikos" which translated means "with a logical sense," in turn, derived from" lógos," which signify either "word" or "order" or "logic." It follows that, from the etymological point of view, the term recalls the art of calculation and ordering, activities both based on rationality, making it simple to understand what lies at the basis of logistics: study, reasoning, and weighting.

Contrarily to what one might imagine, logistics, so the organization of the activity, of a set of people and things, was born and developed since ancient times with a purely military connotation. It found application in the organization of the troops of vehicles and animals' movements to ensure, in all circumstances, what was necessary to live, move and fight in the best possible conditions of efficiency.

After the Second World War, logistics peaked its importance in the military sector, and after the end of the conflict, the concept was extended to the economic and industrial spheres.

For the next twenty years, it was applied almost exclusively for organizing processes.

Finally, the '70s saw logistics transformation from a marginal role to a structured set of activities, and it was realized that an efficient system reduces waste, improves the quality of work, and consequently increases the returns on the business.

In the '80s, there was a new evolution thanks to the introduction in companies of new management logics such as Materials Requirements Planning (MRP), or Just In Time (JIT); the focus shifted to materials management, and for this purpose, the term "material logistics" was coined.

Towards the end of the '80s, logistics transformed again from a set of operational activities to an inter-functional or integrated logistics system that made it possible to achieve the highest performance levels.

In the end, in more recent times, companies become aware that the improvement in the management of flows within the logistics chain can no longer be separated from the involvement of external actors, especially those who can contribute to raising the value conceived by the customer and the Supply Chain is born.

Logistics today could be defined as the strategic coordination of everything involved in the flow of material into a final product to be delivered to the customer; this strategic organization has to increase the entire chain's profit.[104][96]

Concerning logistics in the industry and taking into account the purpose of this analysis, reference will be made particularly to integrated logistics closely related to the management of the entire distribution chain. [90] [26] [111] [25]

4.1.2 The Evolution Of Industrial Logistics up to Industry 4.0

The keyword in logistics is the optimization of the flow of materials within the company, towards suppliers, and towards end customers.

In an increasingly smart and connected future, where people can communicate with anyone else anywhere globally, logistics also has a fundamental role to play, and increasingly innovative means are available.

In the following years, there will be a shift from the so-called "mass production," which produces a few objects in large quantities, to "mass customization," the exact opposite. Therefore, logistics companies will be called to a new challenge concerning delivering relatively few products anywhere in Europe and the world quickly.

In short, the future business will consist of the ability to design, produce, and market more and more items in limited volumes: an unprecedented paradigm shift in consumer society.

The issue of sustainability will also play its part. Indeed, it will be essential to adapt the infrastructure system through new investments and bring with them the capacity for growth and development to meet the green needs of the logistics of the future.

Technology must not be thought of as a substitute for people, but as a complement, as an essential operational support to simplify and improve the work.

Productivity in the industry in which robots support human capital increases by more than double, demonstrating how much innovation can offer a fundamental contribution. Therefore, the new digital work concepts will attract and retain talents even among the youngest, resources that are too often wasted precisely due to the sometimes excessive obsolescence of processes and the mentality of companies most refractory to a change that can no longer be postponed.

However, the Industry 4.0 paradigm and the digitalization of manufacturing processes also impact industrial and distribution logistics from various perspectives.

First of all, logistics must be adapted to the “4.0 factory” needs, where process flexibility and product customization are two important keywords. The so-called industrial

logistics must serve the needs of a manufacturing and production context that tends to be very different from what could probably have been envisaged until a few years ago.
Simultaneously, logistics can benefit from Industry 4.0 application technologies such as automation, augmented reality, cloud computing, and analytics to improve processes and results. Although perhaps not always immediately evident in terms of cost-benefit ratio, the possibilities in this direction are many. In any case, the benefits derived from adopting cooperative applications are potentially disruptive in the logistics field. Here are some examples:
Automation of internal handling processes: the automation of processes through technology is perhaps the most evident effect of industrial revolutions. In logistics, for example, the path that sees the introduction of robots to support operators and easy to program for carrying out internal handling, storage and picking activities seems to be becoming increasingly feasible.
In fact, it is possible to use “intelligent” handling systems able to adapt to the changing needs of the context, allowing to increase productivity. For example, there is a lot of talk about autonomous logistics, whose influence includes self-driving vehicles, from AGVs to drones.
Safety in the workplace increases: technology can contribute to making the workplace safer and, potentially, more productive: thanks to on-board sensors, AGVs perceive the environment and any unexpected obstacles or areas subject to particular constraints and restrictions and react accordingly, avoiding accidents
Also, inside the factory walls, the technologies that enable the collection and analysis of data and the traceability of movements, and the simulation of scenarios can help improve the performance of the logistical-distribution processes of companies operating in the most diverse sectors.
Indeed, the technological solutions available can help companies manage the complexity of many of the current logistic-production systems. Furthermore, someone has also advanced the hypothesis that Industry 4.0 represents the opportunity that many were waiting for to tame and manage growing complexity in terms of products, processes, and relationships.
As specified by the 5G ACIA, "Industry 4.0 integrates the IoT and related services in industrial manufacturing and delivers seamless vertical and horizontal integration down the entire value chain and across all layers of the automation pyramid.
Connectivity is a critical component of Industry 4.0 and will support the ongoing developments by providing robust and pervasive connectivity between machines, people, and objects."

4.1.3 5G Alliance for Connected Industries and Automation

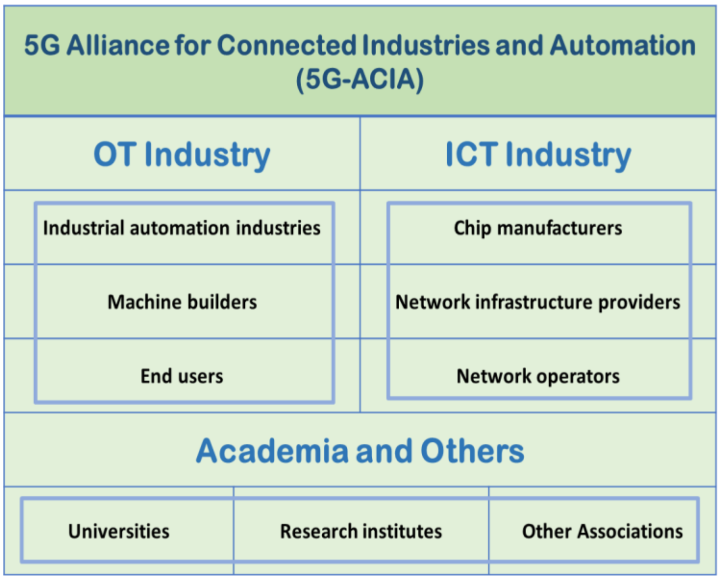


Figure 4.1 - 5G ACIA Structure
Source:5G-ACIA Official Website: www.5g-acia.org/

5G-ACIA (5G Alliance for Connected Industries and Automation) is the central global platform in which various industries from all over the world join and create a new ICT (information and communication technology) and OT (operating technology) ecosystem to shape 5G in the industrial domain.
The members discuss and evaluate the technical, regulatory, and commercial aspects to define a desirable emerging market's structures.
5G-ACIA manages to bring together 5G stakeholders from different sectors, creating an understanding between them and detecting spectrum requirements for industrial 5G networks by exploring new operational models, such as managing private or neutral host 5G networks inside a plant factory. 5G-ACIA members are academic institutions, such as universities or research institutes, and other relevant groups, like authorities and associations, to ensure 5G technology's best applicability for related industries, manufacturing, and processes.
Besides, by bringing together the entire ecosystem, a common language and shared understandings of the relevant aspects are established, and the specific needs of the sector are discussed and processed.
The 5G-ACIA board comprises several high-level international representatives from member organizations discussing the work strategy and deciding and advising their administrative bodies. Qualcomm, Nokia, Huawei, Bosch, Ericsson, Mitsubishi, Siemens, etc., are involved, and the current general president of the association is Mr. Andreas Müller from Bosch. [7][8]
Industry 4.0 will allow humans and droids to interact and work together, with constant communication between robots and the factory. The result will be a symbiotic human-machine partnership.

4.1.4 Real example of Industry 4.0

A well-known company that adheres to the Industry 4.0 project, already mentioned as the company of origin for the president of 5G ACIA, is Bosch, which wants to transform its production environment to offer solutions that communicate with each other, exchange information, and adapt to the production environment's macrosystem. Therefore, it would be systems equipped with sensors and intrinsic AI capable of collecting and reprocessing information in real-time to customize movements.

The tools will consist of open programming languages to guarantee flexibility.

Figure 4.2 - Bosch Active Shuttle
Source: Bosch Rexroth Website

The company plans to adopt Active Shuttles, mobile robots which autonomously transport materials and components to the shop floor. Active Shuttles are intelligent and flexible vehicles suitable for continuous variations in production and plant layout. Being organized in fleets and managed by control software, the enhancement of connectivity and digitalization are the critical elements of this process. Regarding the assembly, some sensors recreate a perfect man-machine collaboration at each station: a component is identified, focused and managed, to process the data and understand the operations that must be done with that component.

Industry 4.0, therefore, appears to be composed of the presence of both hardware and software. [22][23]

4.2 General Introduction to Port Logistics

4.2.1 Brief Overview of The Evolution of The Port Concept

Ports have seen a rapid change in their function within the maritime transport and logistics chain due to multiple and complex factors, such as the globalization of production with the consequent relocation of activities, technological changes, the growing weight assumed by 'Information Technology, the ever-increasing use of containerization for the transport of goods and the considerable size of ships (the so-called phenomenon of naval gigantism).

Furthermore, other significant factors appear to be the emergence of new influential private players and market needs, and the necessity to provide value-added services. Precisely for this reason, in recent years, numerous scholars have addressed the issue of changing the strategic role of seaports in the supply chain, discussing, for example, the integration of maritime transport and intermodal connections.
Today, around 90% of all goods transported between continents are handled by ships, a very high percentage compared to the past. It happens because the sunk costs are amply compensated by the costs per km, which decreases in proportion to the increase in distances; therefore, transport by ship is optimal for long distances.
While ports tended to be tools in the service of the state or colonial powers during the 19th century and the first half of the 20th century, today they fight each other globally and are perceived as a significant component to be optimized for improving efficiency logistics.[34]

4.2.2 The Four Generations of Ports

In general, four categories of traditional ports can be identified without including the more innovative concept of the smart port that will be introduced later.
The historical period taken as a reference in the analysis of this work began in the 70s when the various stakeholders involved in the port activities collaborated closely with each other and the Port Authorities to optimize the internal organization and make the port more efficient. Following the categorization of the UNCTAD36, the first phase is characterized by poor cooperative interaction and high competition between the various ports on the costs for the services offered; the common goal among stakeholders was to attract as many goods as possible.
The emergence of industrial and commercial activities capable of attributing added value to products marks the beginning of the second generation; the port becomes a hub and a place dedicated to providing services for products.
In the 1980s, we saw the introduction of a port community, a strengthening of the links between the city and the port with its users, and an expansion of the range of services offered across the border; thus, it became a logistic platform for trade.
Finally, at the beginning of the 21st century, with the introduction of flexibility obtained through applying lean-thinking and just-in-time industrial techniques in this sector as well, seaports can evolve from the third to the fourth generation.

4.2.3 Port Ecosystem and Operational Efficiency

In the coming years, the transport sector will undergo profound changes again, and 5G will completely revolutionize the port ecosystem as well. The fifth generation of mobile transmission technology will handle a high volume of data traffic without interruption. The demand for wireless capacity in the next decade will increase by more than a thousandfold: this means that more people and more things will be connected to the Internet.

And now imagine all this digitalization that is going on in the port area.

Today, many stakeholders are involved in the arrival of naval cargo. Think about the multitude of services that the arrival of a ship requires and all those necessary to prepare a shipment or store cargo of goods delivered at destination. Therefore, to manage the flow of goods between multiple subjects and control the costs of storage, transport, and handling, the cooperation between innovative information technologies will be fundamental and will enable simplifying systems to manage product handling and, also, the exchange of information in real-time between the various actors involved (manufacturer, transport and logistics company and distributors).

Furthermore, as a modern transport hub, ports play a key role and enable the growth and development of foreign trade, so they could not have been excluded from the digital revolution underway.

Traditional ports depend on human resources to operate container cranes and are characterized by challenging working environments, heavy work intensity, and insufficient staff. Besides, the communication modes are based on fiber or Wi-Fi, and operations and maintenance are costly.

Concerning operational efficiency, also in this area, significant improvements are required as network performance for data management is often suboptimal, with poor stability and low reliability. Imagine how an extra hour of waiting or an additional procedure sometimes means tens of thousands of dollars wasted, precisely because the daily rent for large ships is very costly.

Smart ports will achieve high optimization and performance improvement compared to the current situation, trusting low latency communication, high bandwidth, and high reliability to manage port equipment's control and operational data.

As a result, port automation and smart reconstruction become the primary goals of this vertical business.

Nowadays, high-level automation has already been used in many ports to improve container terminals' productivity and efficiency. Still, the new technology is expected to be implemented in many other operations to remain competitive among ports worldwide in the next three to five years. Being innovative will therefore become a key element to guarantee a competitive advantage among ports. For this reason, even a third of port operators believe that automation can increase productivity by 50% and reduce operating costs by over 50%.

4.2.4 Smart Ports Main Innovative Solutions

As for the smart port, some of the main 5G applications are described below:

- Remote control of gantry cranes and port cranes for containers
- Smart cargo management
- Automated self-driving trucks' logistics

Remote control of gantry cranes and port cranes for containers

If, before, operators had to climb 30 meters high cranes every day and be stuck there for 12 hours without interruption, through the 5G remote-control of gantry cranes, it is possible to meet the service requirements for this activity using multi-channel HD videos. This remote operating system is equipped with a 5G private network with very low latency, high reliability, and wide upstream bandwidth.

Operators can watch the video broadcasting processes in real-time from a central control room. Another advantage is that 5G offers flexible solutions as there are no bulky fiber optic cables to be transferred during the reconstruction or the movement of gantry cranes in different sites.

Cargo handling includes counting, checking for damages on the incoming cargo, and stowing to verify that the goods correspond to the description. These records of information are based on managers' observation skills, whose accuracy and efficiency are limited. Additionally, docks in ports can be dangerous for cargo handling personnel due to sea breezes in winter, scorching sun in summer, constant truck movement, and falling objects from crane containers. The 5G solution provides high definition cameras installed on each dock gantry crane. The HD video from the cameras is distributed locally via multi-access edge computing (MEC) and distributed in the port's server room to keep the data inside the area.

Smart Cargo Management

Smart cargo management and data analysis systems are also integrated on the MEC platform, that enables AI object recognition system: it is a method to acquire information on the port's status, including the number and type of containers, the number of terminal truck operations, the single container's loading position, and the lane number. These data are obtained with rapidity and high precision and without interruption.

The handling of 5G loads via smart management has dramatically improved the work environment so that a single operator can perform two-person work volumes.

Automated self-driving trucks' logistics

The twist locks of the gantry cranes and the container's locking points must be aligned with too high precision at the centimeters, which requires a very high level of driving experience and skills. So, it is not always simple to have adequately prepared personnel available. The shortage of truckers is a big problem for ports, and at the same time, with the port operating 24/7, a feeling of fatigue on the part of the driver is widespread. Automated self-driving trucks' logistics is based on the precise positioning capabilities of 5G and its tracking system via 360-degree video of the interior and exterior of self-driving trucks. The data is transmitted to the MEC control room in real-time, and it is combined with vehicle-road coordination, high-precision positioning, and an automated control that improves the trucks' positioning accuracy.

Once the crane sites a container on the vehicle and verifies this, the truck starts, and its steering wheel turns automatically. The sensors on the system are equipped to identify the road environment so that it is possible to decelerate, brake, turn, avoid objects, and park on its own, choosing the optimal route for the designated location.

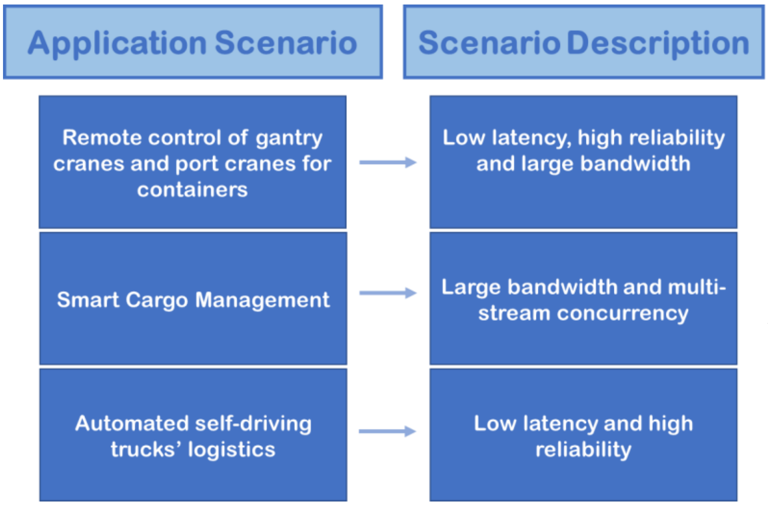


Figure 4.3 - Use cases for Smart Ports
Source: Personal Elaboration

These use cases have been adopted in the Chinese port Ningbo-Zhoushan (NZP), among the world's first for innovation. It will then be fully described among the relevant projects for the taxonomy.[6][11][25]

Other typical use cases for Smart Ports are illustrated below:

- Intelligent Transportation System (ITS);
- Video surveillance through AI recognition;
- Mobile sensors for controlling emissions.

Intelligent Transportation System (ITS)

The Intelligent Transport System (ITS) improves port traffic management by strengthening the traffic flow through a traffic light connected to the central management of port road traffic control with a reliable 5G network. In most ports, traffic lights are connected via fiber, and each modification requires considerable effort to upgrade or replace the corresponding underground cables. If 5G proves to be as secure as it appears to be, modifying existing traffic lights, moving them, or installing new ones would become much more comfortable, faster, and cheaper, and indeed a more reliable system.

Video surveillance through AI recognition

Video Surveillance through AI Recognition is a service for the engineering team that enhances port operations and maintenance experience through augmented and virtual reality applications. These systems are connected via mobile broadband to a central server, and they must provide high data throughput inbound to enable fast delivery of images or videos. Thus, engineers are in their daily work with easy mobile access to construction plans and information on buildings and other technical installations within the port area, receiving data and documentation on-demand via AR/VR tablet applications or glasses.

Mobile sensors for controlling emissions

Mobile Sensors for Emissions Control are environmental measurement sensors that provide real-time data on the port area's current air quality and allow emissions to be measured, offering a better pollution control service. Today this procedure takes place thanks to the ships' connection via an LTE connection and secured VPN tunnels. However, configuring and maintaining these connections and setting up connections for new sensors requires some effort, and also, it is poorly flexible and not reliable enough. With 5G, installing these sensors for environmental measurements and controlling the level of pollution will be easier in the future.
In a nutshell, these systems have transformed the port from a labor-intensive industry to an automated and intelligent one, reducing operational costs and optimizing labor efficiency and safety.

However, it is essential to consider the high costs associated with the reconstruction of ports and the learning process and continuous training necessary to acquire and transmit the skills and retain personnel with specific qualifications on these innovative tools.
These previously described applications are only the first attempt of 5G applications in this vertical sector. In the future, this technology will probably promote the automation of traditional terminals at 360, improving even more production efficiency and bringing economic, environmental, and social benefits to the highest levels.

4.3 Smart Ports in the European Context

The European Union is heavily dependent on ports for global trade but also for its internal market.
About 74% of imported and exported goods and 37% of intra-EU trade take place through ports. So it is clear how digitalization will also affect a key sector like this.
One of the central systems going towards this modernization is the port of Hamburg (Nokia and Deutsche Telekom project), which is testing the 5G network and has already applied AGVs for the handling of goods in operations, reaching 95% of its digitalization in the management of loading and unloading customs.
The digitalization procedure and the systems implanted are similar to the ones described above and to the processes implemented in the Chinese port of Ningbo-Zhoushan aforementioned. In this way, the work will be more accessible thanks to the intensification of the human-machine interaction.
Moreover, 10 thousand drone flights are expected to move goods in the same port by 2025, and autonomous mini-submarines are being tested to control the sedimentation of the seabed and the banks' health.
Also, the Belgian port of Zeebrugge will soon adopt 5G. It has prepared an ambitious development plan for the new mobile technology, and it has already installed six 5G antennas in port at the end of 2020.
The Belgian port is one of the most important European hubs for short sea shipping services and a benchmark at a continental level in new car traffic. However, today it is also a port that aspires to test itself in technological innovation and become a living laboratory for the complete digitalization of port operations.
5G for Zeebrugge is a real investment in the direction of a future that can only be hyper-connected and automated, and the model adopted envisages that the exchange of information between companies, port authorities, and service users takes place quickly. That information is immediately shared for the rapid adoption of efficient solutions.
As for Italy, it is from the ports that Italy begins to embrace the fifth-generation network, and it is a possibility for the country to recover technological authority on international markets. It is not just a hypothesis: Ernst & Young recently illustrated that, if Italy, which, due to its strategic position that makes its ports essential commercial hubs, gained an advantage in the race to 5G, it would benefit from a positive impact on GDP of about 80 billion euros in 15 years.
Located in the upper Tyrrhenian Sea, in the north of Tuscany, the port of Livorno is one of the largest and most important Italian seaports, with an annual traffic capacity of approximately 36 million tons of goods and over 700,000 TEU. It is an essential infrastructure involving 15,000 employees who provide services to nearly 9,000 ships every year.

The focus on the Smart Port in Italy is centered on this port, and there is a project, "Logistics of the future in sustainable smart ports," that emerges within the European research program Corealis and aims to analyze the impact of new connectivity technologies on logistic platforms for ports. The whole program will be explored later among the projects inserted in the taxonomy.

4.3.1 Sustainable Smart Ports

It has been shown that 5G connectivity can generate a multiplicity of direct and indirect benefits for the port system.

It favors the port personnel's security and greater efficiency in the network with logistics and transport, bringing together a powerful speed in locating the containers inside the port, easier management of customs operations, better coordination between the loading and unloading phases, no interruption of incoming and outgoing flows. Moreover, an optimized docking of ships allows time savings and increases competition among ports. In addition to all these benefits illustrated, also the theme of sustainability gains a significant share. In fact, regarding emissions, it is expected a significant annual reduction after the introduction of the 5G ecosystem, generating a positive environmental impact for port cities.

In Italy, a specific indicator will be taken as a reference of the degree of implementation of the Sustainable Development Goals (SDGs), and port KPIs will be chosen among those listed in SDGs in order to understand the level of sustainable development achievable.

The port of Livorno, based on this model, is among the ten decisive initiatives focused on the 17 sustainable development goals set by the United Nations for 2030.

It was presented at the Global Solutions Forum, organized by the Network for the United Nations Sustainable Development held at Columbia University of New York. Moreover, during the Hannover Messe Digital Days, a global event for the manufacturing sector based in Germany, it received the prestigious "Industrial Energy Efficiency Award" for the results obtained in terms of sustainability, increased efficiency, and reduced impact logistics operations within the port. [36][32][82]

4.4 Use cases for Transport and Logistics in General

Given the purpose of the paper, to realize a detailed analysis of logistics projects both in Industry 4.0 and Port logistics, specific reference use cases for the sector are introduced to contribute to a more precise classification in taxonomy.

In fact, 5G is not just another "G"; it is a platform for innovation capable of having an exponentially optimistic impact on our society, our economy, and our environment.

This analysis will classify the impact of 5G in the logistical-port context in different use cases following the Transport and Logistics use cases categorization.

The logistics industry has been relatively laggard with respect to the upcoming digital transformation. However, it now faces low margins, high operating costs, and increasingly stringent customer demands and is therefore faced with an overwhelming need for optimization and efficiency.[93]

Now, the seven use cases are shown in the chart below and will be used to classify projects in the taxonomy in accordance with this different perspective:

Use case		Benefits	Why 5G?
Connected traffic infrastructure	Smart sensors or cameras are integrated into traffic infrastructure to collect data about oncoming traffic and and trigger real-time actions	Reduce congestion Reduce accidents Increase efficiency	Device density Low latency
Real-time routing and optimisation	Sensors collect data throughput the supply chain to improve visibility and optimise processes through real-time dynamic routing and scheduling	Increase supply chain visibility Increase efficiency Increase throughput	Device density Low latency
Automated last 100 yards delivery	Using drones or automated delivery vehicles for the last 'hundred yards' of delivery, where the delivery van acts as a mobile final distribution point	Reduce time for delivery Reduce distance driven by van	Low latency Reliability Location-awareness
Predictive maintenance of fleets	Using dozens of sensors to give an accurate, real-time representation of the status of a vehicle to perform predictive and preventative maintenance	Reduce downtime Reduce spend on maintenance Reduce vehicle replacement rate	Device density Reliability Device costs
Advanced driver assistance	Using cameras to monitor behaviour of the driver and the external surroundings to detect and alert driver to any potential risks	Reduce accidents Reduce damage to vehicle Lower insurance costs	Bandwidth (video data) Low latency
Infotainment for public transport	Better connectivity on public transport to deliver information and entertainment services to travellers e.g. HD video streaming, gaming, video calls	Improve passenger experience Stimulate use of public transport	Bandwidth (video or AR/VR applications)
Automatic vehicle software updates	Vehicles with embedded 5G modules receive over-the-air updates to applications and software systems	Increase efficiency Enable more frequent updates	Bandwidth

Figure 4.4 - Use cases for Transport and Logistics
Source: Miran Gilmore, STL Partners, 5Gs impact on transport and logistics - $280bn of benefits in 2030, available on: www.stlpartners.com/research/5g-transport, 2020

This chart is taken by the report "5Gs impact on transport and logistics - $280bn of benefits in 2030 by Miran Gilmore in collaboration with STL Partners

While some of these use cases already exist today, 5G will be able to improve them and increase their value-added. For example, there are various logistics routing and planning solutions currently available on the market that can calculate the optimal route for a vehicle to follow, but the addition of 5G will allow for more dynamic solutions that can change in real-time to reflect the status of the equipment and the needs of the ecosystem.

4.5 Projects' Preliminary Description

It is now introduced a brief description of all the projects selected for the taxonomy. In this way, a preliminary theoretical analysis is made and it is possible to understand the main elements on which to structure and organize the classification.
In the first part, the focus will be on the projects selected and funded by 5G PPP following a partition based on the three phases of the initiative. [28][12][69]
In the second part, other projects and programmes under the Horizon 2020 European framework will be seen. [28][69]

4.5.1 5G PPP Phase 1

In this first phase, the only project relevant to the industry taken into consideration is SONATA.

SONATA - Service programming and orchestration for virtualized software networks

Start Date:	01-07-2015
Duration:	30 months

SONATA addressed the significant challenges associated with developing and implementing complex services expected for 5G networks.
This project influenced the NFV ecosystem, as it was the first integrated NFV approach to include service composition, testing, and orchestration. SONATA targets both the flexible programmability of the software network and the optimization of its deployment. It doesn't focus only on the management and operational side of NFV but also on the service creation area, and in line with this, it has created a DevOps model to integrate the development and operational management of virtual services. By disseminating its results widely through scientific publications and contributions, will significantly impact incumbent stakeholders, including network operators and manufacturers, and will open the market to third-party developers.

4.5.2 5G PPP Phase 2

Now, some projects are conducted within Phase 2 of the fifth generation Private-Public Partnership (5G-PPP) and funded by the European Commission under the Horizon 2020 framework program.

5G Monarch

Start Date:	01-07-2017
Duration:	24 months

5G-MoNArch researches a flexible, adaptable, and programmable architecture for 5G, and its ultimate goal is to bring the 5G mobile network architecture to the necessary evolution and fully integrate the functions required for industry, media, entertainment, and smart city.

It operates mainly in the implementation of two testbeds: the Smart Sea Port testbed in Hamburg and the Tourist City testbed in Turin, contributing to the verification of performances as a basis for technical-economic validation.

The one of interest for the taxonomy is the first use case concerning Smart Port's concept, which addresses several industrial applications and demonstrates the applicability of the E2E network slicing.

The site examined is the port of Hamburg, where electric vehicles have been applied for handling goods in operations, and the digitalization in the management of the loading and unloading custom functions has reached 95%. In this way, thanks to the intensification of the human-machine interaction, the work is more comfortable: 10 thousand drone flights are expected to move goods in the same port by 2025, and autonomous mini-submarines are being tested to control the sedimentation of the seabed and health of the banks.[42][11]

5G PICTURE - 5G programmable infrastructure converging disaggregated network and compute resources

Start Date:	01-06-2017
Duration:	36 months

The exponential growth of mobile internet traffic requires transforming the traditional closed, static and inelastic network infrastructures into open, scalable, and elastic ecosystems supporting new types of connectivity, high mobility, and new mission-critical services for operators, vendors, and vertical industries. 5G-PICTURE designs a next-generation converged infrastructure that integrates various wireless access network technologies through new wireless, optical, and packet networking solutions.

It proposes a paradigm shift, from the traditional RAN and the recent C-RAN to the “Dis-Aggregated RAN” (DA-RAN) approach, that is a new concept that adopts the notion of “disaggregation” of hardware and software components in the wireless, optical, and storage domains. This function allows disaggregating the two parts by creating a standard "resource pooling" that can be independently selected based on the demand. 5G-PICTURE will demonstrate converged front haul and backhaul services in:

- a smart city environment
- a 5G railway experimental testbed
- a stadium with ultra-high user density [43]

MATILDA - A holistic, innovative framework for the design, development, and orchestration of 5G-ready applications and network services over sliced programmable infrastructure

Start Date: 01-06-2017	
Duration: 30 months	

MATILDA aims to enact a radical change in the approach to software development for 5G-ready applications and virtual and physical network functions and services through the adoption of a programmable infrastructure and the construction of an open development environment that both applications and developers may use.
A multi-site virtualized infrastructure manager supports the cloud computing and IoT resources, while a multi-site NFV Orchestrator provides the lifecycle management of the supported Virtual Network Functions.
In addition, network and application-oriented analytics and profiling mechanisms are supported through real-time processing of the collected data from a set of monitoring streams.
The developed 5G-ready application components, applications, virtual network functions, and application-aware network services are made available for open-source or commercial purposes through a 5G marketplace.
The results obtained during the development of this architecture will be totally engaged in demonstrating five vertical applications concerning various domains.
The one relevant for the taxonomy scope regards Industry 4.0 and addresses both logistic (monitoring of vehicles and transported goods) and production scenarios (real-time scenario detection for quality assurance and collision prevention through the distance calculation in a human-robot collaboration).

4.5.3 5G PPP Phase 3

One5G - E2E-aware optimizations and advancements for the network edge of 5G New Radio

Start Date:	01-06-2017
Duration:	24 months

One5G aims to create 5G New Radio technologies (NR) to support various vertical use cases. The two main scenarios demonstrated are:

- Underserved areas
- Megacities

Therefore, the primary purposes are to increase capacity and energy efficiency while reducing the operating costs in urban and rural areas. [65]

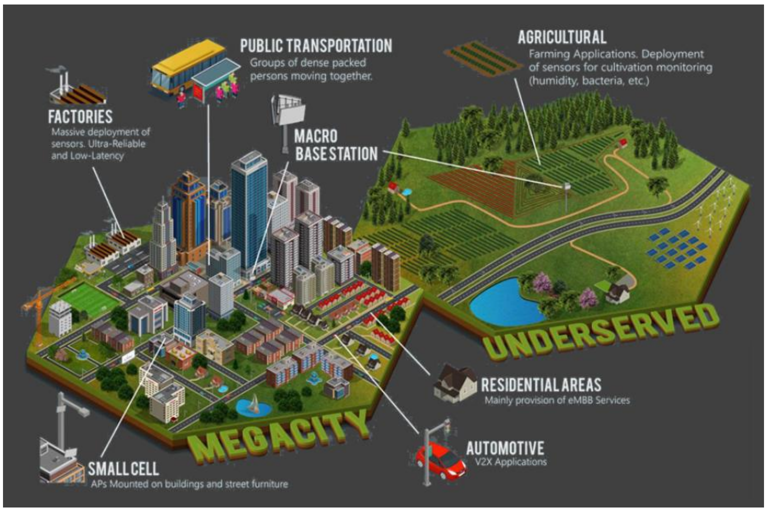


Figure 4.5 - One5G Project Map
Source: EUproject website One 5G, one5g.eu/project/EUproject website One 5G, one5g.eu/project/

5G EVE

Start Date:	01-07-2018
Duration:	36 months

It is the European validation platform for advanced 5G infrastructures in Europe. This 5G-PPP infrastructure project aims to form a single 5G end-to-end structure to validate the KPIs and network services and check the compatibility in Greece, Spain, France, and Italy with Release 16, starting with a progressive evolution from the current Release 15. Its focus is on integrating and validating 5G use cases from various vertical sectors, including Industry 4.0, Smart Transport, Smart Cities & Utilities, Energy, Media & Entertainment, trying to interconnect the different European sites.[39]

5G-VINNI

Start Date:	01-07-2018
Duration:	36 months

It aims to develop an End-to-End 5G framework that can be used first to demonstrate the infrastructure's practical

implementation as support to 5G KPIs and, then, to enable them in vertical industries and test and validate specific applications.
Even if the one included in the taxonomy relates to Industry 4.0, in which control and coordination activities are applied by a set of cooperating robots running on nodes located at the network's edge, there are other important use cases demonstrated in the following vertical sectors:

- eHealth, that is based on monitoring health parameters through smart shirts;
- tourism, in which environments of an improved reality are used to facilitate participants' experience at conferences;
- emergency recovery, based on the implementation of micro-VNF on drones to provide a fast and flexible network edge and give support in case of emergency or issues related to crowded events in remote locations.[47]

5GENESIS - 5th Generation end-to-end network, experimentation, system integration, and showcasing

Start Date:	01-07-2018
Duration:	36 months

Program = 5G-PPP - phase 3
By entering the experimentation phase, the "Genesis of 5G" is currently dealing with the validation of the 5G network KPIs and verifying the 5G technologies through an end-to-end approach for various 5G use cases in both moderate and large-scale events. A key challenge will regard the integration of all the highly diverse R&D results and technologies from the EU and the entire world and create the 5G picture of a potential full-stack, end-to-end 5G platform that meets the defined KPI targets.
The 5GENESIS facility will:

- Adopt an iterative procedure to implement and verify all evolutions of the 5G standard.
- Engage a multitude of technologies and chain innovations ranging among all domains.
- Join heterogeneous physical and virtual network elements under a unique framework open to trials and tests from the vertical industries.

The development program is organized into three cycles (each lasting six months) to upgrade each platform with the R&D activities' last technical achievements. Each phase is then followed by three months of trials. [52]

5GCroCo - 5G cross-border control

Start Date:	01-11-2018
Duration:	36 months

5GCroCo aims to test 5G technologies in the cross-border corridor that connects Metz-Merzig-Luxembourg cities among France, Germany, and Luxembourg and impact the relevant standardization bodies of the telecommunications and automotive industries to define new business models.

5GCroCo experiments with 5G technologies the possibility of providing connected, cooperative, and autonomous mobility (CCAM) services across different countries, achieving an enormous innovative business potential.

However, the seamless provision of connectivity and the uninterrupted supply of services across borders also poses interesting technical challenges making the situation challenging given the multi-country, multi-operator, multi-telco-vendor, and multi-vehicle-OEM scenario of any cross-border layout.

The goal is to define a successful path towards the provision of CCAM services and cross-border scenarios and reduce the uncertainties with proper cross-border deployment of 5G.[50]

5G MOBIX - 5G for cooperative & connected automated mobility on X-border corridors

Start Date:	01-11-2018
Duration:	36 months

The 5G-MOBIX project aims to build a sustainable future for connected and automated vehicles and comprises 55 partners from 10 European countries and Turkey, China, and Korea.

It will develop and test automated vehicles' capabilities using 5G core technology innovations along multiple cross-border corridors and urban test sites, under conditions of vehicular traffic, network coverage stress, demand for services, always keeping in mind the legal, business, and social aspects related to the places.

Similarly to 5GCroCo, the aim is to evaluate the advantages in the CCAM context along x-border and urban corridors using 5G core technology innovations.

Several use cases concerning automated mobility are potential candidates to take advantage of this innovative technology, such as cooperative overtaking, highway lane merging, truck platooning, parking, urban driving, road user detection, vehicle remote control, map updates, media, and entertainment. These tests will make it possible to carry out evaluations and impact assessments of the new business, considering a cost/benefit analysis. The final objective regards new opportunities for 5G-enabled CCAM and suggestions on their implementation. [41]

5G HEART - 5G health aquaculture and transport validation trials

Start Date:	01-06-2019
Duration:	42 months

5G-HEART analyses Healthcare, Automotive, Transport, and Aquaculture use cases based on high-level requirements and network KPIs of each scenario from the end-user perspective.

- In the health area, 5G-HEART will experiment with pill cams for the automatic detection and screening of colon cancer and vital-sign patches and an advanced geo-localization through 5G AR/VR paramedic services.
- Here, concerning the transportation use case, 5G-HEART will validate the platooning, the autonomous, assisted, and remote driving and vehicle data services and diagnosis.
- Then, in the Aquaculture area, the focus will be on the 5G-based transformation of the sector.

Briefly, the essential innovations hosted will be the network slicing, a resource orchestration approach in the access, core, and cloud, and those will result in improved user living environments like healthcare, public safety, farm management, and the creation of new business opportunities within and beyond the project. [40]

5G-SOLUTIONS- 5G solutions for European citizens

Start Date:	01-06-2019
Duration:	36 months

It is based on the formulation of a wide range of innovative and heterogeneous use cases that improve in a complementary way five different vertical sectors directly adopting an end-user-based approach. The vertical domains examined are:

- Industry 4.0, in Belgium, Ireland, and Norway.
- Smart Energy, in Italy.
- Smart Cities, in Ireland and Norway.
- Smart Ports, in Norway.

- Media and Entertainment, in Greece and Norway.

Figure 4.6 - Applications for Vertical Industries, 5G SOLUTIONS
Source: EUproject website SOLUTIONS https://www.5gsolutionsproject.eu/

The use cases have been carefully selected to represent compelling services expected to have high future business potential and economic impact. The approach will be based on a unified, automation-based cross-domain service orchestration that will enable multi-domain slicing and 5G service lifecycle automation.

The 5G-SOLUTIONS architectural concept is based on a modular architecture where the various technological enablers are integrated via open interfaces and APIs. The architecture also provides automatic scaling of resources, leveraging virtualization and cloud automation technologies flexibly according to workload demand. [66]

5G!Drones - Unmanned aerial vehicle vertical applications' trials leveraging advanced 5G facilities

Start Date:	01-06-2019
Duration:	36 months

The 5G! Drones project focuses on use cases related to transport and logistics, public safety, media, and entertainment.

The trials are based on UAVs' use and cover the three ITU functionalities eMBB, URLLC, and mMTC.

To run different types of UAV services at the same time, Network Slicing assumes a fundamental role.

Through the results obtained by the UAVs use cases application, it will be possible to achieve recommendations for 5G further improvements. [48]

5G VICTORI - Vertical demos over common large scale field trials for rail, energy and media industries

Start Date:	01-06-2019
Duration:	36 months

5G VICTORI addresses developing a 5G infrastructure destined to manage a wide range of applications through flexible architectures and unified software control.

Nowadays, vertical industries can only verify use cases in small-scale commercial environments before large-scale deployments.

5G VICTORI will conduct large-scale trials for advanced vertical use cases leveraging on 5G network technologies developed during 5G-XHaul and 5G-PICTURE, 5G-PPP Phase 1 and Phase 2 projects.

5G VICTORI platform aims to transform currently closed, specific infrastructures into open environments where resources and functions are exposed to ICT and vertical sectors and can be employed to compose a very diverse set of services in various ecosystems. [46]

5GROWTH - 5G-enabled growth in vertical industries

Start Date:	01-06-2019
Duration:	30 months

Program = 5G-PPP - phase 3

The main objective of 5Growth is the technical and commercial validation of 5G technologies from the verticals' point of view and following an approach based on field-trials.

In fact, 5Growth aims to empower vertical industries such as Industry 4.0, Transportation, and Energy with an automated and shareable 5G solution based on AI to simultaneously achieve their key performance goals. For this purpose, 5Growth will automate the process to support different verticals across a vertical portal in charge of interfacing the verticals with the 5G End-to-End platforms, receiving their service requests, and building the respective network sections.

AI-based end-to-end network solutions to jointly optimize multiple technologies and domains will be realized.

5Growth will exploit the results obtained during 5G-PPP Phase 2, in 5G-TRANSFORMER and 5G-MONARCH projects, concerning network slicing, virtualization, and multi-domain solutions. Additionally, 5G EVE and 5G-VINNI have been selected as end-to-end platforms for testing 5Growth-specific vertical use cases. [54]

5G-SMART - 5G for smart manufacturing

Start Date:	01-06-2019
Duration:	30 months

Today, the smart manufacturing sector is undergoing a digital transformation that challenges the reduction of manual processes and the increase in efficiency.

5G is destined to be a critical success factor for Industry 4.0, which is the production ecosystem of the future, and 5G-SMART wants to apply this innovative technology to smart manufacturing by demonstrating, validating, and evaluating its potential in real production environments.

5G-SMART will also explore mobile network operators' roles and new business models to accelerate further the adoption of 5G in the manufacturing ecosystem and develop future 5G standards for the sector.

The main objectives of 5G-SMART, briefly, are:

- Develop new 5G-enabled sensors, factory cloud, and network slicing solutions tailored for the manufacturing sector.
- Identify, evaluate and propose advanced and innovative industrial 5G KPIs, with greater attention to industrial features.
- Evaluate and propose new 5G functionalities destined to connected industries.
- Research viable business models for 5G use cases.
- Determine the regulatory aspects related to the implementation of 5G for smart production.
- Disseminate and exploit the results of 5G-SMART and contribute to the development of standards. [44]

5G-ERA - 5G Enhanced Robot Autonomy

Start Date:	01-01-2021
Duration:	24 months

It is oriented towards a user-centric paradigm of integrating vertical knowledge into the existing standardized 5G testing framework to improve the Quality of Experience (QoE). The project addresses the new challenges on experimental facilities for the vertical developers and designers through the following activities:

- Integrating operational processes of essential autonomous robotic capabilities into the MANO open source, ensuring the vertical-specific adaptation to the existing experimentation facilities.
- Realizing an intent-based networking paradigm by aligning the end-to-end (E2E) resource optimization with the autonomous operations.
- Exploiting the NFV/SDN infrastructures efficiently.

- Extending the experimentation facilities into robotic domains through standard APIs under Robot Operating System (ROS).

In fact, robot autonomy is essential for many 5G vertical sectors and can provide multiple benefits in automated mobility, Industry 4.0, and healthcare. 5G technology, on the other hand, has the great potential to enhance robot autonomy.

Use cases from four vertical sectors that include public protection and disaster relief (PPDR), transport, healthcare, and manufacturing will be validated in the project as showcases of the potential of 5G and 5G-ERA to the acceleration of the on-going convergence of robotics, AI & cloud computing and to unlock the next level of autonomy through 5G based learning in general. [38]

TERAWAY - Terahertz technology for ultra-broadband and ultra-wideband operation of backhaul and fronthaul links in systems with SDN management of network and radio resources

Start Date:	01-11-2019
Duration:	36 months

Program = 5G-PPP - phase 3

TERAWAY will develop a disruptive generation of TeraHertz transceivers capable of overcoming this technology's current limitations and will enable their commercial distribution.

By leveraging optical concepts and photonic integration techniques, the project will develop an everyday technological basis for the generation, emission, and detection of wireless signals within an extensive range of carrier frequencies. In parallel, photonics will allow the development of multichannel transceivers that amplify the wireless signals in the optical domain and multibeam optical beamforming to have a radical increase in each wireless beam's direction.

In this way, the project will provide for the first time the possibility of organizing the spectral resources of a network into a shared pool of radio resources that can be coordinated and used flexibly.

TERAWAY will evaluate these transceivers in a high communication coverage requirement and surveillance application scenario of an outdoor mega-event using drones' mobile nodes. Moreover, during the Aalto 5G testbed implementation scenario, an SDN controller checks the management's performances, achieving great benefits for network performance, energy efficiency, and slicing efficiency. [77][38]

5GTANGO - 5G Development and validation platform for global industry-specific network services and apps

Start Date:	01-06-2017
Duration:	36 months

Smart manufacturing comprises the processing of operational data, machine data, and process data, and its objectives are to build a future digital pervasive supply chain and optimize the production process and the machines involved (Factory and Process automation).

5GTANGO exploits the flexible programmability of 5G networks with:

- An NFV-enabled service development kit (SDK).
- A storage platform with advanced validation and verification mechanisms for VNFs and Network Services qualification.
- A modular service platform with an innovative orchestrator to bridge the gap between business needs and network operational management systems. [55]

5G-TRANSFORMER - 5G mobile transport platform for verticals

Start Date:	01-06-2017
Duration:	30 months

5G-Transformer aims to transform today's mobile transport network into an SDN/NFV-based Mobile Transport and Computing Platform (MTP), which brings the “Network Slicing” paradigm into the mobile transport networks by provisioning and managing the platform tailored to the specific needs and requirements of vertical industries.

In a nutshell, the goal of 5G-Transformer is to design, implement, and demonstrate a 5G platform that addresses the challenges mentioned above.[45]

4.5.4 Other UE Financed Projects

Now in this second part, the projects taken in analysis are still funded by the Horizon 2020 initiative but are not among the ones selected by 5G-PPP.

First of all, it is introduced an initiative called **Port of the Future** that includes four of the projects that will be analyzed in the taxonomy:

- **Corealis**
- **DocksTheFuture**
- **Port Forward**
- **Pixel**

Its vision promotes the implementation of projects with innovative concepts and tools that can be used independently by project owners and stakeholders to ensure everyone

the specific objectives expected. The primary purpose is a transferability analysis to promote the peering-up between ports to collaborate on innovative projects and solutions applicable in multiple targeted ports.
Identifying innovative projects with a potential for transferability to other ports allows drawing conclusions or recommendations about whether a model is applicable in other ports. Furthermore, this is only possible through a collaborative effort between ports and enabling port operations KPIs to realize the innovative project. [36]

Now the four projects included in this initiative are presented:

COREALIS - Capacity with a positive environmental and societal footprint: ports in the future era

Start Date:	01-05-2018
Duration:	36 months

COREALIS proposes a strategic and modern structure, supported by the disruptive technologies of the moment to identify and adopt circular economy models in port strategy and operations, improve operational efficiency, optimize shipyards' capacity, and rationalize the flow of goods without further infrastructure investments.
One goal is to allow the port operators to make informed strategic decisions in the medium and long term and become an innovation hub of the local urban space.
The proposed innovations will be tested in real operating conditions in 5 living labs at the port of Piraeus, the port of Valencia, the port of Antwerp, the port of Livorno, and the port of Haminakotka.
The main goals will be to find practical solutions for capacity traffic management, improve efficiency and reduce the total environmental footprint, enhancing the city-port relationship. Indeed, one of the main challenges for European ports is reducing their adverse ecological effects on local communities caused by goods' movement in ports and by distribution activities. To this end, the COREALIS project predicts results both in reducing CO_2 emissions and port noise.

COREALIS aims to establish efficient connections with the land transport network and promote the most energy-efficient modes of transport to achieve citizens' and stakeholders' satisfaction and improve their quality of life.

In summary, COREALIS proposes a strategic, innovative framework, supported by disruptive technologies, including IoT, data analytics, next-generation traffic management, and 5G solutions for modern ports to handle future capacity, traffic, efficiency, and environmental challenges.

It proposes innovations to increase efficiency and optimize land-use while being financially doable, respecting a circular economy, and serving the city.

It will be a pilaster of business innovation, encouraging local start-ups in disruptive technologies of mutual interest. COREALIS innovations are fundamental for the major European ports. [59]

DocksTheFuture - Developing the methodology for a coordinated approach to the clustering, monitoring, and evaluation of results of actions under the Ports of the Future topic

Start Date:	01-01-2018
Duration:	23 months

DocksTheFuture, together with the other projects previously mentioned, will define the Port of the Future, intended as a near future (2030), and this will be possible by facing challenges related to simplification and digitalization of processes, emission reduction, energy transition, electrification, smart grids, port-city interface and the use of renewable energy management.

So, DocksTheFuture will cover many issues from emission reduction to port-city relations issues and the digitalization processes; in particular, it will:

- improve and adjust the Port of Future notions, topics, and their related targets in 2030;
- identify suitable KPIs and relevant monitoring and evaluation of results systems;
- keep in mind R&D and policy recommendations, training packages, and the creation of the network.

With this project, the European Union aims to increase maritime transport and ports into the global logistics chain. In this regard, it should be stated that maritime transport is an essential element in supporting Europe as the leader in global trade. [60]

Port Forward - Towards a green and sustainable ecosystem for the EU Port of the Future

Start Date:	01-07-2018

Duration:	42 months

Port Forward aims at creating a green and sustainable ecosystem for the EU Port of the Future: a Smart, Green, and Interconnected Port.

Specifically, the three solutions can be summarized as below:

- Smart Port Solutions, employing ICT to improve information flows between ports and communities.
- Green Port Solutions, adopting green technologies to minimize the environmental impacts and save resources.
- Interconnected Port Solutions, integrating different modes of transport and various technologies to better monitor and control freight flows.

After all, sustainable development is the present and future for ports that want to lead the industry supported by three cornerstones: Operational Excellence, Insightful Collaboration with partners through the supply chain, and top-notch Safety, Health, and Environmental practices.[73]

PIXEL - Port IoT for Environmental Leverage

Start Date:	01-05-2018
Duration:	36 months

PIXEL is a smart, flexible and scalable solution for diminishing environmental impact while enabling the optimization of port ecosystems' operations through IoT.

In fact, Pixel again proposes a new conceptual and technological model relying on information sharing and IoT, as the means to achieve objectives and ambitions with the implementation of 5G. It enables a two-way collaboration of ports, multimodal transport agents, and cities for an optimal use of internal and external resources, a sustainable economic growth, and environmental impact mitigation towards the Ports of the Future. Built on top of the state-of-the-art interoperability technologies, the project centralizes data from the different information silos where internal and external stakeholders store their operational information by leveraging an IoT-based communication infrastructure to voluntarily exchange data among ports and stakeholders and achieve efficient use of resources in ports.

Ports are critical agents for the cities in which they are located. The economy of a port-city is sensibly tied to the port's evolution, which generally boosts, the population welfare, the growths in employment rates, and the city's image towards the community. However, sometimes this symbiosis can lead to unfortunate situations. Ports can be dangerous for the environmental impact causing traffic bottlenecks, noise, air pollution, and other inconveniences deriving from daily port operations. The effect of these agents on cities and their citizens is a trending topic that should encourage better relations among ports and Smart Cities communities. Framed in achieving this new port concept in a very efficient way, PIXEL briefly aims at bringing every port a step closer to the Port of the Future. The ports involved in the project are the Port of Monfalcone and the Gorizia Interporto. [72]

Now, after this first part concerning the deployment of new ports business models, there will be introduced some projects relating to 5G for industry:

5G CONNI - Industrialised connections through 5G

Start Date:	01-10-2019
Duration:	36 months

The prelude of the fifth generation of mobile communication networks (5G) has been transformational in many directions. Even if 5G technologies such as network slicing can accommodate industrial applications in public and private 5G networks, they have to be considered disruptive and emerging. The EU-funded 5G CONNI project aims to provide an integrated end-to-end 5G test and demonstration network for industrial applications. The plan is to set up two related industrial trial sites in Europe and Taiwan, where selected use cases will be realized and integrated into an end-to-end industrial Private 5G Network demonstrator. The project results will be used to shape the requirements for private network operations. [49]

EVOLVED 5G - Experimentation and validation openness for the long-term evolution of vertical industries in 5G era and beyond

The intense on-going work towards 5G readiness has reached the point where third-party innovators and SMEs should exploit the performance gains provided by 5G infrastructures to create a new, open, and dynamic ecosystem from both technological and marketing perspectives.

Towards the deployment of the 5G performance gains at the application and market level, key contributions are expected by the design and development of Network Applications (NetApps).

In this context, EVOLVED-5G endorses the vision in which the world of NetApps follows the paradigm of mobile applications hosted in a related marketplace.

Moreover, the EVOLVED-5G project will contribute to Industry 4.0.

As one of the central vertical industries, the fourth industrial revolution brings innovative use cases and creates a fertile environment for SME-driven entrepreneurship, where new use case-tailored functions (as NetApps) can be provided to compose digitalized, secured, and automated industrial operations.[61]

INCOMING - Innovation and excellence in massive-scale communications and information processing

Start Date:	01-01-2021
Duration:	30 months

Data acquisition and information processing play a fundamental role in the industry, transportation, and smart energy infrastructures. 5G ensures the communication of data and information efficiently to such advanced infrastructures.

To address the rapid changes and challenges encountered in the ICT sector, the University of Novi Sad (Serbia) founded the Centre for intelligent Communications, Networking and Information processing (ICONIC). The EU-funded INCOMING Project will help ICONIC to become a regional actor for 5G innovation studies. In cooperation with other academic institutions made of high expertises in 5G technology, ICONIC will implement research and work on staff exchanges and training. [84]

HIGHTS - High precision positioning for cooperative ITS applications

Start Date:	01-05-2015
Duration:	36 months

Intelligent transport systems (ITS) are based on the accuracy of the geographical positions of vehicles. Unfortunately, currently, available satellite-based positioning systems cannot provide sufficiently precise position information for many critical applications and in specific challenging environments.

This project addresses this issue by combining traditional satellite systems with innovative use of on-board sensing and infrastructure-based wireless communication technologies to produce advanced ITS positioning systems.

The results will become available for all ITS applications, including also AGVs and truck platooning.

Therefore, the project will incorporate them as building blocks to develop an enhanced European-wide positioning service platform and built on European standards.

At the end of the project, codes and prototypes will be fully open-source and available to the larger research community and the automotive industry. [63]

5G-DIVE - Edge intelligence for vertical experimentation

Start Date:	01-10-2019

Duration:	26 months

5G promises to further enhance IoT potential with vast improvements over 4G by flexibly accommodating a wide range of use cases with diverse service requirements and applicability.
5G DIVE project will conduct 5G end-to-end network testing to prove the value of business models that 5G will offer to two vertical applications: digital twinning and drone fleet navigation.
The trials will be conducted in Europe and Taiwan at 5G end-to-end facilities.
In the taxonomy, it will be analyzed the use case concerning drone fleet navigation. [51]

5GINFIRE - Evolving fire into a 5G oriented experimental playground for vertical industries

Start Date:	01-01-2017
Duration:	24 months

Key industrial sectors are continuously evolving towards Industry 4.0 due to digital and communication technologies. Moreover, new ones in the making, like smart cities, inspiring a unique variety of applications and services.
The salient characteristic of these sectors, known as verticals, is that they are rapidly becoming open ecosystems built on top of common physical infrastructures and resources. It requires a high degree of technological convergence and an enhanced technical capacity to trigger new, innovative products, applications, and services.
5GinFIRE project aspires to imagine and model a holistic and unified environment and find a way to host and integrate verticals and concurrently reconcile their competing and opposing requirements.
Therefore, addressing these fundamental questions, 5GinFIRE main technical objective is to build and operate an Open and Extensible 5G-NFV ecosystem of Experimental Facilities that integrates existing FIRE equipment with new vertical-specific ones and enables experimentation of vertical industries.[53]

AUTOWARE - Wireless autonomous, reliable and resilient production operation architecture for cognitive manufacturing

Start Date:	01-10-2016
Duration:	36 months

AUTOWARE will create and push forward an open Cyber-Physical Production System CPPS ecosystem, allowing companies to access all the different components and develop digital automation cognitive solutions for manufacturing processes.

It will connect several initiatives to strengthen the European SME and leverage cognitive autonomous production processes and equipment towards manufacturing SMEs.

A production system is designed to perform the same process many times optimally. However, the planning and control of production systems have become increasingly complex regarding flexibility and productivity and the decreasing predictability of operations, and SMEs have to face additional challenges to the implementation of automation processes on the cloud.

The basic components for digital automation are available, but SMEs can decide to align, connect, and integrate them to meet their individual manufacturing processes' requirements. [57]

SHOW - Shared automation operating models for worldwide adoption

Start Date:	01-01-2020
Duration:	36 months

It concerns the development of automated vehicles for sustainable urban transport.

Urban traffic represents a severe challenge for European societies seeking effective and sustainable urban transport through technical solutions, business models, and priority scenarios. The EU-funded SHOW project is realized by a consortium of 69 partners and applied in 20 European cities.

It aims to estimate and evaluate autonomous vehicles' role in making urban transport more effective, sustainable, and user-friendly. Its goal concerns the development of a fleet of 74 Automated Vehicles of all types for all transport users in mixed traffic and dedicated lines operating under traffic speeds ranging from 18 to over 50km/h. This innovative concept covers all urban automated mobility needs and all stakeholders' demands. [75]

CIVITAS PORTIS - PORT-Cities: integrating sustainability

Start Date:	01-09-2016
Duration:	51 months

Bringing the focus on ports again, Civitas PORTIS is part of the Civitas 2020 project within which there are also two other projects: DESTINATIONS and ECCENTRIC.

Civitas PORTIS can be seen as multidimensional laboratories where challenges connected with urban mobility are more complicated due to the city and the port's dual system of gravity center. These features are a challenge and an opportunity at the same time, as they provide scope for planning, researching, and implementing integrated mobility solutions in complex urban contexts.

Civitas PORTIS plans, exhibits, and evaluates integrated sets of sustainable mobility measures in 5 major port cities located on the North Sea (Aberdeen and Antwerp), the Mediterranean Sea (Trieste), the Black Sea (Constanta), and the Baltic Sea (Klaipeda). The project also involves the major international port city on the East China Sea (Ningbo).

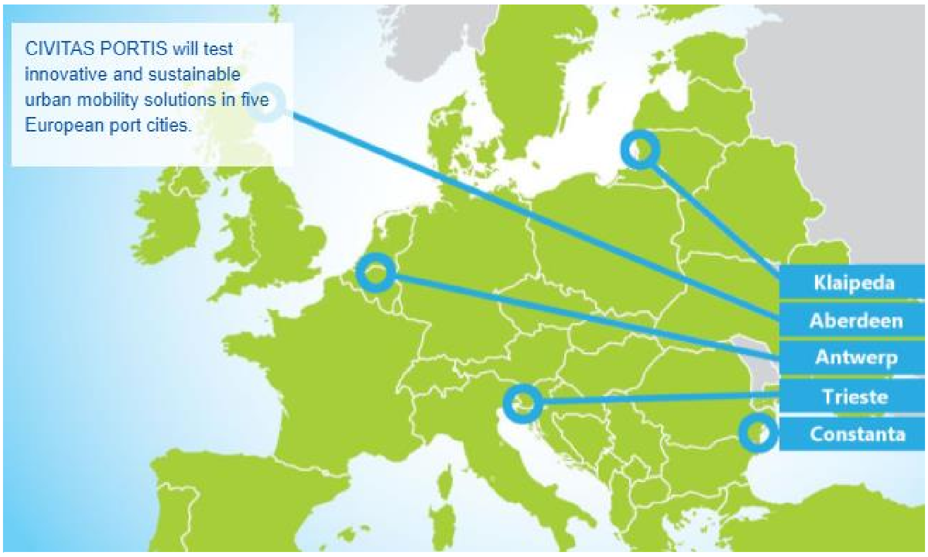


Figure 4.7 - CIVITAS PORTIS Trials Cities
Source: EUproject, website PORTIS /civitas.eu/

In a nutshell, the project aims to show that sustainable mobility can increase functional and social cohesion between city centers and ports while pushing the economy forward and boosting the transition to modern urban environments.

Here below, the main objectives of the project are listed:

- Improve governance for better cooperation between cities and ports
- Create more sustainable and healthier city-port environments
- Shape mobility systems integrated with a transport infrastructure
- Improve the efficiency of urban freight transport

Even if there is only a general description of PORTIS in the taxonomy, particular attention should be paid to the Chinese port Ningbo-Zhoushan (NZP).

It is relevant to introduce a brief shortline as it represents one of the significant innovations in port systems based on 5G technologies.

Its deployment started in 2018 when Huawei decided to help China Mobile Zhejiang build its first 5G port application pilot project at NZP.

In April 2019, the consortium successfully verified the operations, management, and video applications of remote gantry cranes based on the 5G network. Then, it launched the first independent and controllable 5G VoNR service between the port and Hangzhou during the same year.

In May 2020, Huawei, together with China Mobile Zhejiang, the first telecom company to create and initiate a 5G online store to empower 5G smart ports, Zhejiang Seaport Group, and Shanghai Zhenhua Heavy Industries signed a strategic agreement to produce 5G demo applications for Ningbo 5G + Smart Port.

Thanks to the enormous commitment of its consortium, today Ningbo-Zhoushan has achieved four firsts thanks to the project

- It has been the first system to adopt the E2E (End to End) and MEC network slicing. It has a dedicated channel solution for a packet slicing network (SPN) and iMaster Network Cloud Engine (NCE), a solution that provides intelligent connections, ensuring satisfactory low-latency performance.
- It is the first port to control the 5G gantry crane remote control, creating six 5G powered gantry cranes.
- In this sense, concerning the previous applications, it is also the first port with an end-to-end upgrade solution that meets the large connection needs of port gantry cranes, self-driving trucks, video surveillance systems, and other services.

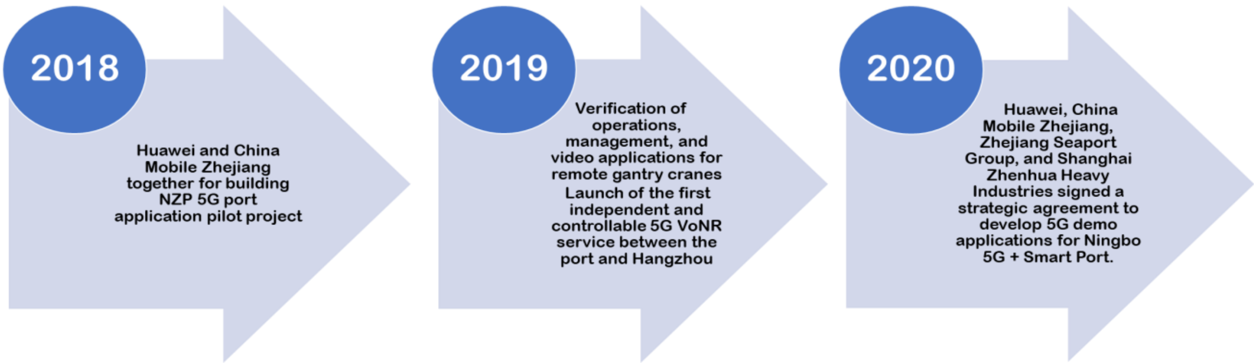


Figure 4.8 - NZP Development Timeline
Source: Personal Elaboration

NZP enjoys full 5G network coverage, with pilot port applications in regular commercial use, realizing colossal cost and efficiency benefits. 5G technology can help build world-class ports by driving digital transformation and stimulating an economic revival in the post-pandemic era.

In NZP, 5G smart port services cover core operating procedures. In particular, three main 5G applications for cargo ship unloading should be described: remote control of gantry cranes and port cranes for containers, smart cargo management, and automated self-driving trucks' logistics.[74][82]

CLUSTERS 2.0 - Open network of hyper-connected logistics clusters towards physical internet

Start Date:	01-05-2017
Duration:	38 months

Clusters 2.0 is a project under the Horizon 2020 framework that aims to leverage European Logistics Clusters' potential for a sustainable, efficient, and fully integrated transport system. It relies on an Open Network of Logistics Clusters supporting local, regional and European development and tryint to neutralize the local impact such as congestion, noise, land use, and local pollution levels.

It enhances and advances the coordination among logistics stakeholders and European logistics clusters, crucial for generating growth, employment, and competitiveness.

If well-established, these geographically concentrated sets of logistics-related businesses and operations, like transport carriers, warehouses, and third-party logistics service providers, could evolve into prosperous sources of innovation.

During the last three years, the project addressed challenging activities to meet important objectives, such as:

- Increase the engagement, performance, and coordination of terminals and hubs in the clusters.
- Achieve a significant step forward in the European Transport performance through a hyper-connected network of logistics hubs and clusters.
- Develop low cost, low capital, and investment intensive enhanced goods handling and transhipment solutions.

The Living Lab is focused on scenarios related to two vertical sectors:

1. Intermodal transportation development in Dourges.
2. Aircargo handling at airports in Athens port, Brussels Airport, Heathrow and Trelleborg.

The final goal is to convince regional bodies to bundle their volume in a regional hub to share their data to develop new connections.

Additionally, a Dynamic Terminal Management Platform, composed of a slot booking app, a community portal, a visibility app, and a real-time status application, will be tested to synchronize cross-company processes in terminals, meeting the challenges of non-synchronized activities through different applications.

Bout the intermodal scenario, the focus is on how logistics clusters can act as independent actors within the supply chain to collect shippers' transportation flow data.

Concerning the aircargo scenario, the objective is to create a visibility solution that will allow the different air-cargo supply chain actors to collaboratively plan, execute, and track their shipments through the data-sharing platform.

The intermodal scenario will be analyzed in the taxonomy.[58]

5GCAR - Fifth generation communication automotive research and innovation

Start Date:	01-06-2017
Duration:	24 months

There are two on-going industrial trends, one in the mobile communications industry and one in the automotive industry, that will jointly provide new capabilities and functionality for upcoming intelligent transport systems and future driving.
5GCAR builds a strong consortium from the automotive and the mobile communications industry to develop innovation at the intersection of those industrial sectors and support a fast and successful path towards safer and more efficient future driving.

5G DRIVE - 5G Harmonised research and trials for service evolution between EU and China

Start Date:	01-09-2018
Duration:	34 months

The Horizon 2020 project 5G-DRIVE will bridge together current 5G developments in Europe and China through joint trials and research activities to facilitate technology convergence, spectrum harmonization, and business innovation before the large-scale commercial deployment of 5G networks occurs. It will trial and validate the interoperability between EU and China 5G networks for enhanced Mobile Broadband and impact the validation of standards in V2X solutions.
The project's activities are structured around three main pillars:

- Testing and demonstrating the latest 5G key technologies in eMBB and V2X scenarios in pre-commercial 5G networks through trials in Finland, Italy, and the UK.
- Researching key innovation in networking slicing, network virtualization, 5G transport network, edge computing, and New Radio features to fill gaps between standards and real-world deployment.
- Boosting and increasing EU-China collaboration on 5G at all levels through extensive dissemination and exploitation actions.

Also, several project activities, including the definition and implementation of trials, will parallel the Chinese twinning project. [37]

LessThanWagonLoad - Transport solutions in the Antwerp chemical cluster

Start Date:	01-05-2017
Duration:	36 months

It develops a smart specialized logistics cluster for the chemical industry in the Port of Antwerp to shift freight transport from road to rail.

The LessThanWagonLoad project aims to create a smart specialized logistics cluster for the chemical industry in the Port of Antwerp to shift transport volumes from road to rail freight. This objective will be realized by developing new rail transport solutions for single pallets and new added value rail freight services for the industry within the Antwerp chemical cluster. These potential new services consist of parking, repair, picking, cleaning for chemical wagons, rail connected cross-docking of pallets, and improving rail connections by setting up mixed trains with conventional and maritime container volumes. These innovations will be possible thanks to the complementarity of modern technologies.

The project primarily focuses on Antwerp and the chemical industry. However, the new concepts can also be leveraged to other logistical hubs within different sectors. [70]

LOGISTAR - Enhanced data management techniques for real-time logistics planning and scheduling

Start Date:	01-06-2018
Duration:	40 months

LOGISTAR's objective is to enable effective planning and optimization of transport operations in the supply chain by taking advantage of horizontal collaboration and relying on the increasingly real-time data gathered from the interconnected environment.

Moreover, real-time decision-making, visualization of freight and transport tools will be developed to deliver information and services to the various agents involved in the logistic supply chain, freight transport operators, clients, industries, and other stakeholders such as warehouse or infrastructure managers.[71]

NexTrust - Building sustainable logistics through trusted collaborative networks across the entire supply chain

Start Date:	01-05-2015
Duration:	42 months

NEXTRUST's objective is to increase efficiency and sustainability in logistics in Europe by developing interconnected and trusted collaborative networks along the entire supply chain.

NEXTRUST will build these trusted networks ideally bottom-up with partners, adding multiple layers of transport flows that have been de-coupled and then re-connected more effectively along the supply chain.

It will focus on research activities that create collaboration in the market on subjects validated through pilot cases in live conditions.

In the end, three significant logistics projects that will be used 5G-LOGINNOVbaseline will focus on the actual work included in the taxonomy. [64]

AEOLIX - Architecture for european logistics information exchange

Start Date:	01-09-2016
Duration:	36 months

AEOLIX establishes a cloud-based collaborative logistics ecosystem for configuring and managing logistics-related information. It aims to contribute to the EU's political priorities, optimize the flows of goods, facilitate the management, and reduce the supply chain administrative burden to use existing resources better.

For this purpose, it will develop a platform to connect logistic information systems with the various features needed to produce an immediate exchange of information and support logistical decisions and develop the architecture for a distributed open design that will exchange information among the leading logistics players.

During the project, the logistics-related business challenges have been selected as use cases to research during several living labs and validate and prove the advantages of the platform.[56]

FENIX - European federated network of information exchange in logistix

It is a three-year European project that aims to support the development, validation, and deployment of digital information systems and the EU's core transport network.

It counts 11 pilot sites, which will be implemented in 9 European countries and will further develop the work carried out within the two projects AEOLIX and SELIS's living labs.

Fenix will develop the first European federated data sharing architecture serving the European logistics community of shippers, logistics service providers, mobility infrastructure providers, cities, and authorities to offer interoperability between existing and future individual platforms.

The idea of FENIX aims to create a valid federative network for the exchange of Business to Administration (B2A) and Business to Business (B2B) data and for sharing the results with the transport and logistics operators.[68]

SELIS - Towards a shared European logistics intelligent information space

Start Date:	01-09-2016
Duration:	36 months

SELIS research focuses on designing the SELIS Community Nodes (Open Architecture) and creating the following three Unique Value Propositions addressing the supply chain:

- Enhanced Supply Chain Collaboration and Knowledge Sharing with inbuilt Trust and Governance
- SELIS "Out of the box Cloud data and services decentralized infrastructure" to form and manage virtual communities for logistic chains
- Key SELIS Enablers to speed up the formation of a single logistics information space in Europe

The SELIS project has a Knowledge Base and Observatory web portal to provide a centralized space for all relevant articles, publications, and documents to be hosted in a structured way and with easy accessibility.

This portal will be used as part of the project's valorization and dissemination plan. [96]

Chapter 5. Taxonomic Contribution for 5G in Industry and Port Logistics

5.1 Global 5G Contextualization through PEST and SWOT Analyses

5.1.1 5G Hype and the Cycle of Innovation

5G technology, with its applications and new services, will lead to the transition to Digital Life, transforming the way of living, working, and communicating through a series of innovations, from cities to the Smart Home, to the Internet of Things, to the Cloud for professionals and personal use, virtual reality, augmented reality, industry 4.0 and much more.

This innovation is expected to have a broad consensus, particularly in the industrial world, and be adopted in various sectors.

However, the concept of "5G" has spread so widely that it is difficult to classify which applications can be most helpful and how many benefits they bring as they are different from one sector to another.

The cycle of a new technology begins with the trigger phase, in which there is a solution without knowing yet the problem to solve.

Subsequently, from this initial phase in which the technology spreads and is known by the people, a peak of expectations is reached: the innovation is applied for any applications without entirely realizing its usefulness.

Then, there is a phase of disillusionment, in which with the drop in expectations, a negative slope is drawn, and many people abandon the market because they discover the real application of the technology doesn’t correspond to the one they pursued.

Once the issues for which 5G is an ad hoc solution are individuates, therefore, the commercialization phase begins and 5G now is approaching this phase.

However, as also mentioned before, 5G has become a kind of hype; in other words, it is a topic of broad interest for researchers and experts from different sectors and industries, and as it is the enabling technology of numerous applications, it is challenging to understand those that best suit the innovation.

To not get lost and keep in mind what the real applications may be, it is essential to proceed with a classification of 5G according to multiple criteria and to understand which proper use will apply for this innovative technology. [81]

Moreover, after a reasonable classification, it will be easy to analyze and deduce the future of 5G.

5.1.2 PEST Analysis

The first examination concerns a general contextualization of the 5G world from a global point of view obtained through PEST analysis to study the external factors of the context and evaluate the situation globally, defining the real environment of a world ready to adopt 5G. [10]

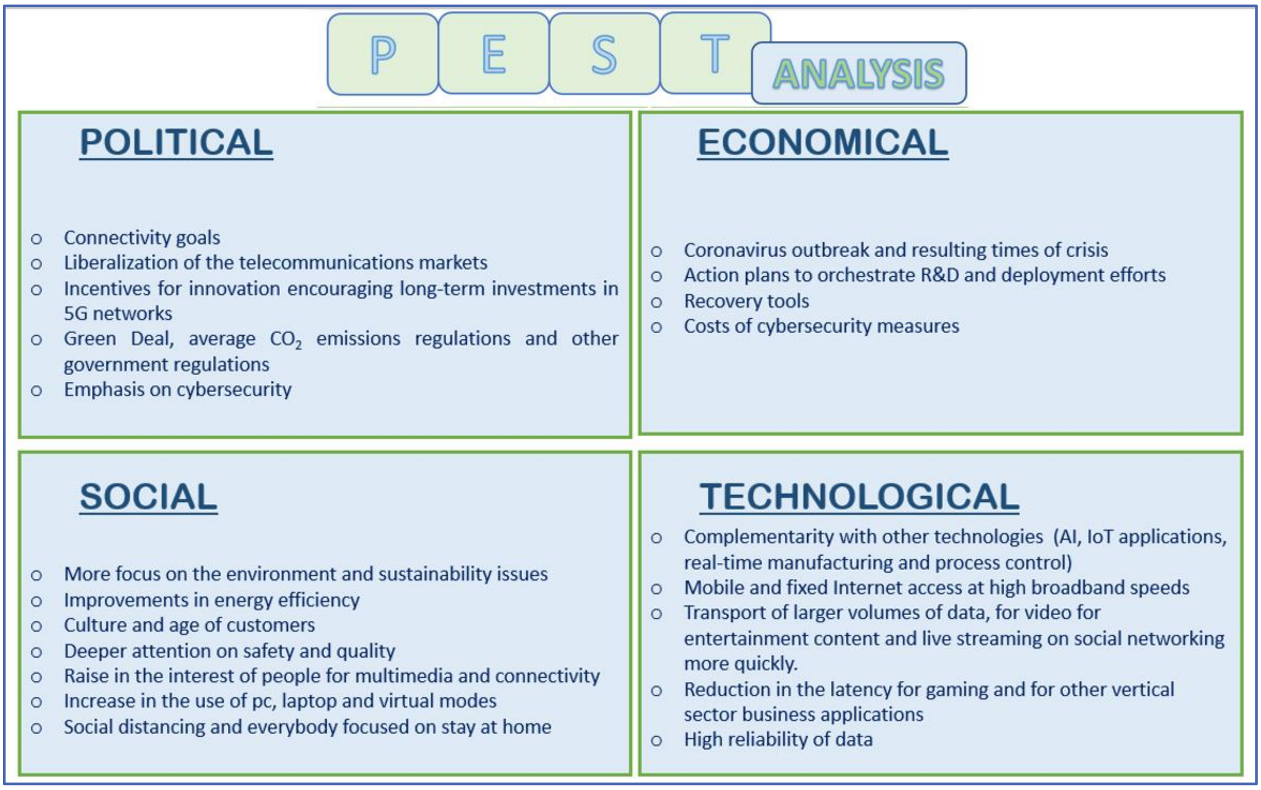


Figure 5.1 - Contextualization through PEST Analysis
Source: Personal Elaboration

From the PEST analysis's generic results, it can be briefly noted that the government will undertake various initiatives to achieve connectivity goals at the political level.
Also, from an economic point of view, there will be national and international incentive plans for investments in R&D despite the slowdown caused by the onset of the Coronavirus outbreak, which has slowed down the construction and development of infrastructure and led to a reduction in the average income of many citizens and SMEs, decreasing their willingness to purchase or invest in technologically innovative equipment.
From a social perspective, 5G innovations would be of major importance since spending a lot of time at home generates a constant need to be connected, especially in the working environment. In fact, a system that has become enormously widespread is smartworking, which can also be strengthened and improved with the new 5G technology.

Regarding the technological aspect, the adoption of 5G will have many different improvements; it will enhance and support many existing technologies, which will enable applications that are currently impossible without more robust connection support. It will also guarantee improvements in reliability, flexibility, and data speed. Some schemes have already been outlined, but there is not yet one emerging that seems more powerful than the others. As the dominant paradigm has not emerged yet, many new entrants seek to access this unique market or build new business models independently. Even industries that are already part of the market, MNO on the one hand, and verticals that already existed but have undergone changes in operations by introducing this technology must find a point of transition to maintain their competitive advantage against all newcomers.

5.1.3 SWOT Analysis

From this general analysis, however, the need for a more specific assessment emerges. A SWOT analysis is introduced to examine what opportunities and threats are presented by this new technology and the strengths and weaknesses related to its implementation process. Below, the SWOT Analysis summary table.

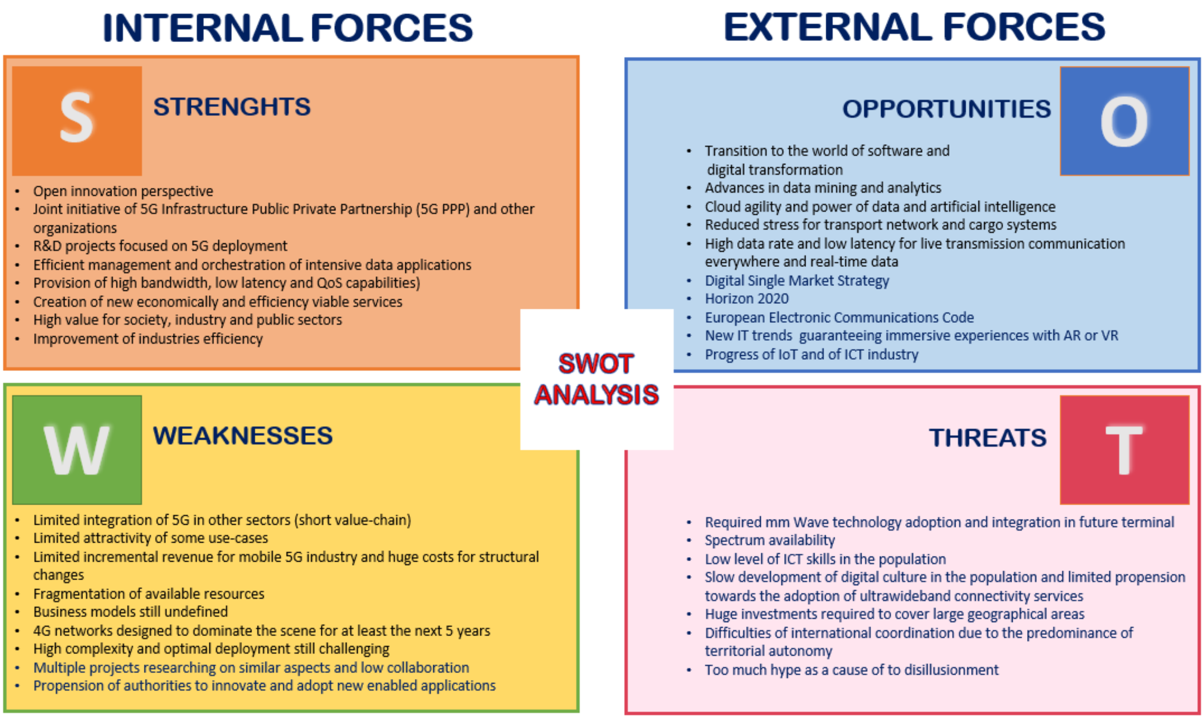


Figure 5.2 - SWOT Analysis
Source: Personal Elaboration

The innovation linked to 5G, despite deriving from the evolution from past technologies, is undoubtedly revolutionary, completely changing the use and purpose that society has been used to expect from mobile technology networks or in industries, thus resulting in radical change technology.

Different perspectives can be considered to define innovation.

From a technical point of view, innovation can be both competence enhancing and competence destroying depending on who the interested stakeholders are: talking about MNOs, this technology could probably be competence destroying from some point of view; they have to remodel their strategy. Instead, concerning new entrants in the market or new sectors involved in using this innovative technology, it is a case of competence enhancing innovation compared to the significantly less automated systems that were previously in use.

Furthermore, it can be classified as a core innovation linked to all the network's core components; in fact, the network changes both in terms of application method, type of use, and requirements necessary for its use, so it changes completely.

It will most likely be categorized as a disruptive innovation, which means that the incumbents face a significant change, maybe the market leaders fall back, and a company that was not a market leader assumes this role. Here it is likely that entrants enter the sector and become leaders.

In a radical innovation, everything changes, both from a technical side and from the relationships between the network components, so it is hard to manage this situation.

5.2 Creation of a taxonomy for 5G logistic projects

At this point, there are all the elements necessary for the creation of a taxonomy, a fundamental approach to the innovation, in order to obtain a complete overview of it, and understand its expected and latent potential.

Nowadays, it is difficult to characterize the critical success factors of 5G initiatives, as there is a large number of projects that work on different objectives, as described in the previous chapter. The dataset will specifically contain a detailed analysis of approximately 40-50 European-funded global interest projects concerning the application of 5G in port logistics and logistics or the strengthening and construction of 5G infrastructures.

Moreover, from this taxonomy, it will be possible to obtain a complete list of the stakeholders involved and the main common elements emerging from different projects. The data acquired will be analyzed using statistical tools for clearly highlighting the success factors, trends, and future paths in which all these projects are moving, along with different aspects (e.g., business model, purpose, industry).

5.2.1 Methodology

As regards the method adopted for the realization of the taxonomy, resuming the previous chapters, three main phases can be distinguished. The first step is characterized by a general analysis conducted on the state of the art of 5G in general, defining the terminology for requirements and standards and the current European approach towards this new technology.

Subsequently, further analyses were carried out regarding the logistics and port logistics sectors to understand the most influential innovations applicable to the industry.

The second phase consists of a descriptive analysis of each of the projects (partially included in the previous chapter): the data achieved will be examined according to different criteria and aggregated on a cluster-based analysis to be inserted in taxonomy: Cluster analysis is a statistical method to aggregate data with common characteristics for simplifying data processing. It works by organizing items into groups or clusters based on how they are associated. The goal of cluster analysis is to find similar subjects, where "similarity" between each subject means a global measure of the entire set of characteristics.

This methodology will facilitate the further steps in which the dataset will be used for statistical purposes and to find new trends and business models.

5.2.2 Selection of Projects

The information on projects has been extrapolated from the 5GPPP website or Cordis.ue or Global5G.org: these are platforms containing all the projects funded within the Horizon 2020 framework ad by the European Union.

The following keyword list was used to research projects: 5G for Port Logistics, 5G Industry 4.0, Smart Ports, 5G Logistics, 5G for Industry, 5G Ports, 5GPPP.

In taxonomy, both projects in progress and projects already completed have been inserted, with the additional choice of including new projects undertaken recently.

In this way, a larger sample of data is covered, and valuable information can be easily obtained on various fronts, considering the time reference. In addition, the progress of the projects was checked in order to ensure that the information necessary for the taxonomic classification was available for each of them.

To give a complete reference, the time horizon between the start dates of the projects varies from 2015 to 2021, and their end date is set between 2017 and 2024, and below there is a timeline containing all the projects in chronological order (ordered following the expected end date of the projects) and cataloged in relation to the different phases of 5GPPP. [102]

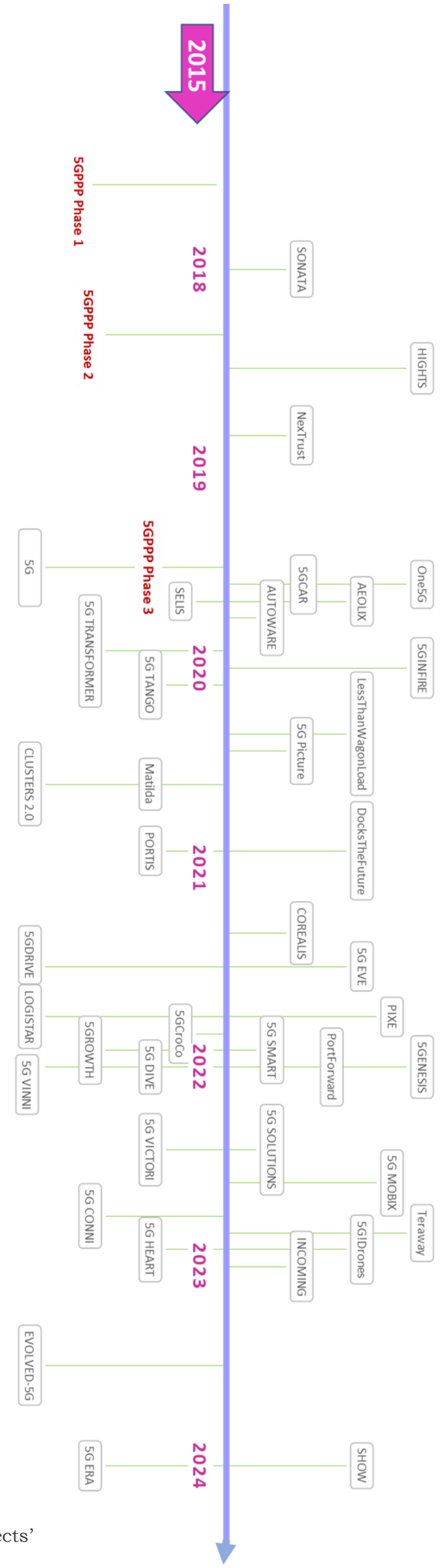


Figure 5.3 - Timeline based on projects' end dates

5.2.3 Construction of Taxonomy

The structure of the taxonomy is based on three levels of detail.

At the first level, three classes are used to classify different aspects of the projects selected: Description, Business Model and Purpose. Then, each axis is structured at the second level into different categories representing the main characteristics that distinguish and compare the various projects.

Therefore, for each of these categories, the sub-categories provide more accurate information at the third level. These sub-categories are elements defined a priori to enclose the project under analysis in one of these predefined subdivisions and create a statistical basis for the next steps.

In this subsection, the taxonomy is carefully described in all its categories and subcategories:

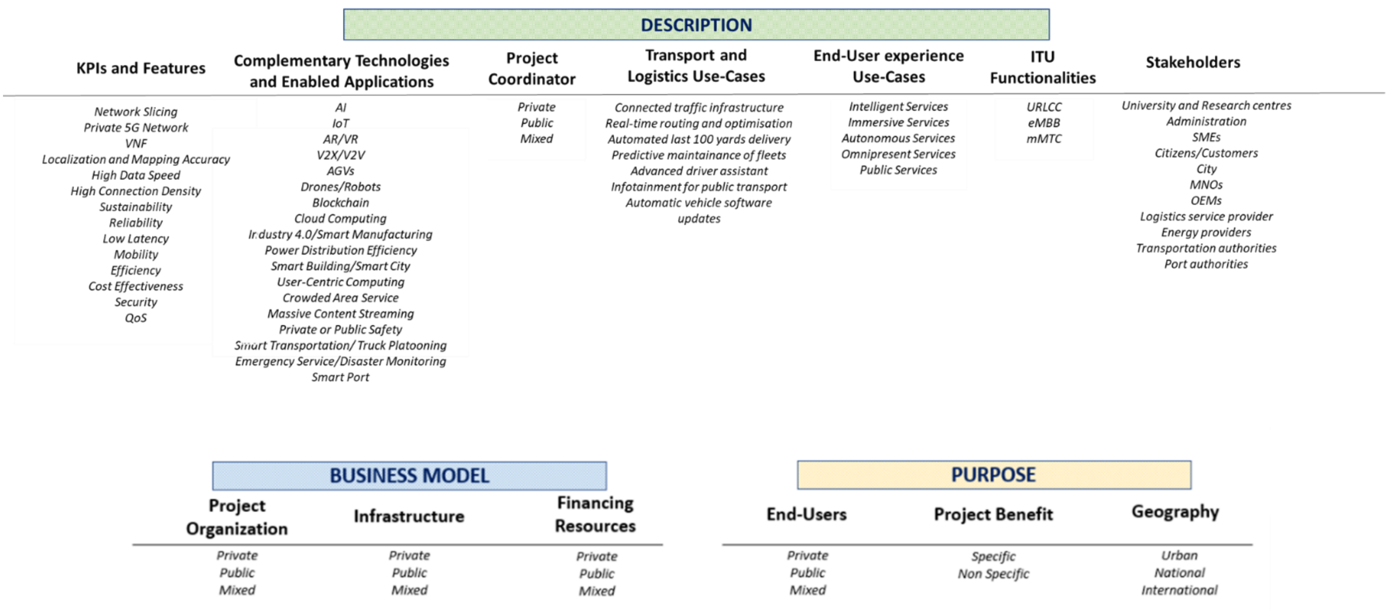


Figure 5.4 - Taxonomy Layout
Source: Personal Elaboration

Now the three classes and their respective categories and sub-categories are analyzed in more detail:

"Description" offers a general overview of the project and its context, with particular attention to the innovative elements enabling trials on different applications to which the projects aim. It also includes the analysis of use cases according to different perspectives.

An introduction to the categories under this class can be consulted below:

5G project	Expected Results	Description						
		KPIs and Features	Complementary Technoogies and Enabled Applications	Project Coordinator	Transport and Logistics Use-Cases	End-User experience Use-Cases	ITU Functionalities	Stakeholders
5G TANGO - 5G Development and Validation Platform for global Industry – specific Network Services and Apps	Factory and process automation	Network Slicing	AI	Public	Real-Time Routing and	Autonomous	URLCC	University and Research
		VNF	IoT			Omnipresent	eMBB	Administration
		QoS	Smart Manufacturing				mMTC	SMEs
		Reliability	Industry 4.0					Logistics service provider
		Low Latency						
		Security						
		High Data Speed						

Figure 5.5 - Taxonomy Description Class
Source: Personal Elaboration

KPIs and Features consist of elements that didn't exist before or had a potential improvement thanks to the introduction of 5G, and they, in turn, permit the creation of new use cases and applications or the advancement of technologies complementary to 5G. Therefore, they constitute both qualitative indicators of recent performances never seen before and innovative components explicitly related to 5G.

The next category contains both Complementary Technologies and Enabled Applications to combine the fact that one as well as the other benefit from 5G.

As it was decided to examine projects mainly concerning the logistics and port sector, the main technologies in this sector that collaborating with 5G give rise to new applications will be deducted.

At the same time, under this column, each project indicates the particular applications that are objects of trials and research. The result will be a general overview of the most enabled applications in this 5G field will be obtained, in order to be able to search for similarities and correlations between different projects.

The Project Coordinator is the body that defines the strategy and sets the milestones of the project, dealing with its coordination and management.

The sub-categories into which it is divided are public, private, and mixed.

It is now explained how these sub-categories do not refer only to this item, but will also be clusters of other categories, precisely because it is essential to note whether the coordination of a project and even other elements, such as financial resources, organization, the infrastructures used, etc. are provided by a public or private body or by a mixed entity, when both public and private bodies have interests in developing and promoting innovative projects and cooperate to find better solutions.

The private sector aims to improve efficiency in supply chain automation and in every area of applied logistics, and the public bodies aim at pushing innovation while guaranteeing a high-level quality of life to society.

Subsequently, the three classifications for use cases align with the three different perspectives seen in previous chapters.

The ITU functionalities subcategory groups the projects depending on the ITU classification.

The end-user perspective column classifies the projects following the categories defined by users' perceptions.

The transport and logistics use cases include the main functions related to the world of logistics and cluster the projects based on their main logistics objectives. If the project aims to improve the infrastructure or the network, for example, it is inserted in the "Real-Time Routing and Optimisation" subcategory as this enhancement surely helps ameliorate the processes.

As regards the Stakeholders, they are numerous and diversified because an innovative activity such as the adoption of new technologies in different industrial sectors always involves different subjects (universities and research centers, SMEs, customers and citizens, the city itself, and the MNOs who are seeing their business changing as noted in the SWOT analysis), each with their roles and objectives.

"Business Model" addresses the aspects of the project management and the financial and operational organization beneficial to the project to clarify the business and governance models and the trends that can be derived for future deployments. Another interesting topic regards the providers of infrastructures, equipment, and financial resources, and in the three related columns it is required to select if activities are held by a private, public, or mixed entity.

Now the three columns are described in more detail:

5G project	Expected Results	Business Model			Purpose		
		Project Organization	Infrastructure Financing	Financial Resources	End-Users	Project Benefit	Geography
5G TRANSFORMER - 5G Mobile Transport Platform for Verticals	*Enable vertical industries to meet their service requirements and aggregate and federate transport networking and computing fabric*	*Mixed*	*Mixed*	*Public*	*Mixed*	*Specific*	*International*
COREALIS - Capacity with a pOsitive enviRonmEntal and societAL footprInt: portS in the future era	*Achieve a significant step forward for future ports to maximize their capacity and efficiency with minimum infrastructure upgrades, while at the same time ameliorating the port-city relation*	*Mixed*	*Mixed*	*Public*	*Mixed*	*Non Specific*	*International*

Figure 5.6 - Taxonomy Business Model and Purpose Classes
Source: Personal Elaboration

Project organization refers to the structure of the project. It is sometimes not so simple to be handled and requires collaboration among different entities, with specialists and workers from various departments that work under the project coordinator.

These collaborations, as already mentioned, can be public, private, or mixed.

Many times it takes the form of a Public-Private Partnership (PPP) or similar organizations: in these cases, the Government grants, for a fixed number of years, the right to use the public facilities to a private company.

Infrastructure financing refers to the supply of physical assets such as infrastructure, equipment, vehicles, and devices by public, private, or mixed entities. In a Public-Private Partnership, a mixed entity is indicated as infrastructure financing because the organizing body offers the infrastructures and facilities, and private entities typically provide the equipment and devices.

Financial resources indicate the entity in charge of financing the project and undoubtedly represent a fundamental element within a business model.

It is essential to investigate the financing methods and the key resources to get an idea of the budget available and, at the same time, the interest aroused by the project.

For simplicity in taxonomy, if the percentage covered by the fund is more significant than 80% of the total budget, it is indicated as Public Investment.

To conclude, there is the "Purpose" class that examines the project's aim by verifying the type of end-user who will adopt and benefit the solution, the geographical target covered, and eventually if it has already a specific objective or if it is the solution of problems that will be identified only at the end of the project, after several trials on different applications.

End-user, which refers to the actors who benefit from the project results, can be, again, a private subject, a public or a mixed body.

The project benefit indicates whether the project's purpose has already been identified or if it is still a solution to unknown problems.

This category also gives the means to understand at what point of the development the project under analysis generally is without looking at the date and duration.

It can be marked as specific or non-specific. In the case of a non-specific project, the result that will be achieved may not be very clear, and the designers can still be working on development or trials.

Geography indicates if the innovative concepts and solutions researched will be applicable only in a specific context, or if they could be valid also for similar vertical sectors and in different areas. The three subcategories used to cluster are urban, national, international. A pilot project is often tested thoroughly and conceptually in a city taken as a trial to understand each problem fully.[28]

Once the solution has been implemented, the project is scaled down in other cities, saving time and costs and achieving economies of scale. In this case, the project becomes transnational, thus involving different cities or even counties, and is indicated in the taxonomy as an international project.

5.3 Statistical Analysis of the Taxonomy

5.3.1 Introduction to the Descriptive Statistics

The following statistic investigates the taxonomic dataset related to EU 5G projects.

The analysis was conducted using the XLStat statistical tool and Excel plugins to individuate the most significant values again through a cluster-based approach. The aim is to check if similar trends occur in diverse projects and investigate new possible business models.

Firstly, it is constructed a descriptive statistic to assess the frequency of each subcategory in the taxonomy.

For the sake of simplicity, the results are reported together with the categories that will be introduced later.

KPIs and 5G Features

The first element examined is the category of KPIs and Features, under the Description class, and it is checked the frequency distribution of each 5G feature contained in the category among the various projects discussed. The results are summarized in the following chart:

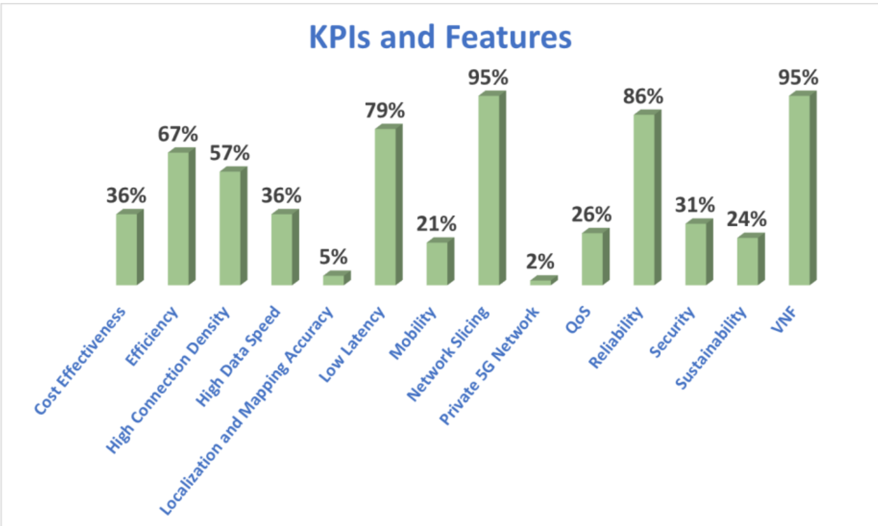


Table 5.1 - Frequency Distribution of Subcategory in the Taxonomy: KPIs and Features
Source: Personal Elaboration

First of all, it is noticed that Network Slicing and VFN are present in almost all the projects analyzed. In fact, being the main features of innovation introduced with 5G, we try to exploit its potential to realize different applications. Other elements with high attendance rates in the projects are Low Latency and High Reliability. However, in these cases, the values are not too much high to indicate a constant presence in each project and, therefore, be helpful in outlining trends.

They still stand out for their high presence within the High Connection Density and Efficiency dataset.
There is also an average but still significant presence in most of these KPIs. Only two have such low-frequency percentages that it would be counterproductive to use them to outline models, Private 5G Network and Location and Mapping Accuracy.
Again, with the subcategories of KPIs and 5G Features, brief factor analysis is carried out by examining their correlation with each project and thus outlining the relationships between them to see if some have significant correlations that can lead to saying that often or always together.
Therefore, the latent factors will be sought through the aggregations of KPIs that emerge from the analysis as significantly correlated.
In this way, through these aggregations, the macro-objectives requested by these features within the projects under analysis will be outlined.
During the factor analysis performance, we chose to use three components as they already represented 60% of the variance, and the results are briefly summarized in the following graph.
The detailed procedure followed for the factor analysis in all the steps will be better explained later during the examination of other characteristics in which the same method will be applied.
Notice that the chart has to be seen as a tridimensional chart, thus to ease the comprehension, the KPIs belonging to diverse latent factors have been distinguished with different colors: factor 1 in red, factor 2 in yellow, and factor 3 in blue.

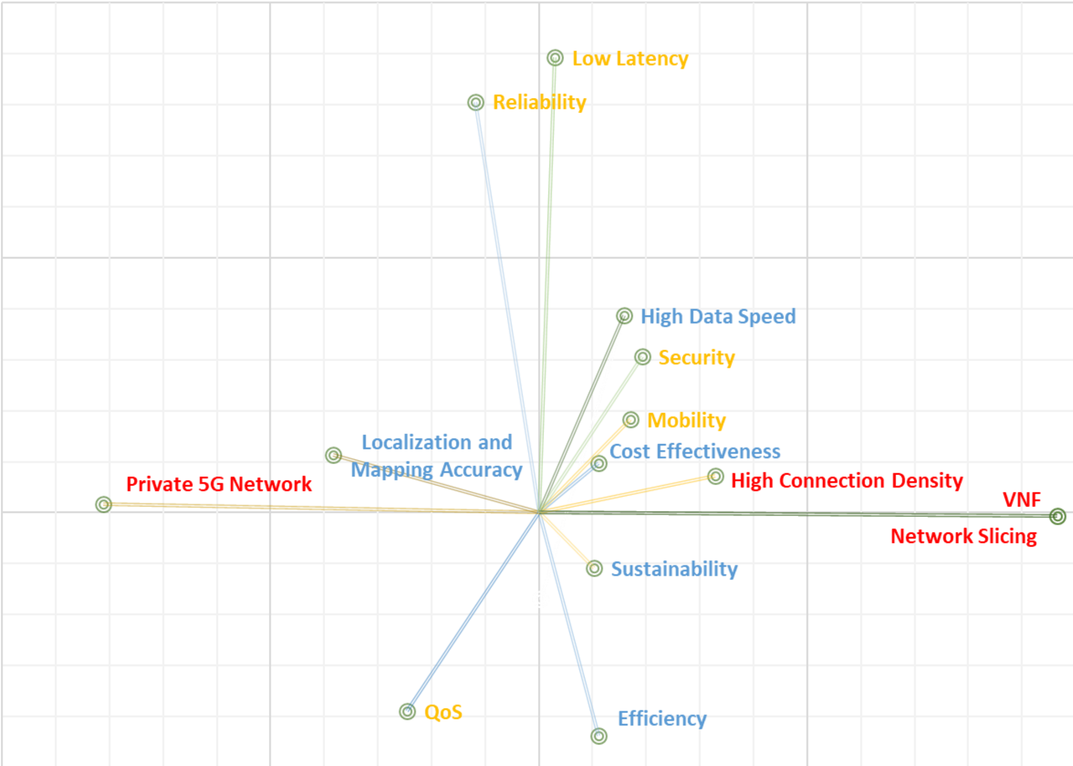


Table 5.2 - KPIs Clusterization through Factor Analysis Varimax
Source: Personal Elaboration

The first factor contains Network Slicing, VFN, and High Connection Density, and again, in contrast to them, Private 5G Network, which confirms what has been said in state of the art, that trials are being carried out on methods that allow for a private network instead of sharing, through slicing, with others who could be the competitors themselves.

However, this latter indicator appears with shallow frequency in the dataset. This factor is defined as Network Improvement, as both with network slicing and virtualization of services and with a high density of connections, but also with the 5G Private Network, optimized network services and an improvement in these performances are obtained.

The second relationship appears between mobility, reliability, security, and low latency, negatively correlated with QoS. In fact, the service quality usually is negatively correlated with the network's traffic and positively with the resources used to manage the network. With the increase in the number and types of services and traffic offered compared to the capacity of the network, the problem of service quality has begun to become crucial and increasingly considered. Therefore it is taken into account that in projects that require high mobility, reliability, security, and low latency, perhaps for different services and applications, the QoS will not be optimized.

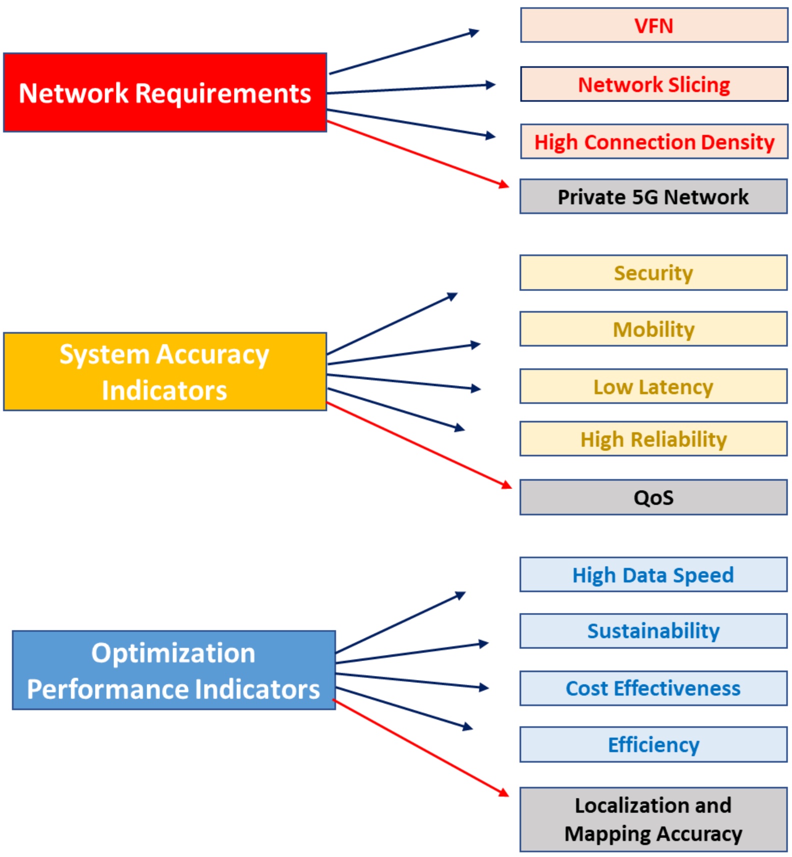


Figure 5.7 - Latent Factors for 5G KPIs and Features
Source: Personal Elaboration

In conclusion, the last factor represents the optimization of the processes and includes cost-effectiveness, efficiency, sustainability, and high data speed. There is a negative correlation between localization and mapping accuracy with other applications: one cause may be the use of millimeter waves to optimize other characteristics, which, however, generate physical blockages of the signal due to walls and buildings. However, this negative correlation can also derive from the fact that the frequency of Location and Mapping Accuracy is extremely low.

These results are enclosed in the graph on the left.

Complementary Technologies And Enabled Applications

As for complementary technologies and enabled applications, it has been chosen to put in the same category to highlight how both benefit from the introduction of 5G, even if the one hand because of the collaboration with 5G and on the other for the improvement of services offered and the ability to enable enhanced applications.

Since the benefits of 5G KPIs will then be fully assessed on all technologies and applications contained in this category, as regards frequency and frequency, it is divided between complementary technologies and enabled applications in order to see which ones have a higher frequency in each of the two subgroups.

In fact, technologies such as IoT, AR and VR, but also AI, Blockchain, Cloud and Edge Computing, are expected to become much more efficient and reliable thanks to the technical characteristics and performances obtainable with 5G. These results will then be tested by verifying the correlations.

These technologies together, and the improvement they will achieve, will, in turn, help enable and improve applications in most Industry 4.0 and Smart Manufacturing, Smart Transportation and Truck Platooning, Smart Building and Smart City projects.

The frequency distribution of complementary technologies among projects selected can be seen in the chart below:

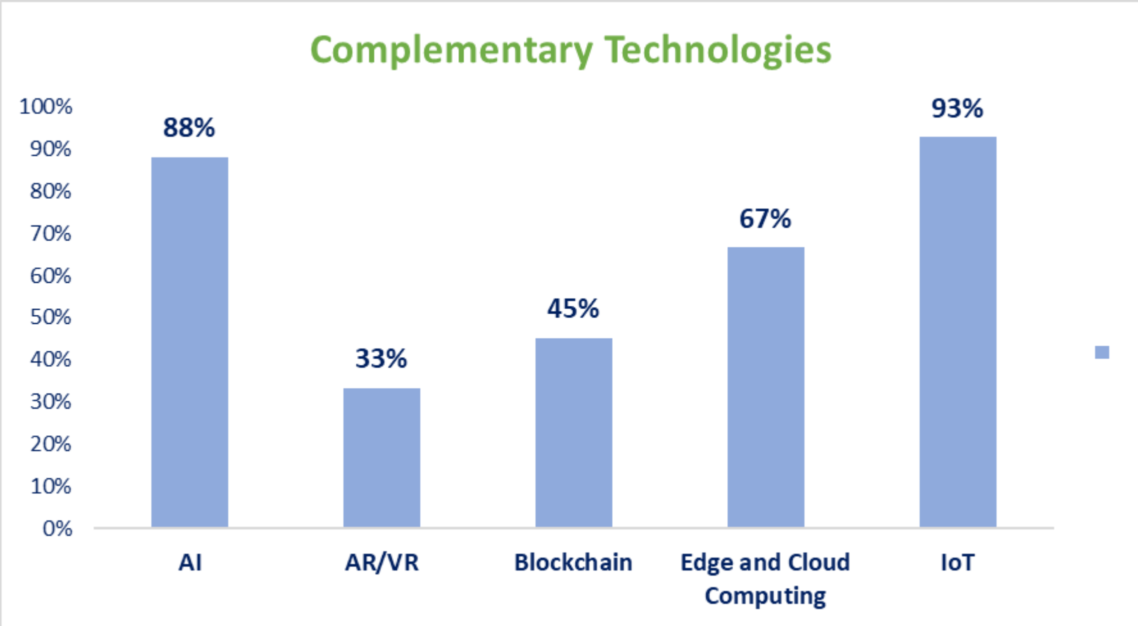


Table 5.3 - Frequency Distribution of Subcategory in the Taxonomy: Complementary Technologies
Source: Personal Elaboration

Some of them, in particular AI and IoT, which have the highest frequency among the projects examined, will, in turn, be fundamental for the realization and improvement of other use cases and applications; edge and cloud computing are also very important in the industrial sector, especially edge technology, which by cutting the trajectories that information must take will offer a clear advantage in terms of latency and reliability.

Similarly, the blockchain is a beneficial element for managing and storing data in environments where there is high connection density, such as industries, smart ports, and smart cities.

Finally, although AR and VR offer valuable services to workers and carry out industrial operations, they provide an immersive experience within smart vehicles. Their presence and collaboration with 5G in projects focused mainly on the industry is less compared to that found for other technologies.

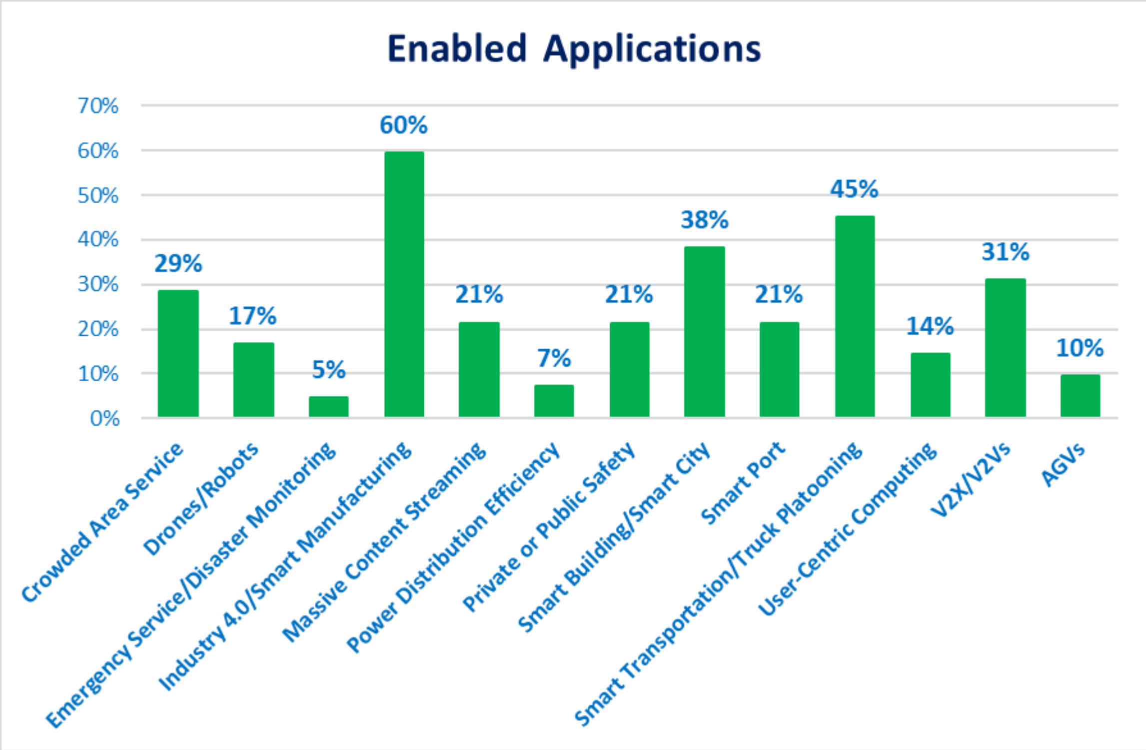


Table 5.4 - Frequency Distribution of Subcategory in the Taxonomy: Enabled Applications
Source: Personal Elaboration

From this graph, it is undoubtedly noticed that the frequency between applications in the dataset varies a lot: on the one hand, Industry 4.0 and Smart Transportation are present in almost all the projects analyzed. Smart buildings and smart cities, in particular, also have a relevant frequency. On the other hand, applications for ports or others appear in a very small percentage (about 20% or even less) despite being the taxonomy's main focus. Therefore, it is assumed that although port projects are a good number, there are many more projects related to industry. However, applications such as drones, robots and AGVs also rarely appear in the analyzed projects. The selected projects' major trend seems to be about general process optimization, increasing reliability and decreasing process latency.
Finally, some applications not particularly related to the sector under analysis, appear in some parallel projects and other applications, but have a low frequency. Some examples are Power Distribution Efficiency or Emergency Service & Disaster Monitoring. This disproportionality in the frequency of applications must therefore always be taken into consideration for subsequent analyzes.
As regards the creation of business models, it was decided not to limit ourselves to deciding a trend based on the frequency trend of the individual categories, but we will evaluate which KPIs related to 5G act on specific technologies or applications and what the impact in each of these cases, thus carrying out an analysis that searches for the correlations between the two categories.

Since the selected projects belong to specific vertical sectors, the correlations between the two categories will be high, but some trends will be defined anyway.

5.3.2 Relationship among Enabling Features and Complementary Technologies & Enabled Applications

As explained above, the need to deepen the examination of the existing links between the KPIs and Features of 5G and the complementary technologies & enabled applications present in the data set of the project is evident.

It is necessary to investigate the requirements of 5G that give more significant advantages in the industrial sector and how applications and technologies this phenomenon occurs.

The procedure consists of a statistical analysis that evaluates the actual relationships between Complementary Technologies and Enabled Applications and KPIs and Features.

A new factor analysis will then be performed regarding these relationships to see if some of the features of 5G work well together and if there are repeating trends in both upgrading the existing technologies and enabling new applications. Subsequently, the

T.REQUIREMENT x PROJECTS	*Cost Effectiveness*	*Efficiency*	*High Connection Density*	*High Data Speed*	...
5G CONNI	$i_{1,1}$	$i_{2,1}$	$i_{3,1}$	$i_{4,1}$	...
5G DIVE	$i_{1,2}$	$i_{2,2}$	$i_{3,2}$	$i_{4,2}$	...
5G ERA	$i_{1,3}$	$i_{2,3}$	$i_{3,3}$	$i_{4,3}$	...
5G EVE	$i_{1,4}$	$i_{2,4}$	$i_{3,4}$	$i_{4,4}$	...
5G HEART	$i_{1,5}$	$i_{2,5}$	$i_{3,5}$	$i_{4,5}$	...
5G MOBIX	$i_{1,6}$	$i_{2,6}$	$i_{3,6}$	$i_{4,6}$	...
5G Monarch	$i_{1,7}$	$i_{2,7}$	$i_{3,7}$	$i_{4,7}$	...
5G Picture	$i_{1,8}$	$i_{2,8}$	$i_{3,8}$	$i_{4,8}$	...
5G SMART	$i_{1,9}$	$i_{2,9}$	$i_{3,9}$	$i_{4,9}$	...
5G SOLUTIONS	$i_{1,10}$	$i_{2,10}$	$i_{3,10}$	$i_{4,10}$	...
5G TANGO	$i_{1,11}$	$i_{2,11}$	$i_{3,11}$	$i_{4,11}$	...
5G TRANSFORMER	$i_{1,12}$	$i_{2,12}$	$i_{3,12}$	$i_{4,12}$	...
...	...	...	...	...	...
Total	$\sum_{k=1}^{42} i_{1,k}$	$\sum_{k=1}^{42} i_{2,k}$	$\sum_{k=1}^{42} i_{3,k}$	$\sum_{k=1}^{42} i_{4,k}$	...

APPLICATION X PROJECTS	*V2X/V2Vs*	*Smart Transportation/Truck Platooning*	*User-Centric Computing*	*Smart Port*	...
5G CONNI	$j_{1,1}$	$j_{2,1}$	$j_{3,1}$	$j_{4,1}$	...
5G DIVE	$j_{1,2}$	$j_{2,2}$	$j_{3,2}$	$j_{4,2}$	...
5G ERA	$j_{1,3}$	$j_{2,3}$	$j_{3,3}$	$j_{4,3}$	...
5G EVE	$j_{1,4}$	$j_{2,4}$	$j_{3,4}$	$j_{4,4}$	...
5G HEART	$j_{1,5}$	$j_{2,5}$	$j_{3,5}$	$j_{4,5}$	...
5G MOBIX	$j_{1,6}$	$j_{2,6}$	$j_{3,6}$	$j_{4,6}$	...
5G Monarch	$j_{1,7}$	$j_{2,7}$	$j_{3,7}$	$j_{4,7}$	...
5G Picture	$j_{1,8}$	$j_{2,8}$	$j_{3,8}$	$j_{4,8}$	...
5G SMART	$j_{1,9}$	$j_{2,9}$	$j_{3,9}$	$j_{4,9}$	...
5G SOLUTIONS	$j_{1,10}$	$j_{2,10}$	$j_{3,10}$	$j_{4,10}$	...
5G TANGO	$j_{1,11}$	$j_{2,11}$	$j_{3,11}$	$j_{4,11}$	...
5G TRANSFORMER	$j_{1,12}$	$j_{2,12}$	$j_{3,12}$	$j_{4,12}$	...
					...
					...

Table 5.5 - Binary Charts representing the frequency of KPIs and Applications in Projects
Source: Personal Elaboration

results will be taken as a model, or some applications will be chosen, and the requirements that enable them will be indicated for them.

The preliminary phase concerns creating two binary tables where each row represents a project, and each column corresponds respectively to a KPI or a technology/application. Here the positive matches (when the KPI or the technology/application being analyzed occurs in a specific project) are indicated with 1, while the negative ones with 0.

The table referring to the technical requirements in the projects is then converted into a matrix [42x15], and a matrix [1x42] is created for each of the 18 applications included in the taxonomy: here too we represent the presence of a specific application in projects with 1 by applying the same binary method described above (if the application is absent it is instead marked with 0).

PROJECTS X APPLICATION	5G CONNI	5G DIVE	5G ERA	5G EVE	...	Total
V2X/V2Vs	$j_{1,1}$	$j_{1,2}$	$j_{1,3}$	$j_{1,4}$	...	$\sum_{k=1}^{42} j_{1,k}$

Table 5.6 - Analysis of Single Applications
Source: Personal Elaboration

$$\begin{pmatrix} j_{1,1} & j_{2,1} & j_{3,1} & j_{4,1} & \cdots & \sum_{k=1}^{42} j_{1,k} \end{pmatrix} \times \begin{pmatrix} i_{1,1} & i_{2,1} & i_{3,1} & i_{4,1} & \cdots \\ i_{1,2} & i_{2,2} & i_{3,2} & i_{4,2} & \cdots \\ i_{1,3} & i_{2,3} & i_{3,3} & i_{4,3} & \cdots \\ i_{1,4} & i_{2,4} & i_{3,4} & i_{4,4} & \cdots \\ i_{1,5} & i_{2,5} & i_{3,5} & i_{4,5} & \cdots \\ i_{1,6} & i_{2,6} & i_{3,6} & i_{4,6} & \cdots \\ i_{1,7} & i_{2,7} & i_{3,7} & i_{4,7} & \cdots \\ i_{1,8} & i_{2,8} & i_{3,8} & i_{4,8} & \cdots \\ i_{1,9} & i_{2,9} & i_{3,9} & i_{4,9} & \cdots \\ i_{1,10} & i_{2,10} & i_{3,10} & i_{4,10} & \cdots \\ i_{1,11} & i_{2,11} & i_{3,11} & i_{4,11} & \cdots \\ i_{1,12} & i_{2,12} & i_{3,12} & i_{4,12} & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \sum_{k=1}^{42} i_{1,k} & \sum_{k=1}^{42} i_{2,k} & \sum_{k=1}^{42} i_{3,k} & \sum_{k=1}^{42} i_{4,k} & \cdots \end{pmatrix}$$

Table 5.7 - Product of Matrices
Source: Personal Elaboration

At this point, from the product of the matrices, 18 result-matrices [1x15] are obtained. With those results, a table is constructed representing the total frequency of each KPIs and Features in projects that refer to particular technologies and applications; therefore, each technical requirement's frequency no longer pertains to a context related to the single project but a perspective based on its relation with the category Complementary Technologies and Enabled Applications is given.

RESULT MATRIX	Network Slicing	VNF	Private 5G Network	High Connection Density	Low Latency	Mobility	Reliability	Security	QoS	Cost Effectiveness	Efficiency	Sustainability	High Data Speed	Localization and Mapping Accuracy
IoT	37	37	1	21	26	9	32	12	11	13	25	9	11	2
AI	37	37	0	21	25	9	30	12	10	13	24	9	11	1
AR/VR	14	14	0	8	7	4	9	5	2	5	7	1	10	0
Blockchain	17	17	1	9	11	3	14	5	7	7	15	4	9	0
Edge and Cloud Computing	28	28	0	9	25	2	23	3	3	3	8	1	3	1
Crowded Area Service	11	11	0	8	6	1	8	1	4	6	9	5	5	0
Drones/Robots	6	6	0	3	5	3	5	2	1	3	4	1	2	0
Emergency Service/Disaster Monitoring	2	2	0	2	2	0	2	1	0	0	1	0	2	0
Industry 4.0/Smart Manufacturing	23	23	1	14	16	5	20	8	8	11	16	6	7	0
Massive Content Streaming	9	9	0	7	6	0	8	1	2	2	5	0	4	0
Power Distribution Efficiency	3	3	0	3	2	1	2	0	0	1	2	0	2	0
Private or Public Safety	8	8	0	6	8	3	9	3	2	0	3	2	3	2
Smart Building/Smart City	15	15	0	9	13	6	15	5	2	7	10	4	10	1
Smart Port	8	8	0	4	7	2	7	3	0	6	7	3	6	0
Smart Transportation/Truck Platooning	17	17	0	12	13	5	16	6	3	8	11	9	5	2
User-Centric Computing	5	5	0	3	3	1	4	3	2	1	4	1	2	1
V2X/V2Vs	12	12	0	7	11	4	12	9	2	4	7	4	5	2
AGVs	4	4	0	2	4	3	4	3	0	1	2	2	1	1

Table 5.8 - Representation of the Result Matrix
Source: Personal Elaboration

The rows are in order so that the complementary technologies appear first and then the applications so it is possible to have both an overall view of the result or a separated one based on personal preferences.

Regarding the columns, the grouping of the factors obtained earlier with the factor analysis on the KPIs and Features category was followed. Before analyzing the results obtained, it is still necessary to consider some precautions and carry out some intermediate steps.

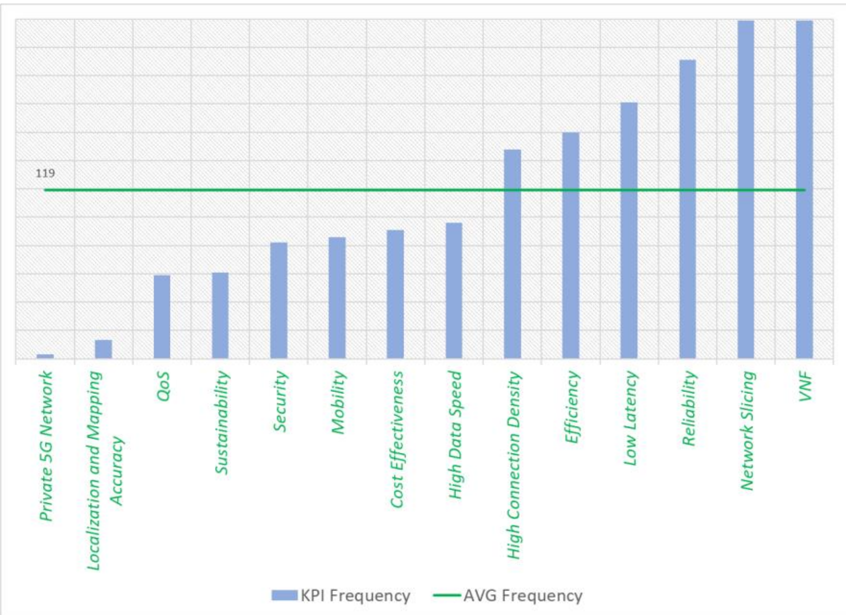


Table 5.9 - Comparison among Mediane and Average
Source: Personal Elaboration

The first intermediate step regards the average frequency and the median of each technical requirement in different applications (derived from the result matrix before): they are calculated to see if the number of values below the central value and those above are more or less equivalent: the average is 119, and the median is 93,5.

Looking at the two results, it can be noticed that the distribution is not symmetrical; the median is very low compared to the average. Therefore, the contribution to technologies and applications will be made mostly by 5G KPIs and Features with a frequency below the average.

The median is so low because there will be many different KPIs, but most of them will have a low frequency in relation to many applications.

This feature can help to integrate various projects' functions and find new solutions towards innovation and continuous improvement because, on the one hand, there will be the features present in most of the projects, and then there will be those with a very low frequency that we will try to aggregate in order to obtain some innovative trends.

As mentioned before, also for applications, the frequency of appearance is not the same among different projects analyzed in taxonomy. Precisely for this reason, the last point of this preliminary part consists of calculating the ratio between the results obtained in Table 5.8 - Representation of the Result Matrix and each application's frequency to have a more objective and general result. Therefore, the percentage of incidence of each KPI and Feature on a specific technology/application is identified.

RESULT MATRIX	Network Slicing	VNF	Private 5G Network	High Connection Density	Low Latency	Mobility	Reliability	Security	QoS	Cost Effectiveness	Efficiency	Sustainability	High Data Speed	Localization and Mapping Accuracy
IoT	95%	95%	3%	54%	67%	23%	82%	31%	28%	33%	64%	23%	28%	5%
AI	100%	100%	0%	57%	68%	24%	81%	32%	27%	35%	65%	24%	30%	3%
AR/VR	100%	100%	0%	57%	50%	29%	64%	36%	14%	36%	50%	7%	71%	0%
Blockchain	89%	89%	5%	47%	58%	16%	74%	26%	37%	37%	79%	21%	47%	0%
Edge and Cloud Computing	100%	100%	0%	32%	89%	7%	82%	11%	11%	11%	29%	4%	11%	4%
Crowded Area Service	92%	92%	0%	67%	50%	8%	67%	8%	33%	50%	75%	42%	42%	0%
Drones/Robots	86%	86%	0%	43%	71%	43%	71%	29%	14%	43%	57%	14%	29%	0%
Emergency Service/Disaster Monitoring	100%	100%	0%	100%	100%	0%	100%	50%	0%	0%	50%	0%	100%	0%
Industry 4.0/Smart Manufacturing	92%	92%	4%	56%	64%	20%	80%	32%	32%	44%	64%	24%	28%	0%
Massive Content Streaming	100%	100%	0%	78%	67%	0%	89%	11%	22%	22%	56%	0%	44%	0%
Power Distribution Efficiency	100%	100%	0%	100%	67%	33%	67%	0%	0%	33%	67%	0%	67%	0%
Private or Public Safety	89%	89%	0%	67%	89%	33%	100%	33%	22%	0%	33%	22%	33%	22%
Smart Building/Smart City	94%	94%	0%	56%	81%	38%	94%	31%	13%	44%	63%	25%	63%	6%
Smart Port	89%	89%	0%	44%	78%	22%	78%	33%	0%	67%	78%	33%	67%	0%
Smart Transportation/Truck Platooning	89%	89%	0%	63%	68%	26%	84%	32%	16%	42%	58%	47%	26%	11%
User-Centric Computing	83%	83%	0%	50%	50%	17%	67%	50%	33%	17%	67%	17%	33%	17%
V2X/V2Vs	92%	92%	0%	54%	85%	31%	92%	69%	15%	31%	54%	31%	38%	15%
AGVs	100%	100%	0%	50%	100%	75%	100%	75%	0%	25%	50%	50%	25%	25%

Table 5.10 - Representation of the Relative Result Matrix (ratio among the Result Matrix and the Frequency

It is decided to highlight in yellow the relationships with an incidence greater than 60% to indicate that the specific technical requirement appears more than half of the times in projects referring to that particular application displayed on the row. Moreover, the frequencies highlighted in red are the most significant, with a percentage greater than 90%.

After an initial observation of the results, the topic introduced with the comparison between mean and median is resumed, evaluating now the average correlation percentage of each KPI in technologies and applications.

Those with a high ratio for each application are unrelated to something special, but in general, present in all the projects analyzed. Similarly, if an element has very low correlations with each application, its frequency in the taxonomy may be thought to be too low to define a trend. In both of these cases, the values must be removed.

Network Slicing	VNF	Private 5G Network	High Connection Density	Low Latency	Mobility	Reliability	Security	QoS	Cost Effectiveness	Efficiency	Sustainability	High Data Speed	Localization and Mapping Accuracy
94%	94%	1%	60%	72%	25%	82%	33%	18%	32%	59%	21%	43%	6%

Table 5.11 - Average correlation percentage of each technical requirement to the applications
Source: Personal Elaboration

For example, VNF and Network Slicing are highly correlated with each application, and by looking at the dataset, they are present in almost all projects and not related to any specific application. Similarly, the Private 5G network or Localization and Mapping Accuracy also are insignificant samples for defining a trend because they are only developed in few projects under analysis.

The following steps regard a cleaning procedure of the dataset obtained, including as significant KPIs only those having an average relationship with the applications between 8% and 92% (it can be seen as a Gaussian distribution) and removing data with correlations too low or too high with every application.

The data highlighted in green are selected, and the red numbers in Table 5.11 - Average correlation percentage of each technical requirement to the applications are removed

Excluding these four values, the final result can be observed, which identifies as significant all the correlations between applications and technologies and KPIs in which the frequency value of this KPI in the specific technology or application is greater than the relative average of the KPI. In this case, the relationship is indicated as "YES" consists of obtaining the final result of the previous matrix and considering all the

Complementary Technologies

RESULT MATRIX	Network Slicing	VNF	Private 5G Network	High Connection Density	Low Latency	Mobility	Reliability	Security	QoS	Cost Effectiveness	Efficiency	Sustainability	High Data Speed	Localization and Mapping Accuracy
IoT	YES	YES	YES	NO	NO	NO	YES	NO	YES	YES	YES	YES	NO	NO
AI	YES	YES	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO
AR/VR	YES	YES	NO	NO	NO	YES	NO	YES	NO	YES	NO	NO	STRONG	NO
Blockchain	NO	NO	YES	NO	NO	NO	NO	NO	YES	YES	STRONG	NO	YES	NO
Edge and Cloud Computing	YES	YES	NO	NO	YES	NO	YES	NO	NO	NO	NO	NO	NO	NO
Crowded Area Service	NO	NO	NO	YES	NO	NO	NO	NO	YES	YES	YES	STRONG	NO	NO
Drones/Robots	NO	NO	NO	NO	NO	YES	NO	NO	NO	YES	NO	NO	NO	NO
Emergency Service/Disaster Monitoring	YES	YES	NO	STRONG	STRONG	NO	YES	YES	NO	NO	NO	NO	STRONG	NO
Industry 4.0/Smart Manufacturing	NO	NO	YES	NO	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO
Massive Content Streaming	YES	YES	NO	YES	NO	NO	YES	NO	YES	NO	NO	NO	YES	NO
Power Distribution Efficiency	YES	YES	NO	STRONG	NO	YES	NO	NO	NO	YES	YES	NO	STRONG	NO
Private or Public Safety	NO	NO	NO	YES	YES	YES	YES	YES	YES	NO	NO	YES	NO	YES
Smart Building/Smart City	NO	NO	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES	YES	YES
Smart Port	NO	NO	NO	NO	YES	NO	NO	YES	NO	STRONG	YES	YES	STRONG	NO
Smart Transportation/Truck Platooning	NO	NO	NO	YES	NO	YES	YES	NO	NO	YES	NO	STRONG	NO	YES
User-Centric Computing	NO	NO	NO	NO	NO	NO	NO	YES	YES	NO	YES	NO	NO	YES
V2X/V2Vs	NO	NO	NO	NO	YES	YES	YES	STRONG	NO	NO	NO	YES	NO	YES
AGVs	YES	YES	NO	NO	STRONG	STRONG	YES	STRONG	NO	NO	NO	STRONG	NO	YES

values that have a correlation greater than that of the respective average of that KPI. If, on the other hand, the frequency of that KPI in that application or technology is more than 20% above the average (i.e. it is greater than average = 1.2 (AVG)), then it is a strong relationship between the two corresponding elements and is therefore indicated with “STRONG”.

Table 5.12 - Relations among KPIs and Complementary Technologies & Enabled Applications
Source: Personal Elaboration

Here other paths for the business models can be outlined so that in correspondence with each of the applications or technologies, these cross relationships that are found between the various KPIs are taken into account in the case of future projects.
Then, it is approached the phase of defining more detailed clusters through a factor analysis that will investigate the applications' primary factors, trying to group 18 elements into 3 or 4 components.

5.3.3 Factor Analysis for Applications

Variables	AGVs	AI	AR/VR	Blockchain	Cloud Computing	Crowded Area Service	Drones/ Robots	Emergency Service/Disaster Monitoring	Industry 4.0/Smart Manufacturing	IoT	Massive Content Streaming	Power Distribution Efficiency	Private or Public Safety	Smart Building /Smart City	Smart Port	Smart Transportation /Truck Platooning	User-Centric Computing	V2X/V2Vs
AGVs	**1,00**	0,39	0,37	0,12	0,23	0,10	0,56	0,37	0,27	0,37	0,22	0,22	0,65	0,39	0,25	0,53	0,34	0,70
AI	**0,39**	1,00	0,74	0,74	0,76	0,61	0,77	0,59	0,92	0,99	0,76	0,51	0,56	0,70	0,69	0,70	0,72	0,68
AR/VR	**0,37**	0,74	1,00	0,65	0,72	0,40	0,66	0,84	0,63	0,72	0,77	0,70	0,74	0,83	0,68	0,60	0,58	0,69
Blockchain	**0,12**	0,74	0,65	1,00	0,72	0,74	0,51	0,54	0,77	0,72	0,79	0,54	0,45	0,64	0,72	0,46	0,73	0,50
Cloud Computing	**0,23**	0,76	0,72	0,72	1,00	0,63	0,55	0,66	0,77	0,77	0,87	0,69	0,58	0,56	0,51	0,51	0,77	0,56
Crowded Area Service	**0,10**	0,61	0,40	0,74	0,63	1,00	0,48	0,36	0,64	0,60	0,64	0,61	0,23	0,52	0,64	0,57	0,49	0,37
Drones/Robots	0,56	0,77	0,66	0,51	0,55	0,48	1,00	0,48	0,66	0,76	0,56	0,60	0,62	0,77	0,68	0,63	0,47	0,60
Emergency Service/Disaster	**0,37**	0,59	0,84	0,54	0,66	0,36	0,48	1,00	0,49	0,57	0,70	0,69	0,77	0,67	0,56	0,51	0,58	0,69
Industry 4.0/Smart Manufacturing	**0,27**	0,92	0,63	0,77	0,77	0,64	0,66	0,49	1,00	0,95	0,72	0,44	0,45	0,60	0,65	0,64	0,73	0,60
IoT	**0,37**	0,99	0,72	0,72	0,77	0,60	0,76	0,57	0,95	1,00	0,74	0,49	0,54	0,69	0,68	0,69	0,73	0,67
Massive Content Streaming	**0,22**	0,76	0,77	0,79	0,87	0,64	0,56	0,70	0,72	0,74	1,00	0,70	0,59	0,64	0,58	0,55	0,65	0,57
Power Distribution Efficiency	**0,22**	0,51	0,70	0,54	0,69	0,61	0,60	0,69	0,44	0,49	0,70	1,00	0,55	0,69	0,53	0,46	0,42	0,48
Private or Public Safety	0,65	0,56	0,74	0,45	0,58	0,23	0,62	0,77	0,45	0,54	0,59	0,55	1,00	0,64	0,44	0,59	0,64	0,76
Smart Building/Smart City	0,39	0,70	0,83	0,64	0,56	0,52	0,77	0,67	0,60	0,69	0,64	0,69	0,64	1,00	0,79	0,57	0,50	0,66
Smart Port	0,25	0,69	0,68	0,72	0,51	0,64	0,68	0,56	0,65	0,68	0,58	0,53	0,44	0,79	1,00	0,64	0,49	0,59
Smart Transportation/Truck	**0,53**	0,70	0,60	0,46	0,51	0,57	0,63	0,51	0,64	0,69	0,55	0,46	0,59	0,57	0,64	1,00	0,45	0,66
User-Centric Computing	**0,34**	0,72	0,58	0,73	0,77	0,49	0,47	0,58	0,73	0,73	0,65	0,42	0,64	0,50	0,49	0,45	1,00	0,67
V2X/V2Vs	**0,70**	0,68	0,69	0,50	0,56	0,37	0,60	0,69	0,60	0,67	0,57	0,48	0,76	0,66	0,59	0,66	0,67	1,00

Table 5.13 - Factor Analysis: Correlation Matrix
Source: Personal Elaboration

The first result of the factor analysis is the correlation matrix in which the dataset is deeply examined. Note that some correlations are high and others are low: this feature is positive because it indicates that the dataset has a structure: two variables are expressions of an underlying latent variable if they are correlated among themselves, so, by looking at the correlation matrix, it will be understood their membership into a group. By observing the matrix horizontally, the major correlation appears between IoT and AI, which correlates significantly with Industry 4.0. AR gives other relevant relationships with Smart Building/Smart City and Emergency Service/Disaster Monitoring or Massive Content Streaming and Cloud Computing.

Evaluation of the Explained Variance

The next indicator taken into the analysis is called the MSA, or measure of sampling adequacy, ranging from 0 to 1.

0 means that all variables have no correlation with each other and no structure, while 1 means that all variables are related and represent a large structure. Values should generally be more significant than 0.7. In this case, the MSA level equals KMO 0.802, which indicates a good sample.

Kaiser-Meyer-Olkin measure of sampling adequacy:	
AGVs	0,658
AI	0,794
AR/VR	0,877
Blockchain	0,702
Cloud Computing	0,829
Crowded Area Service	0,844
Drones/Robots	0,754
Emergency Service/Disaster Monitoring	0,819
Industry 4.0/Smart Manufacturing	0,763
IoT	0,786
Massive Content Streaming	0,879
Power Distribution Efficiency	0,823
Private or Public Safety	0,812
Smart Building/Smart City	0,917
Smart Port	0,765
Smart Transportation/Truck Platooning	0,753
User-Centric Computing	0,829
V2X/V2Vs	0,803
KMO	**0,802**

Table 5.14 - Factor Analysis: Kaiser-Meyer-Olkin MSA
Source: Personal Elaboration

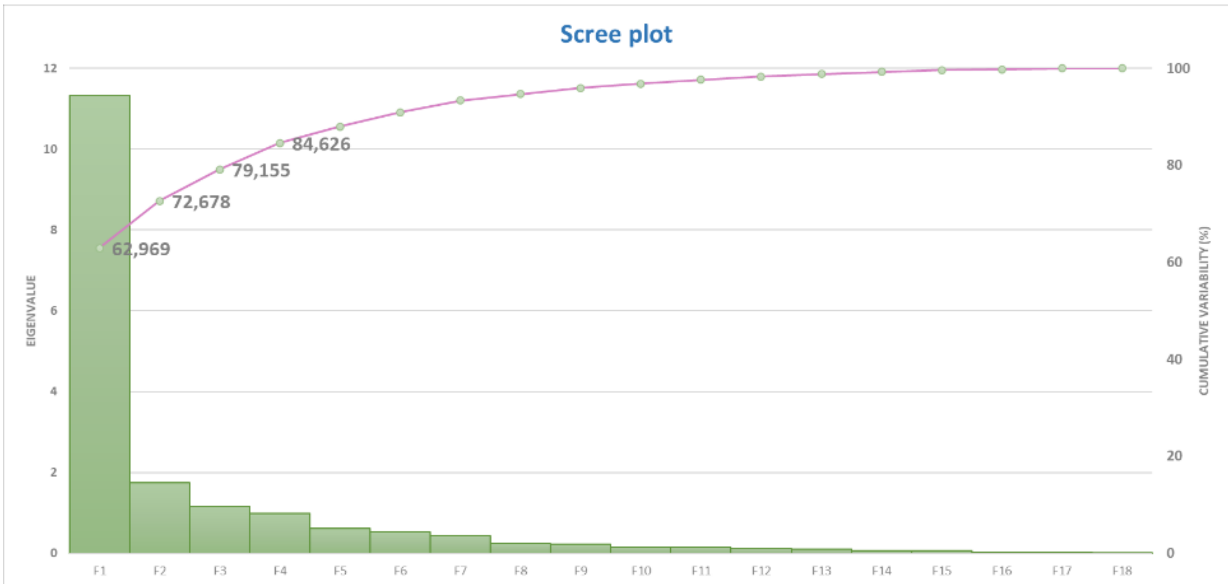


Table 5.15 - Factor Analysis: Scree Plot
Source: Personal Elaboration

Moreover, by looking at the scree plot, component 1 has a very high eigenvalue, so it is evident that the extraction of one factor already represents a considerable part of the variance, but reducing all the sample to only one variable can cause the loss of important information.

Application of the Varimax Rotation

Observing the variables' allocation to the factors, the pattern doesn't appear very clear. Therefore, a further iteration is needed and the Varimax rotation is applied to simplify columns and understand better which variables are tied to a specific matrix.
It is verified that the portion of variance explained is still enough (almost 80%) and also that it is better distributed among the factors:

Percentage of variance after Varimax rotation:			
	Factor 1	**Factor 2**	**Factor 3**
Variability (%)	35,540	18,837	24,779
Cumulative %	35,540	54,377	79,155

Table 5.16 - Explained Variance after Varimax
Source: Personal Elaboration

The chart below shows the pattern obtained after the Varimax rotation: the situation is outlined, and factors clearly summarize each technology/application.
The highlighted values correspond to the factor in which this application's variance is more significant, making the factor the best representative.

Factor pattern after Varimax rotation:			
	Factor 1	**Factor 2**	**Factor 3**
AGVs	0,058	**0,913**	0,082
AI	**0,829**	0,389	0,284
AR/VR	0,413	0,375	**0,738**
Blockchain	**0,782**	-0,008	0,457
Cloud Computing	**0,648**	0,102	0,600
Crowded Area Service	**0,782**	-0,087	0,290
Drones/Robots	0,553	**0,566**	0,294
Emergency Service/Disaster Monitoring	0,224	0,351	**0,826**
Industry 4.0/Smart Manufacturing	**0,898**	0,249	0,194
IoT	**0,842**	0,376	0,259
Massive Content Streaming	0,626	0,096	**0,660**
Power Distribution Efficiency	0,326	0,086	**0,802**
Private or Public Safety	0,157	**0,670**	0,625
Smart Building/Smart City	0,479	0,391	**0,584**
Smart Port	**0,663**	0,262	0,366
Smart Transportation/Truck Platooning	0,565	**0,567**	0,197
User-Centric Computing	**0,611**	0,286	0,391
V2X/V2Vs	0,372	**0,714**	0,407

Table 5.17 - Factors' Pattern after Varimax Rotation
Source: Personal Elaboration

These are the components that now explain the 18 initial variables; they are the latent factors.

Factor 1	AI	Blockchain	Cloud Computing	Crowded Area Service	Industry 4.0/Smart Manufacturing	IoT	Smart Port	User-Centric Computing
Factor 2	AGVs	Drones/Robots	Private or Public Safety	V2X/V2Vs	Smart Transportation/Truck Platooning			
Factor 3	AR/VR	Emergency Service/Disaster Monitoring	Massive Content Streaming	Power Distribution Efficiency	Smart Building/Smart City			

Table 5.18 - Applications' Classification among Factors
Source: Personal Elaboration

Factor 1 includes all the technologies complementary to 5G most frequent in industry and also industrial applications with the vertical sectors of industry and the port, with the focus on particular scenarios such as Crowded Area Service and User-Centric Computing -> Industry Main Applications

The second-factor concerns applications of logistic mobilization and all the tools that offer autonomous services, such as robots, drones, AGVs, and intelligent vehicles, components characterized by low latency and high reliability, which facilitate the operations of various vertical fields -> Industrial Complements

The third factor concerns a more immersive use of 5G, and are those that are undoubtedly innovative, centered on the users and the innovative applications they can benefit from, but less tied to the specific world of industry. For example, as explained above, here is AR / VR technology, useful in many aspects of industrial life, but its applicability is still linked to media and entertainment and not to this sector -> Parallel 5G Technologies and Applications

The following graph shows the association of these three factors indicated to the projects under analysis, and it emerges that Factor 1 is present in all of them, in fact, all the projects examined are made up of complementary 5G technologies that enhance the industry and the port logistics sector and the industry it represents.

64% of projects have only one or two factors, so only Factor 1 or the combination of 1-2 or 2-3. Only about 35% of the projects contain all three factors.

It, therefore, happens in many cases that the projects concerning the applications linked to Factor 2 do not have those of Factor 3 and vice versa, and this demonstrates how they all contain industry as their main theme, but then differ in turn between projects containing limited factor 1, or which in addition to a general focus on the industrial or port world, follow the development or trials of tools aimed at guaranteeing automated services (drones, robots, smart transportation, AGVs, ...) or even in the case of factorial component 3, projects that follow other themes in parallel with industry, such as power distribution efficiency, emergency monitoring, public safety,... or aspire to immersive experiences through AR and VR.

These are the trends that can be used for the development of specific business models for the sector.

Furthermore, further analyzes will then relate the factors obtained with the project budgets and time references.

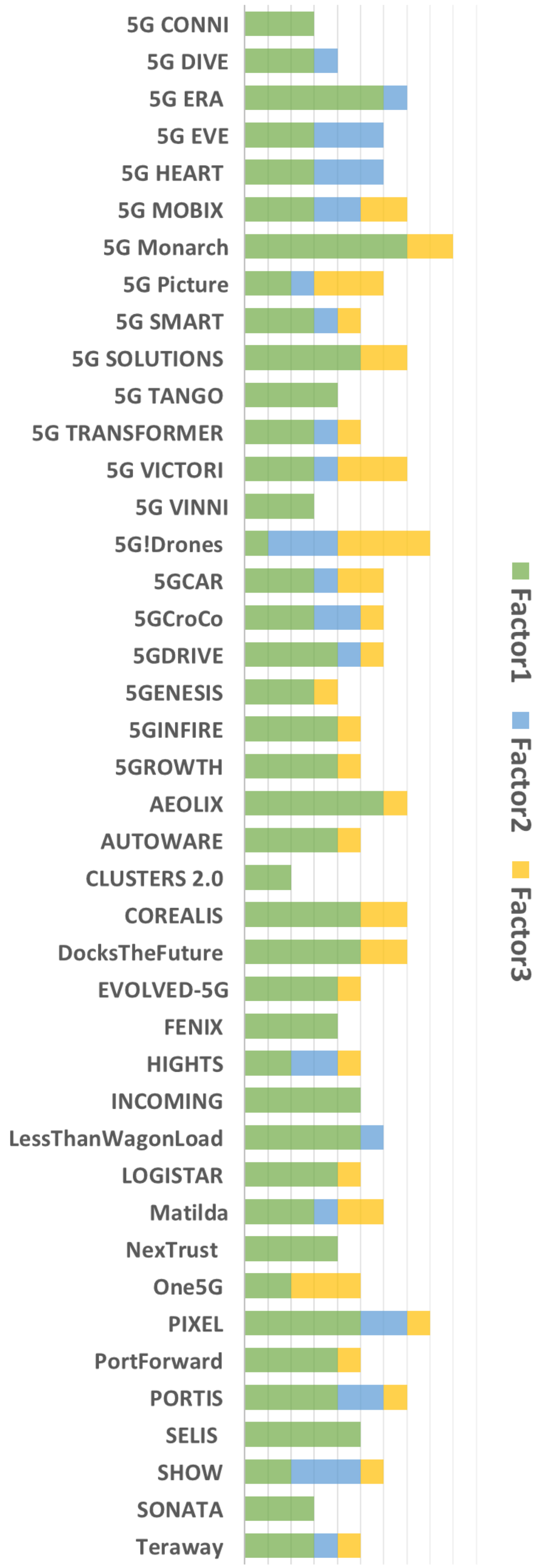


Table 5.19 - Representation of Projects through Factors
Source: Personal Elaboration

5.3.4 Use cases: comparison of different perspectives

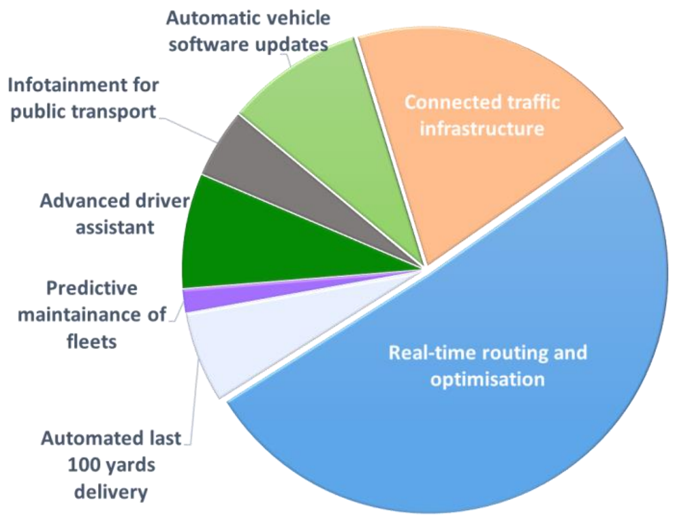


Figure 5.8 - Transport and Logistics Use cases
Source: Personal Elaboration

Concerning use cases present in the taxonomic classification of projects, as anticipated, the three views described in the previous chapters were used.

As for the specific classification for transport and logistics, as expected from the industry trend, the most significant slice of use cases is made up of real-time routing and optimization.

It is clear that the effect of latency and high reliability made available by 5G offers optimization scenarios concerning the processes of Industry 4.0.

The second use case that appears most in the projects analyzed is connected traffic infrastructure, in fact the analysis of data traffic and optimization systems in the real-time management field are widespread in the trials supported today in Europe. Only these two use cases represent in logistics and ports, about 70% of the total.

The other scenarios frequently encountered in the projects analyzed are Automatic Vehicles Software Updates, Advanced Driver Assistant, and Automated Last 100 Yards Delivery, clearly important and relevant applications for handling both in the industrial and port sectors.

It is now analyzed the correlation between KPIs and features introduced by 5G and the two most frequent use cases according to this perspective in order to see which components contribute most to their enhancement.

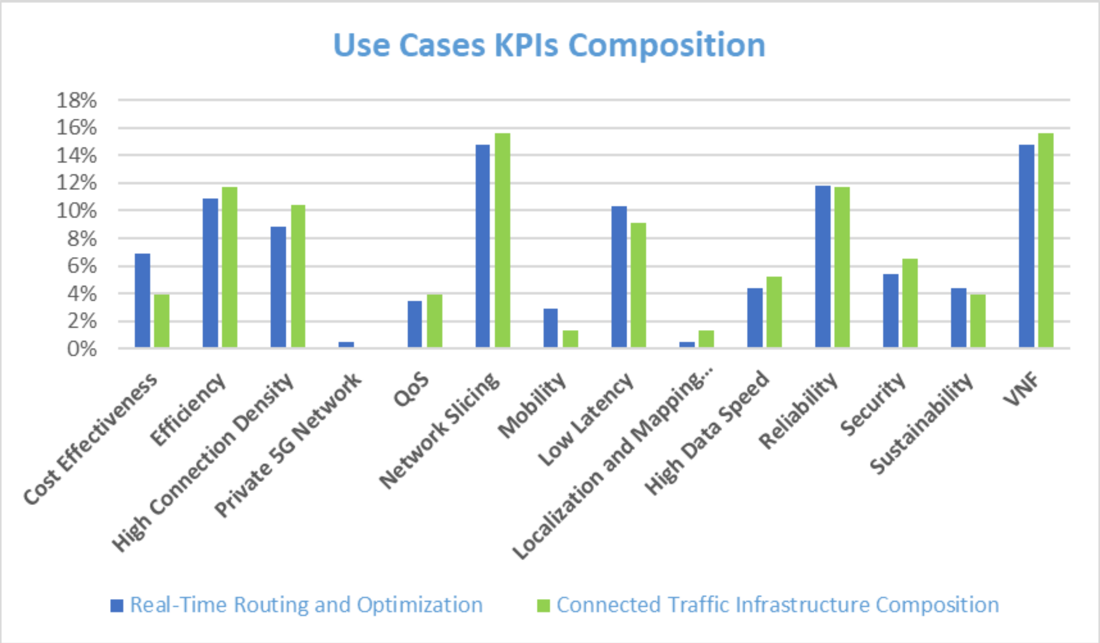


Table 5.20 - Relation among most common Transport and Logistics use cases and KPIs and Features
Source: Personal Elaboration

The calculation is made by comparing the relative frequency of each of the two use cases.

The values that emerge for the business models in the two use cases are Efficiency, Low Latency, High Reliability, and High Connection Density, as well as, of course, Network Slicing and VFN, for which it has already been told that are excessively related to all projects to be useful in outlining trends. Furthermore, having a similar trend can also be a way to assume that the two use cases often occurred together in the same projects.

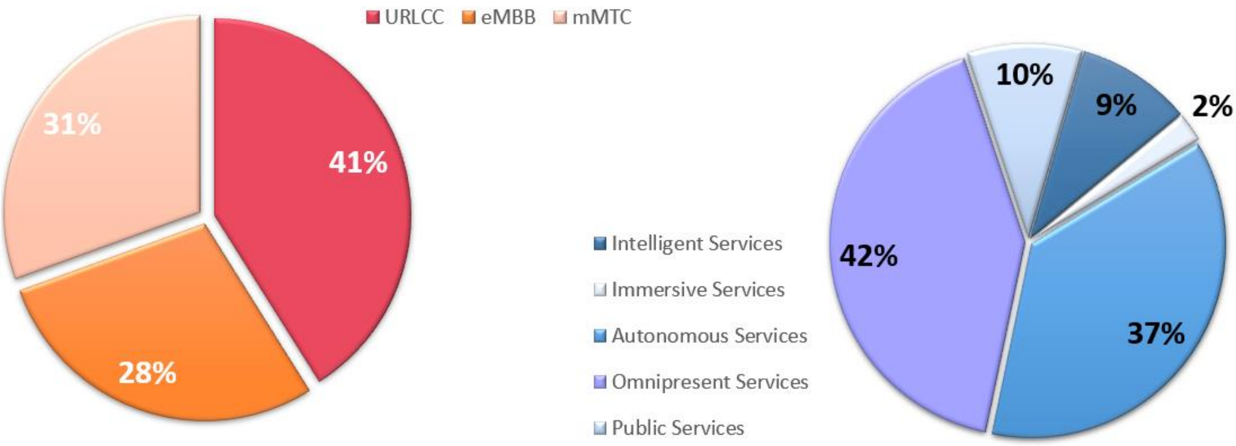


Figure 5.21 - ITU functionality and End-User Perspective use cases
Source: Personal Elaboration

Regarding the other two perspectives seen in the state of the art, they are in line with the previous classification results.
Concerning the categorization according to ITU functionalities, the use case URLLC, therefore enabled by the low latency and high reliability that 5G offers, prevails over the other two, but without achieving an evident prevalence. In fact, the other percentages are also relevant, and all three use cases have been identified for most of the logistics applications in industry and ports.
As far as the end-user perspective is referred, the most frequent use case relates the omnipresence, which is linked to the IoT applications and therefore to the whole sphere of intelligent buildings such as ports and factories.
Secondly, autonomous services emerge, associated with use cases such as drones, robots, and smart transportation.
The result shows that the use cases that prevail are those related to the industrial sector on which the analysis is focused. Other use cases also emerge but in much lower percentages and often associated with these two just described.
The two use cases, being widely correlated, are supposed to appear often together in the same project. Let's see if it is possible to outline again a trend of the Key Features that most contribute to projects characterized by those use cases to evaluate whether there are correlations with the industry cases earlier introduced.

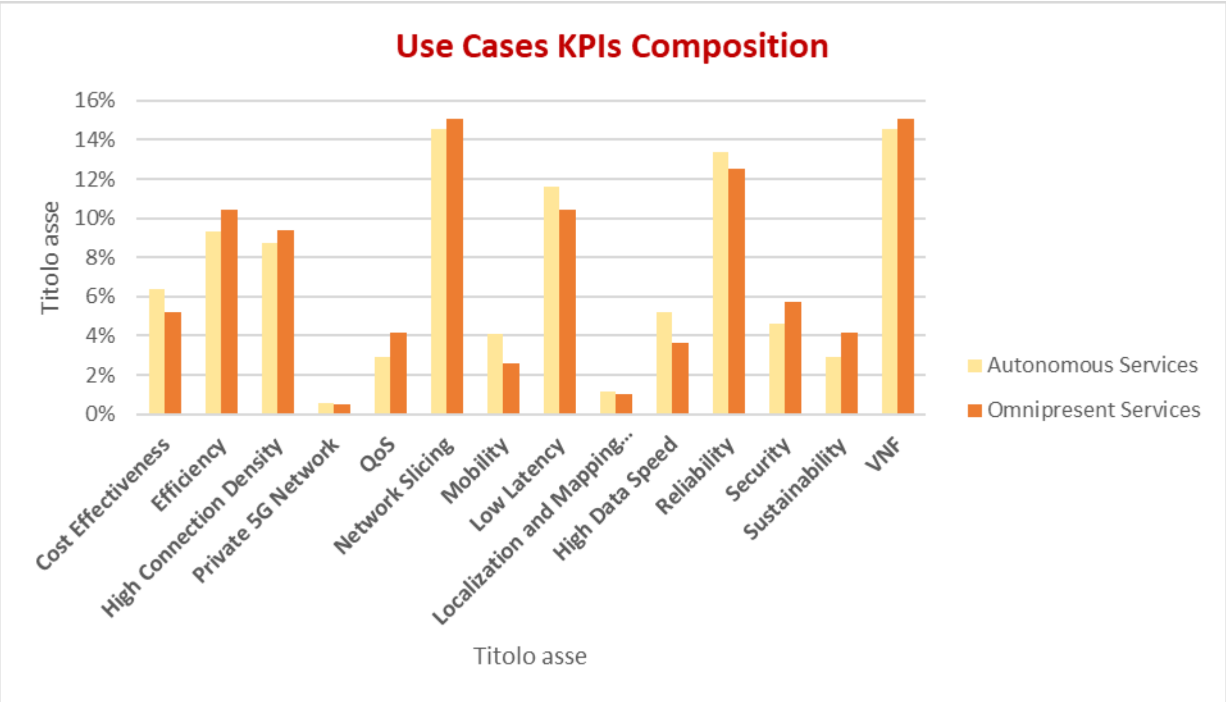


Table 5.22 - Relation among most common Transport and Logistics use cases and KPIs and Features
Source: Personal Elaboration

In future business models, the four scenarios analyzed can be related as they have similitudes in the respective projects' KPIs. In fact, observing the trends that are very similar to those obtained in the chart relating to the Transport and Logistics use cases, it is assumed that the presence of a transport and logistics use case between connected traffic infrastructure, and real-time routing and optimization presupposes the existence of Automated or Omnipresent among the end-user perspective use cases.

5.3.5 Stakeholders' Analysis

In the following pie-chart, there is a list of stakeholders. They are numerous and with different roles. However, the percentages are very high, as the fundamental agents participating in each project, or very low, in fact depending on the project, there are different actors pertaining to the specific vertical sector, such as OEMs, MNOs, Port Authorities, Logistics Service Providers, etc., and their distribution is low.

However, some representatives have higher frequencies and appear in each project, and they are the administration, SMEs, universities, and research centers.

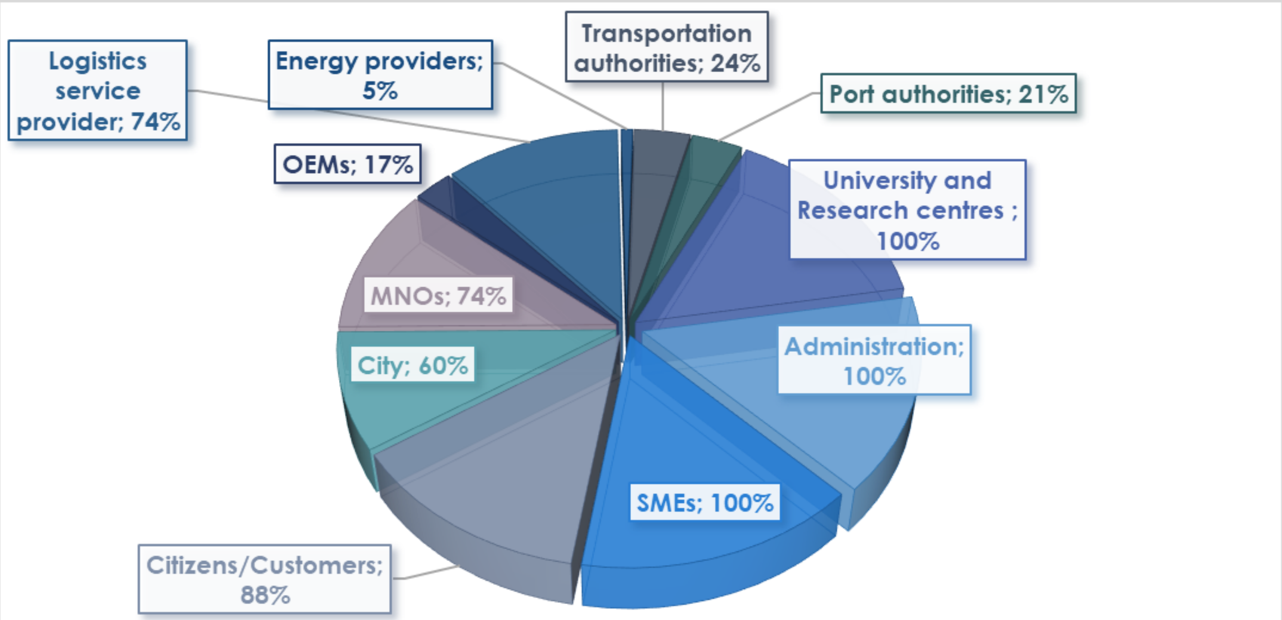


Figure 5.9 - Stakeholders' Frequency Map
Source: Personal Elaboration

The number of service logistics providers is significantly high. In fact, as the field under analysis, the frequency of logistics-related stakeholders is not surprising. Finally, the figure of the city and the citizen is always of considerable importance.

The city is deeply involved in many applications and offers the possibility to experiment with innovative features as a way to improve its citizens' quality of life.

The mapping of stakeholders is a key design activity in human-centered design processes, and as LOGINNOV follows a stakeholder-based approach, also in this classification, it helps visualize all the stakeholders, roles, and relationships.

On the one hand, there are the internal exponents (SMEs, Administration, Vertical commercial Authorities, etc.) of the project, and on the other hand the external (cities, customers and citizens, universities and research centers, etc.) and within the initiative, they are put on the same level, highlighting the balance that must be generated and the aptitude for collaboration.

Finally, they can be classified into two macro-groups: those with an interest in the projects and those with the power. Those interested in the project suffer an impact depending on the project progress or simply want to be part of this context, such as logistics service providers, citizens, customers, cities, MNOs, OEMs, energy suppliers, transport authorities, port authorities.

Those who have the power can change things with their own hands, both positively and negatively. Here there are universities and research centers, administration, SMEs, etc.

5.3.6 Projects Management and Organization

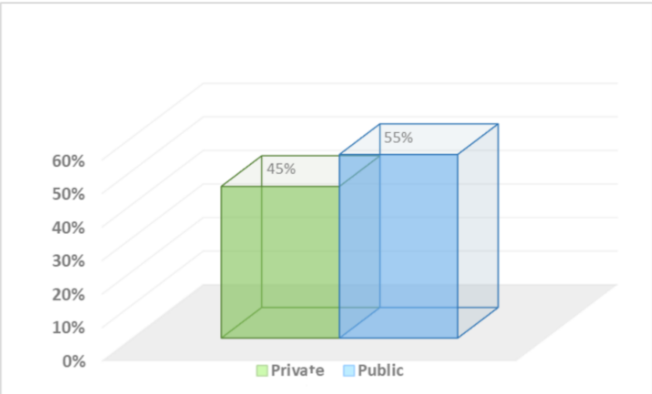


Table 5.23 - Frequency Distribution of Subcategory in the Taxonomy: Project Coordinator
Source: Personal Elaboration

Referring again to the Description Class, another relevant element to be examined is the Project Coordinator. In this case, looking at the frequency distribution, it shows no significant differences among public and private coordination even if the public slightly prevails.

A mixed entity coordinates no project.

The coordinator refers to the project manager, a specific individual who is in charge of the monitoring phase and it is a continuous process that extends from the beginning to the end of the project. The purposes of this activity are:

- the verification of the progress of tasks and the achievement of expected results;
- the implementation of the necessary actions in case of difficulties or delays and the ongoing update of programs and work schedules.

For this reason here the option “mixed” is not kept because the coordination of a project is an issue concerning a specific individual responsible for strategic management for the entire duration of the project. Therefore it has to be declared if he is acting as an individual or within an institution.

Furthermore, by incorporating this element under analysis with the applications examined above, the following trends are obtained:

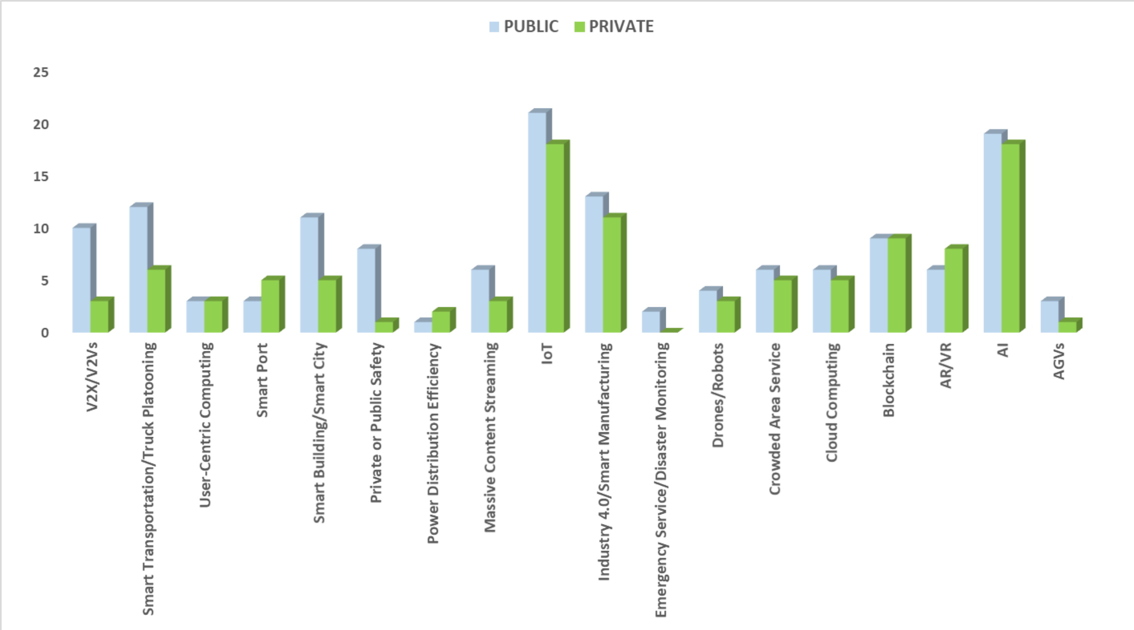


Table 5.24 - Project Coordinator trends in Applications
Source: Personal Elaboration

It is noted that an evident prevalence of public coordination appears in the V2X and V2Vs, Smart Transportation and Truck Platooning, Smart Building and Smart City, and Private or Public Safety applications.

In fact, it can be assumed that the latter are applications of greater public interest since they cause a benefit at the level of the environment and society, and therefore members of public administration are put to strategic guidance.

The next step concerns an analysis of Project Organization, regarding the Business Model Class, in which it is observable a very different trend compared to the previous. In most cases, the project organization is in the hands of both public and private entities and, therefore, is mixed.

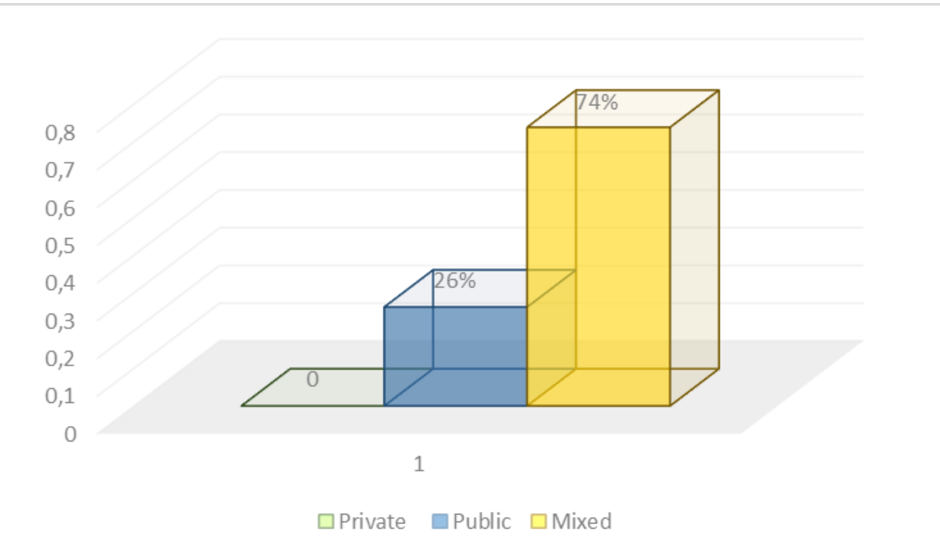


Table 5.25 - Frequency Distribution of Subcategory in the Taxonomy: Project Organization
Source: Personal Elaboration

This trend occurs because for an organization to function correctly, several players are needed. Additionally, most of the projects are under the 5GPPP, which, as introduced in the previous chapter, is an organization made up of a partnership between public and private entities. PPPs claim to unite two worlds, namely, "Public" and "Private", which often identify two separate and different realities. In fact, private entities look to the profitability of the investment made, while the public entity must ensure that the service is guaranteed at costs that the community can bear in a fair, continuous, and transparent way.

As for financial issues, most of the time, they are almost totally covered by public investment. There are numerous public calls to which organizations can apply.

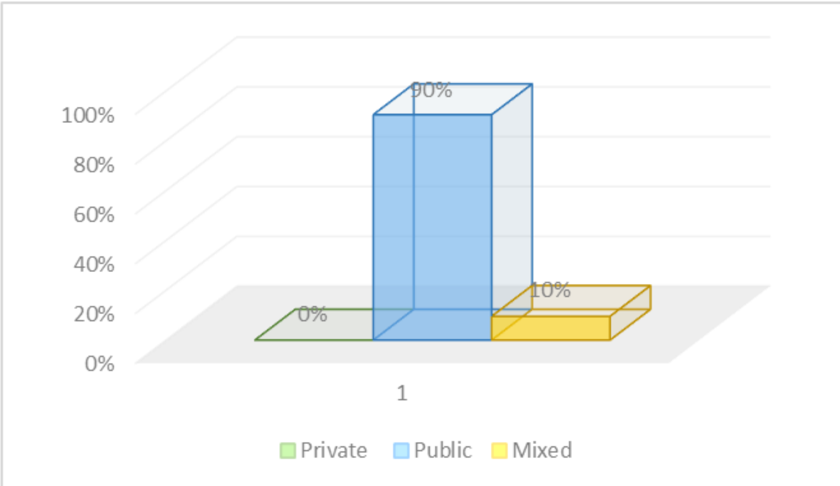


Table 5.26 - Frequency Distribution of Subcategory in the Taxonomy: Financial Resources
Source: Personal Elaboration

However, most of the time, the fund is allocated within the Horizon 2020 framework in projects examined.

For simplicity, if the percentage covered by the fund is greater than 80%, in taxonomy it is indicated as Public Investment. In most cases, a private individual does not have sufficient funds to bear this magnitude's costs in an innovative context and without support.

Since mixed investments are few compared to public ones, there is no significant data to correlate fund investments with the type of application or technology.

About infrastructures, however, the opposite trend occurs; there is a net prevalence of mixed body infrastructures' funding (83%). Public investment is very few, and Private financing alone is not found (it is more probable that public entities own infrastructures). In fact, it is usually provided by both the public and private sectors:

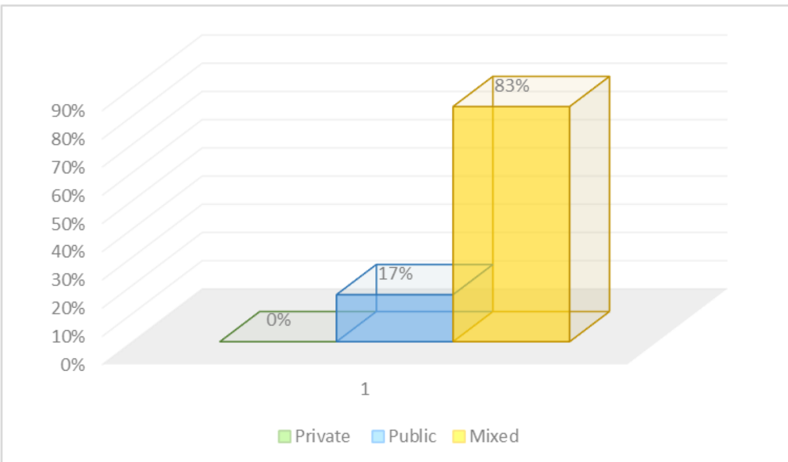


Table 5.27 - Frequency Distribution of Subcategory in the Taxonomy: Infrastructure
Source: Personal Elaboration

often, the companies in the vertical sectors involved among the stakeholders have an interest in investing in innovation and supply equipment and materials available, working alongside the EU and public funding,

Furthermore, in all projects under 5GPPP, the infrastructures are directly provided by the organization, and in this case, it is a matter of supply by mixed bodies.

5.3.7 Budget Analysis

Another interesting element to be examined is the budget and its relations with the other elements in taxonomy. These two tables represent the monetary investment of each project in taxonomy and its comparison with the average amount invested by other initiatives:

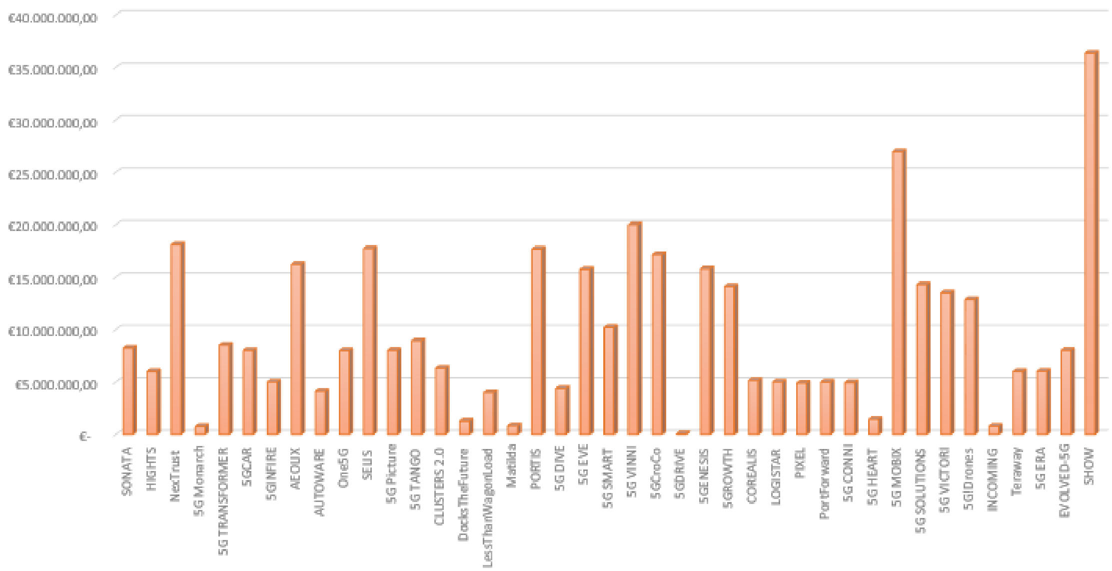


Table 5.28 - Project Budget Calculation
Source: Personal Elaboration

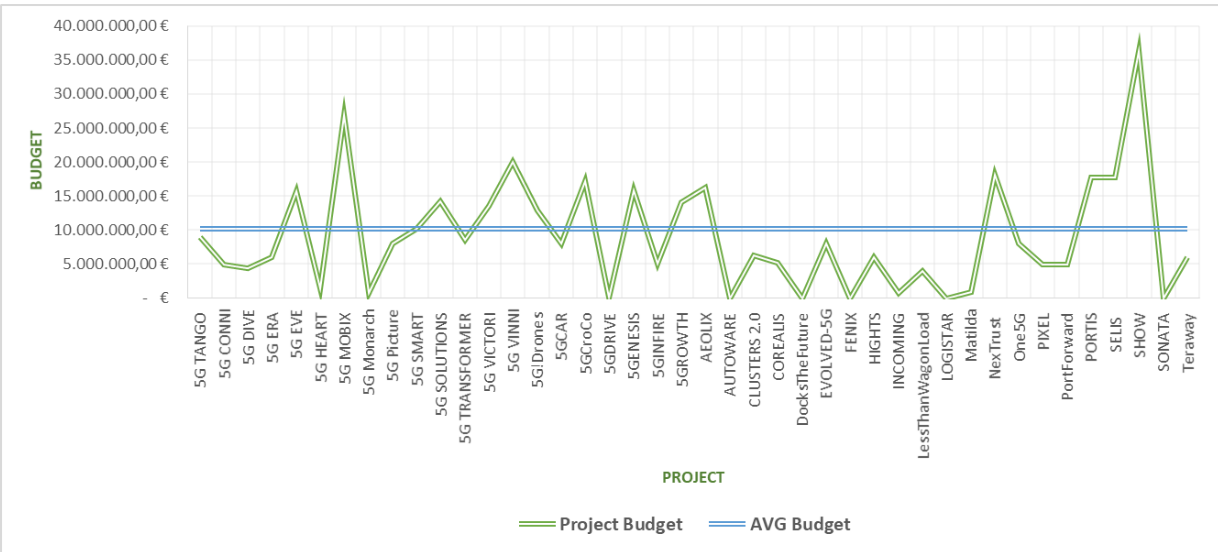


Table 5.29 - Projects' Budget Comparison with AVG Investment
Source: Personal Elaboration

The highest budget is invested in the SHOW project, financed by a public body with an amount of € 36,367,554. A relevant fund is also devoted in the MOBIX Project. As for the others, there are several comparable investments above average and others, rarer, much lower. The calculation of the average and the median (respectively 10,207,688 euros and 7,997,250 euros) also highlights that numerous projects, more than a half of the sample, have a budget that exceeds 10 million euros and the funds, in almost every case, are given by public institutions.
As regards the correlation between Budget and Applications, it emerges that substantial amounts have been used in particular concerning AGVs and Private or Public Safety applications.

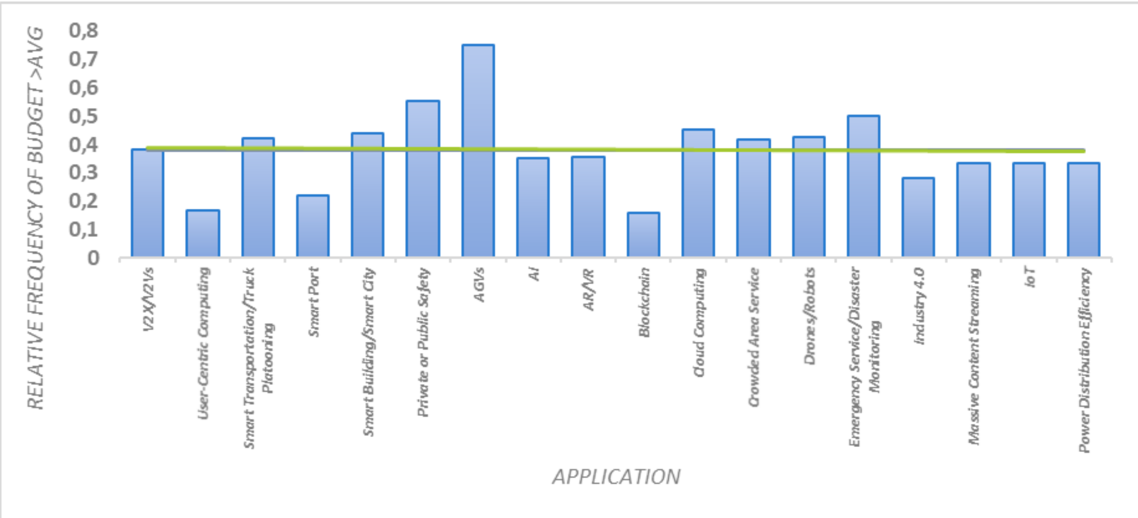


Table 5.30 - Comparison among Budget and Applications
Source: Personal Elaborationa.

The total estimated budget is € 377,684,455, and the amount of mixed funding, where there is also a significant contribution from a private body, is € 30,904,264.
It is therefore outlined that the European Union provides almost all the budget in projects.
A significant public figure oscillates around half of the 700 million invested in digitization by Horizon 2020. It should also be remembered that this is a small sample analyzed and also that from 2021 there will be the new European budget investment estimated under Horizon Europe, much higher than the previous one.
European funding derives from public funds: every project that receives a contribution is therefore called upon to impact society positively.
Therefore, in addition to focusing on a specific application, the budget also provides for projects with the highest impact and economic return on investment.

Finally, to make known the results of a project and ensure that as many beneficiaries as possible are reached, the dissemination phase is fundamental. It consists of promoting the project results and generating a positive "multiplier effect", to transform what has been achieved in valuable and inspiring elements for other interventions.

5.3.8 Timeline Contextualization

After the budget analysis, it is essential to introduce a contextualization based on time and see if the loans follow a trend over the years. For this reason, the reference to the date of each project comes into play.

It is decided to put the final date since the projects all lasted between 24-48 months; therefore, they are pretty comparable among each other, and in this way, the time horizon best describes the current situation of the projects active today, offering an overview also for the years to come up to 2024.

Referring to the timeline in figure 5.3, each project's end-date is connected to the respective budget after this chronological categorization. Noting no particular correlations apart from the most conspicuous investments as the recently implemented ones, however, the conclusion is that this is not enough to outline a trend based on budget and time. In fact, there are also many recent situations in which the invested funds are meager, and in the same way, past investment values are well above the average.

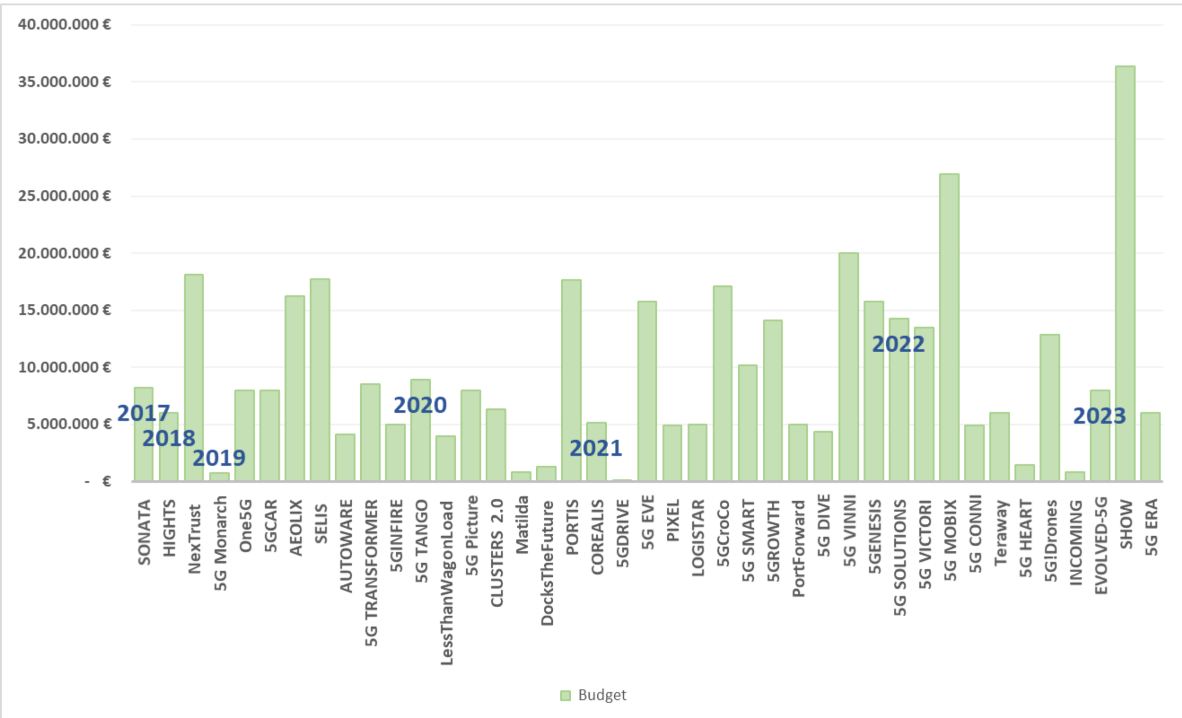


Table 5.31 - Chronological Budget Analysis
Source: Personal Elaboration

It is noted that from 2017 to date, the projects undertaken within this vertical field have significantly increased. Between 2015-2018, the projects were mainly focused on improving the network and upgrading the infrastructure. However, only recently, from 2019 onwards, a general focus on applications for the different vertical sectors has been undertaken, and therefore a large number of initiatives related to industry and logistics have begun.

The first feature contextualized chronologically is the budget, noting that in the first years, although the sample is very small, bringing to make assumptions of still a tiny focus on the industrial sector innovation, it is noted that in the projects completed in 2020 and 2021, the budgets related to those projects are very low, to then become significant in projects that will end in 2022-2023. Furthermore, it is noted that in the projects of 2022 to 2023, mixed investments occur, therefore also consisting of a substantial private investment and public funds.

However, this is not enough to outline a clear trend. There are also many recent situations in which the invested budgets are meager, and in the same way, past investment values are well above the average.

As a summary, here below it is shown the chart chronologically ordered, inclusive of the attributions of the projects to the respective factors on the principal axis and the related budgets on the secondary axis.

As regards the association between time and components outlined in factor analysis, no trend emerges. The only element that stands out is that in older projects, the presence of the second factor linked to logistic mobilization, smart transport, V2V, and V2X is less than the trends of the following years. Instead, it appears often the third factor as they were probably focusing on the network infrastructure in those first years.

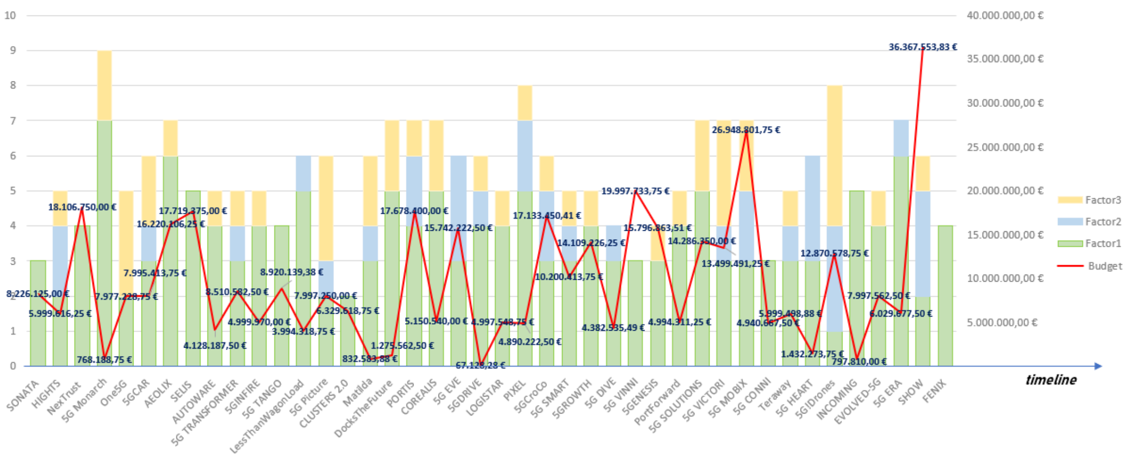


Table 5.32 - Summary with Budget and Factors' Allocation of projects ordered chronologically by end date
Source: Personal Elaboration

Finally, again about the temporal contextualization, the item Project Benefits in the "Purpose Class" already give a preliminary idea on this time context.

Usually, its result is specific only if the project has already been completed or is in an advanced project phase. Otherwise, it is not yet outlined, not clear, as illustrated previously in the sub-categories description.

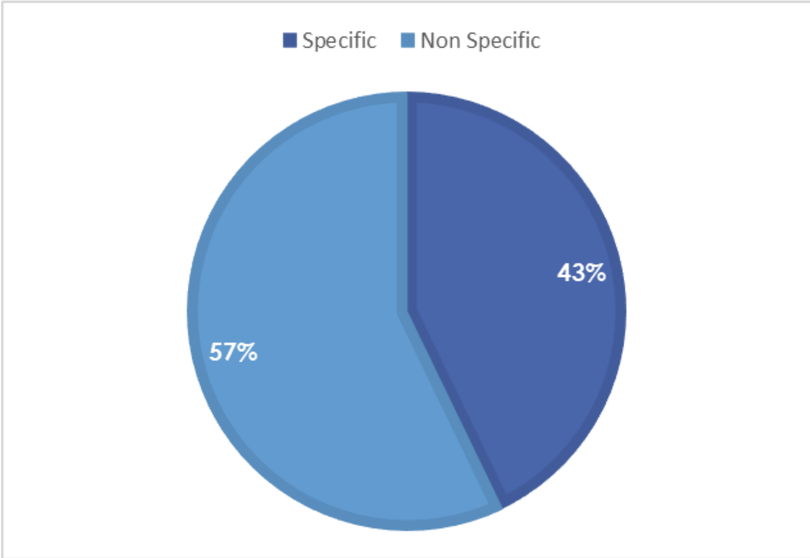


Table 5.33 - Frequency Distribution of Subcategory in the Taxonomy: Financial Resources
Source: Personal Elaboration

Within the dataset used, the projects that have been completed or already having a quite clear and outlined result within this dataset are 43% of the total.

It can be assumed that for the realization of taxonomy, it is necessary to have a baseline of already completed projects to see all the necessary characteristics and have a clear idea of the project's progress.

In the same way, to enrich the sample, it is also essential to have a contextualization that is as current as possible, involving in the sample also projects recently undertaken in order to see in which direction the future goes and if the focus of the applications remains the same or varies over time.

5.3.9 End-User of the Project

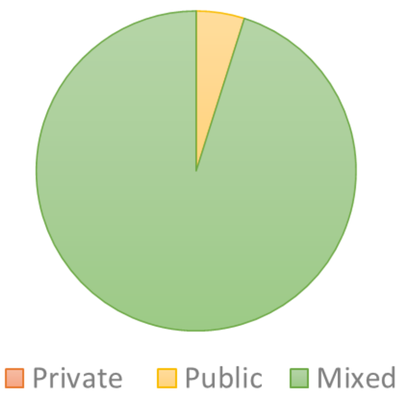


Table 5.34 - Frequency Distribution of Subcategory in the Taxonomy: End User
Source: Personal Elaboration

Although very frequently the benefit of the project and the results obtained through it are not fully outlined until its conclusion, the services that can derive from them will affect both private individuals and public bodies. This is verifiable by the frequency distribution on the left, where in fact, it appears that the end-user benefit concerns mixed entities in 92.8% of cases. As seen from the business model class and from the analysis of the stakeholders involved, from the trend related to project coordination, the public and private commitment are both very significant, so this result confirms what their previous commitment is. It can be deduced that they are committed to obtaining benefits, albeit different, but on both fronts.

If, on the one hand, the public entity looks at digitalization and an increasingly efficient, optimized, and sustainable system, directions in which each of the projects contained in the taxonomy leads, on the other hand the private commitment wants to derive private advantages deriving from innovation applied to their production processes and products, or to keep up with new technologies, in order to earn or maintain its share of the market and maintain a competitive advantage.

5.3.10 Geographical Context

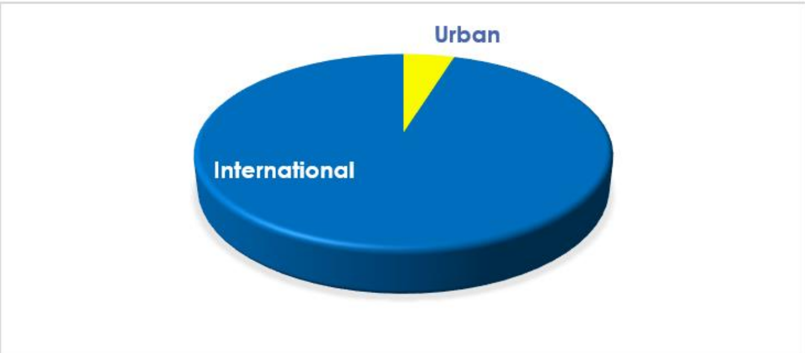


Table 5.35 - Frequency Distribution of Subcategory in the Taxonomy: Geography
Source: Personal Elaboration

The latest analysis aims to assess the geographical context to which the various projects under consideration are aimed.

As can be seen from the pie chart on the side, the data is not very significant, in fact almost all of the projects have the goal of reaching a larger area than a single urban center or national context. Confirming what said in the description of the subcategory, trials are usually carried out in certain cities, ports, or business or transport infrastructures, and from these tests, it is then derived a concept that is adaptable if similar conditions or needs arise elsewhere.

Therefore, the projects' solutions are flexible, and in 95% of the cases analyzed, they are transferable in an international environment.

In reality, even the cases that in taxonomy emerge as belonging to an urban context, such as LessThanWagonLoad and 5GMonarch, develop the trials in a specific territory or district, such as the port of Hamburg, and then aim to obtain results that can be expanded, transferred and implemented elsewhere.

Conclusions

This thesis addressed in all its phases the creation of a final taxonomy as a tool to explore new approaches to logistics of the future in the industrial sector and ports, in collaboration with 5G-LOGINNOV, a European project started in September 2020 and deployed by ICE-ICT for City Logistics and Enterprises laboratory.

Its purpose is to obtain a detailed understanding of technologies and applications, extracting the significant benefits derived from 5G and putting aside the hype concept that characterizes it as a solution to issues not precisely defined.

In this way, in each chapter, key elements are covered to have the foundations and information necessary for an accurate classification.

First of all, the state-of-the-art technology is presented with a general overview of the technologies contributing to digitization, the most common enabled applications, and standardization organizations.

Moreover, to give a "big picture" of the European situation on 5G, a summary of 5GPPP and other European initiatives, and the digitalization incentives, coming from policies undertaken at the public level, together with regulations and funds, investment and budgets, and from private engagement in R&D initiatives and projects are illustrated in detail.

Then, after a contextualization of logistics and ports, containing the future expectations and the related applicability of scenarios such as Industry 4.0 and smart ports, a synthetic analysis is provided for each of the projects to highlight the principal elements and objectives.

A final step includes the general effects of 5G from a political, economic, social, and technological perspective and a focus on the situation for those stakeholders in the markets or that aim at entering, considering the strengths, weaknesses, and in particular opportunities and threats.

In this way, all the elements for a good classification are achieved. The taxonomy, created with a cluster-based approach, is structured into three main classes, Description, Business Model, and Purpose, and provides a complete summary of the dataset of about 40/50 projects analyzed. The observations that are drawn from this clusterization and its statistical analysis are many. First of all, it is outlined that in the industrial and port logistics activities sector, there is a general commitment from both public entities and private individuals.

In the managerial and strategic aspects, the private sector is the most dedicated, while for financial resources and infrastructures, it is the public sector that gives a considerable contribution.

All these incentives stimulate research and facilitate an innovation-oriented approach. In fact, it emerges that there is the contribution of universities and research centers and SMEs in all projects. This trend outlines that companies can use students' academic training to carry out tasks of interest to all stakeholders.

Concerning stakeholders, the taxonomy results confirm all actors' involvement to improve and optimize logistics and operations, which are mainly dedicated to greater productivity and better conditions for workers in the port ecosystem and industry. Cities and customers are also interested in this direction because they can benefit from optimized services and a lower environmental impact.

KPI and Functions and their association with the second category of Complementary Technologies and Enabled Applications constituted the main focus of the analysis in extracting from them the major benefits deriving from 5G in terms of services and applications.

First of all, it emerges that the innovative features of 5G such as Network Slicing and VFN, appear as objects of experimentation or source of contributions in almost all projects, confirming that "softwarization" is one of the key elements in the transition to digitalization.

Then, concerning the other KPIs, reliability, latency, and efficiency are the more recurrent in projects from a frequency distribution analysis.

Factor analysis is then carried out to aggregate the features following similar trends in more than one project and the resulting three macro clusters are Network Requirement, System Accuracy Indicators, and Optimization Performance Indicators. The system accuracy indicators are those with a higher distribution frequency, as expected from industrial processes that require precision and efficiency.

For technologies ready to collaborate with 5G in logistics and business industries, IoT and AI, Edge and Cloud Computing, and Blockchain are the fundamental ones.

AR and VR are considerable only secondly; in fact, being technologies expecially destined to the media and environment sector rather than the industrial one, in this field they give minor contribution compared to the others. Indeed, the applications in which there is primary focus are Industry 4.0 and Smart Manufacturing, Smart Transportation, and Smart Buildings and Smart Cities.

The relationship between these three elements, summarized in the two categories of 5G KPI and Complementary Features and Technologies and Enabled Applications, delineates different paths to be followed for future models and innovation methodologies by identifying the cases where one of the two categories is strongly correlated to the other.

Also, concerning the use cases, it is possible to outline some tendencies. First of all, the most frequent use cases are those related to the optimization of industrial processes and the use of robots, drones, and smart transportations. The correlation between them emerges in different projects since, also here, the prevailing ones in the three use cases categorizations analyzed composed of similar or identical KPIs and 5G Features.
For what concerns the budget, it is noticed that in the projects completed in 2020 and 2021, the investments are meager, to then become significant in projects expected to reach completion in 2022-2023. However, projects from 2022 to 2023 are mainly funded with mixed investments compared to other years, so a cause of the budget increase may be due to substantial private investment in addition to public funds.
To conclude with a time contextualization, from 2017 to date, the projects undertaken in this field have significantly increased. Between 2015-2018, the projects were mainly focused on improving the network and upgrading the infrastructure. However, only recently, from 2019 onwards, a general focus on applications for the different vertical sectors has been undertaken, and therefore a large number of initiatives related to industry and logistics have begun.
Regarding the geographical context, the aim is to do projects that can be flexible and recreated at an international level and in multiple contexts even though the trials may take place in a single city.
The general perception given is that nowadays, both Government and companies are really concerned about digitalization and intervene with various incentives, and collaborating in many directions.
Following this tendency and expectations, in the coming years, the result will be a complete revolution of the systems in use today, even because of many other scenarios that will come to light and bring new business models.
In this framework, a significant contribution can be given by the projects and trends analyzed in this thesis, which are potentially exploitable as guidelines in the standardization, implementation, and deployment of 5G projects in the industrial sector.

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