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5G-DIVE Techno-economic Analysis

Abstract

This deliverable provides a techno-economic analysis of the platform tailored for the 5G-DIVE use cases. It studies the business implications of the Industry 4.0 and Autonomous Drone Scout use cases, analysing the overall impact in terms of CapEx and OpEx. The outcome of this study is a set of recommendations to allow more sustainable business models.

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Disclaimer

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List of Acronyms

- 5G-PPP: 5G-Public Private Partnership
- ADS: Autonomous Drone Scout
- AI: Artificial Intelligence
- API: Application Programming Interface
- AWS: Amazon Web Services
- B2B: Business 2 Business
- CapEx: Capital Expenditure
- CMM: Coordinated Measuring Machine
- CSP: Communication Service Provider
- DCSP: Data Centre Service Provider
- DEEP: 5G-DIVE Elastic Edge Platform
- DSP: Digital Service Provider
- eMBB: Enhance Mobile Broadband Communication
- EMS: Element Management System
- GPS: Global Positioning System
- HW: Hardware
- IoT: Internet of Things
- M2M: Machine to machine
- ML: Machine Learning
- mMTC: Massive Machine Type Communications
- MVNO: Mobile Network Operator
- NOP: Network Operator
- NPN: Non-Public Networks
- NR: New Radio
- NSaaS: Network Slice as a Service
- NSaaSP: Network Slice as a Service Provider
- OpEx: Operational Expenditure
- OSP: Operation Support Provider
- OSS/BSS: Operation Support System/ Business Support System
- SaaS: Software as a Service
- SAR: Search and Rescue
- SC: Service Customer
- SIM: Subscriber Identity Module
- SLA: Service Level Agreement
- SP: Service Provider
- SW: Software
- UAV: Unmanned Aerial Vehicle
- uRLLC: Ultra Reliable Low Latency Communications.

- VISP: Virtual Infrastructure Service Provider
- ZDM: Zero Defect Manufacturing

Executive Summary

This deliverable aims at reporting the work done under Task T1.2 T*echno-economic analysis and business model validation*, resulting in a preliminary and quantitative economic evaluation of the 5G-DIVE system and its economic impact on the 5G-DIVE pilots. It completes the business aspects of the consolidated Edge and Fog, namely the 5G-CORAL system reported in [1], by analysing the business model impact on the Capital and Operation Expenditure (CapEx/OpEx) of each particular use case.

The objectives of this deliverable can be summarized in the following three points: *i)* elaborate the techno-economic analysis of the 5G-DIVE project; *ii)* identify the key issues impacting the overall CapEx and OpEx in the vertical pilots and use cases targeted in the project; and *iii*) provide an insight on the economic and operational feasibility of the 5G-DIVE system from different angles.

For such objectives, the analysis performed in this deliverable is divided into two parts: *i)* stakeholders' flows and business models in order to understand their economic relationships; and *ii)* the techno-economic analysis itself based on the evaluation of the CapEx and OpEx impact derived from the introduction of the 5G-DIVE use cases.

The stakeholders' flows describe the 5G ecosystem composed by the different stakeholders, such as factory owners, system integrators, communication and cloud providers. In this deliverable, we analysed the different 5G-DIVE use cases to understand how the market could address the business demand coming from this kind of vertical customers. As every day more companies are assuming more than one stakeholder role, it seems reasonable to assume that, for these verticals, the solutions would take the form of a turn-key project, resulting in a new role referred to as *System & Service Provider*. We will centre our analysis in this new stakeholder, creating a business model for it.

The methodology proposed in this deliverable allows us to understand what are the economic benefits that result in savings or increase on revenues as well as the different costs associated to the introduction of the 5G-DIVE use cases. With such information, we reported the techno-economic analysis of both pilots in the form of a table, showing the economic viability of the Industry 4.0 use cases and the viability of the Autonomous Drone Scout use cases in terms of lives saved and social welfare.

1. Introduction

This deliverable reports the work done under Task T1.2 T*echno-economic analysis and business model validation.* It aims at *i)* analysing the business relationships between the different stakeholders participating in the 5G-DIVE pilots and *ii)* to evaluate the benefits and costs derived from the introduction of the 5G-DIVE solution.

For such purposes, the document is organized in the following 4 sections:

- In Section 2, the different stakeholders that participates in the 5G-DIVE project are identified. Based on them and assuming that the proposed solutions for the different verticals would take the form of a turn-key project, it is possible for companies to assume more than one stakeholder role. As a result, the focus on this document is set on a new role referred to as *System & Service Provider*, defined as a combination of the capabilities of some other stakeholders. Moreover, the possible stakeholders' flows regarding money and information are identified in this section. Among them one is selected to continue with the techno-economic analysis.
- In Section 3, a business model canvas for the role of the *System & Service Provider* is proposed. It showcases the value proposition of the 5G-DIVE project and its DEEP platform. Two additional business model canvas from the application provider perspective are included in this section: one for the Industry 4.0 and another for the Autonomous Drones Scout.
- In Section 4, the methodology used for the techno-economic analysis is described. It is based on the specific characteristics of each use case and three pillars, namely *i)* 5G; *ii)* Cloud, Edge & Fog; and *iii)* Artificial Intelligence.
- In Section 5, the main benefits impacting on the overall CapEx and OpEx for each of the 5G-DIVE use cases are analysed, based on the methodology presented in Section 4 demonstrating the economic viability of the project.
- Finally, in Section 6, the main insights and outcomes are presented, and further steps are identified.

2. Stakeholders' analysis

This section aims at identifying the main stakeholders that participate in the business model presented in this document. In addition, the most feasible commercial approaches stakeholders' flows regarding money and information are also identified.

2.1. Stakeholders

5G-PPP is working, through collaborative research projects and standardisation bodies, on specifying and developing the main elements in the 5G architecture. In the whitepaper 5G Network Architecture published by 5G-PPP in February 2020 [2], the different stakeholders and roles in the 5G ecosystem are defined.

The 5G ecosystem will enable different stakeholders (such as, factory owners, system integrators, communication providers, cloud providers, and other entities) to efficiently interact, e.g., by means of virtualisation, standardised interfaces and protocols, and/or open APIs.

Figure 2-1 is a consolidated and agreed 5G stakeholder role model among several projects proposed by 5G-PPP. It is taken as a base to the role mapping approach used in the 5G-DIVE project.

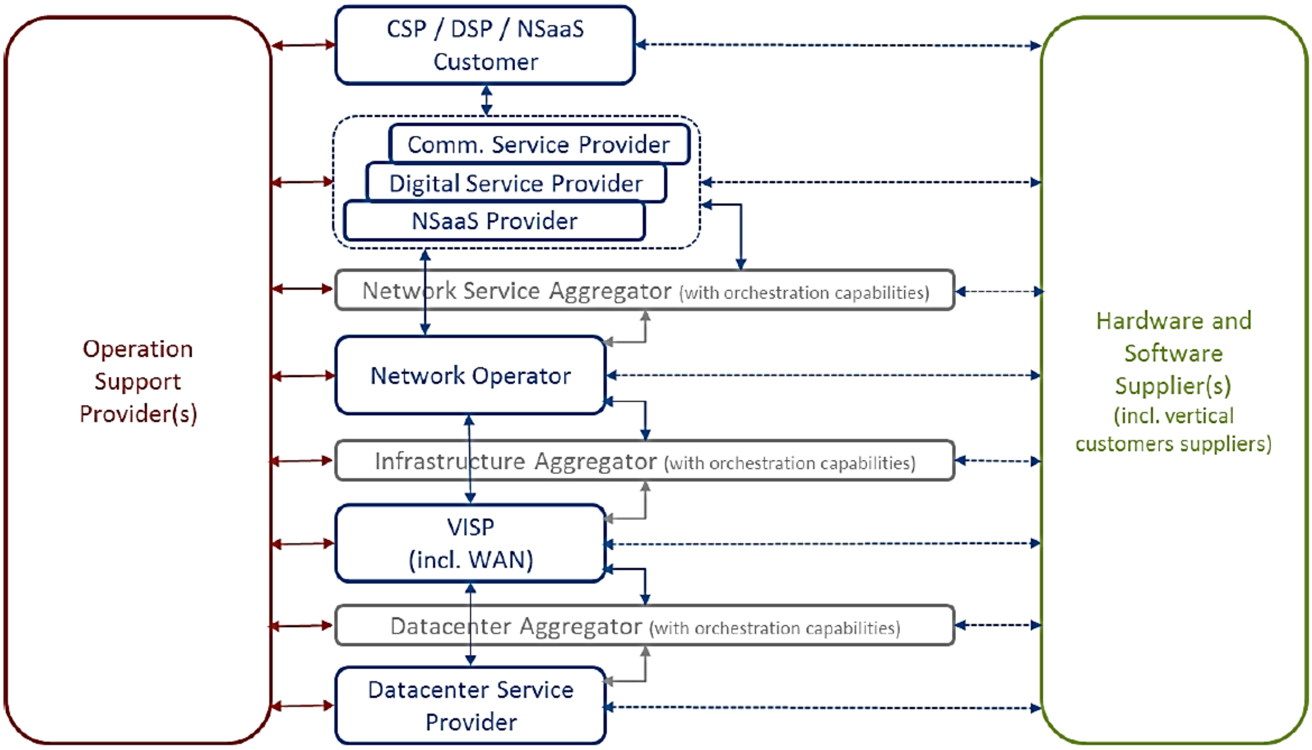

FIGURE 2-1: 5G-PPP STAKEHOLDER ROLE MODEL [2]

The roles identified in Figure 2-1 are the ones that follows:

- *Service Customer (SC)*: The service customer is the final user consuming services that are offered by a Service Provider (SP). In the context of 5G-DIVE project, the main service customer can be considered the factory owner and the drones' owner in the case of the Industry 4.0 and Autonomous Drone Scout pilots, respectively. Both are referred usually referred as the verticals.
- *Service Provider (SP)*: It comprises three different sub-roles, depending on how they interact with the Service Customer (SC) by providing network aggregated services:
    - *Communication Service Provider (CSP)*: It offers traditional communication services such as mobile access, voice, messaging etc. In most of the situations, this role is played by the Network Operator (NOP).
    - *Digital Service Provider (DSP)*: It is the stakeholder in charge of offering digital services such as enhanced mobile broadband and IoT to various vertical industries.
    - *Network Slice as a Service (NSaaS) Provider (NSaaSP)*: It provides a network slice along with the services that it can support. The NSaaSP provides tailored services in a virtually dedicated network for the verticals. The services part of the slice could include the ones provided by the CSP and DSP.
- *Network Operator (NOP)*: The Network Operator (NOP) orchestrates resources from multiple Virtualised Infrastructure Service Providers (VISPs). It designs, deploys, operates, and maintains the network services that are offered to SPs.
- *Virtualisation Infrastructure Service Provider (VISP)*: It provides the virtual infrastructure that is needed to allow the provision of 5G services. It involves both networking and computing resources. Examples of this would be operators that support MVNOs in the networking side and cloud provides (e.g., AWS) in the computing side.
- *Data Centre Service Provider (DCSP)*: It provides datacentre services and designs, builds, and operates its data centres. This is the case of carrier houses (e.g., Interxion).

In addition to the previous stakeholders, there are two other secondary stakeholders that should be also considered:

- *Operation Support Provider (OSP)*: Provides traditional OSS/BSS and EMS functions, SLA Management, and intelligent monitoring.
- *Hardware/Software Supplier (HW&SWS)*: Hardware and software supplier to any of the stakeholders, including the customer.

Following the 5G-PPP analysis on stakeholders, we have analysed the different 5G-DIVE use cases to understand how the market could address the business demand coming from this kind of vertical customers.

In this respect, it seems reasonable to assume that, for these verticals, the solutions would take the form of a turn-key project, then giving room for companies that can assume more than one stakeholder role of those described before.

In order to follow such rationale, **the focus on this document is set on a new role referred to as *System & Service Provider***. It is defined as a combination of the capabilities of some of the previous stakeholders:

> A *SYSTEM & SERVICE PROVIDER* IS THE STAKEHOLDER THAT COMBINES SP (INCLUDING CSP, DSP AND NSAAS) AND NOP CAPABILITIES.

This new stakeholder intends to be the point of contact gathering all other stakeholders. As a result, 5G-DIVE stakeholders are those seen by the *System & Service Provider*.

One possible example of a *System & Service Provider* is a network operator that not only provides network capabilities but also a range of different services such as connectivity, over-the-top applications and edge computing that result in selling a service customer a complete system.

In the 5G-DIVE project, the following stakeholders are considered:

- *System & Service Provider*: Performs the integration of different solutions for satisfying the vertical needs and delivering the final service to the vertical.
- *Vertical*: Referred to as *Service Customer* in 5G-PPP terminology:
    - *Factory owner:* Provides the environment where all the required machinery is installed, such as robotic systems, production lines and cameras.
    - *Drones' owner*: Provides the drones and the capacity to operate them under different missions.
- *Application Provider*: Provides the applications to the vertical, being able to provide a service (e.g., digital twin, ZDM, mMTC, drone location, drone fleet coordination).
- *5G Communication Provider:* Provides the entire 5G infrastructure, including the 5G Core and 5G-NR coverage at the vertical premises.
- *Cloud & Edge Provider*: Provides the virtualization infrastructure required to allow the provision of applications and 5G services. It involves both networking and computing resources.
- *5G Communication Vendor*: Provides the equipment required by the 5G communication provider (e.g., network operator).
- *Cloud, Edge & Fog Vendor*: Provides the equipment required by the Cloud provider to design, build, and operate its data centres.
- *Vertical Equipment Vendor*: Provides the machinery, robotic systems, cameras and drones required to the provisioning of the aforementioned use cases.

In Table 2-1, the mapping of the previous 5G-DIVE stakeholders to the 5G-PPP stakeholders can be found:

TABLE 2-1: 5G-DIVE STAKEHOLDERS MAPPING

	OSP	SC	CSP	DSP	NSaaSP	NOP	VISP	DCSP	HW&SWS
Vertical		X							
System & Service Provider	X		X		X	X			
Application Provider				X					
5G Communications Provider			X		X	X	X		
Cloud & Edge Provider					X		X	X	
5G Communication Vendor									X
Cloud, Edge & Fog Vendor									X
Vertical Equipment Vendor									X

2.2. Stakeholders' flows

In order to introduce the stakeholders' flow analysis, we propose two different analysis: *i)* vertical stakeholder flow and *ii) System & Service Provider* stakeholder flow:

2.2.1. Vertical Stakeholder flow

When analysing the monetary and information flows among the previous stakeholders, the most common approach is described in Figure 2-2 that we refer to as vertical stakeholder flow.

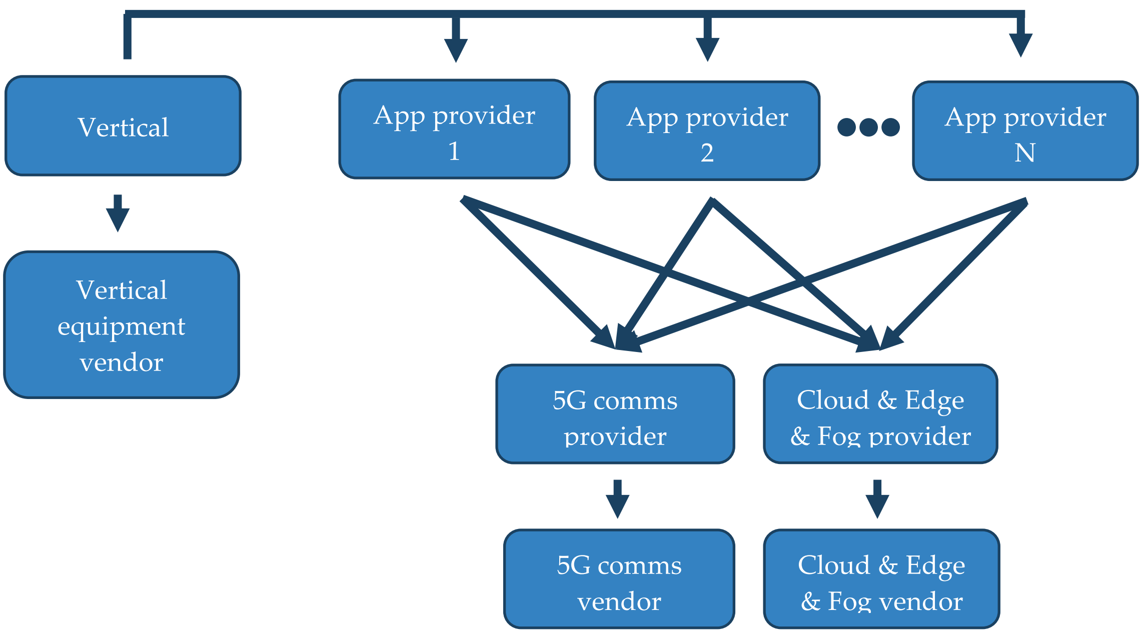

FIGURE 2-2: VERTICAL STAKEHOLDERS' FLOW

In this stakeholder flow, the focus is set in the vertical. The vertical establishes a business relationship with a vertical equipment vendor and with an application provider for each application the vertical needs to compose its service. At the same time, each of the application providers will establish a business relationship with a 5G communications and a Cloud, Edge & Fog provider that rely on their corresponding vendors.

2.2.2. *System & Service Provider* stakeholder flow

In 5G-DIVE, we propose a novel approach for analysing the monetary and information flows among the different stakeholders by introducing the *System & Service Provider*. This approach is depicted in Figure 2-3.

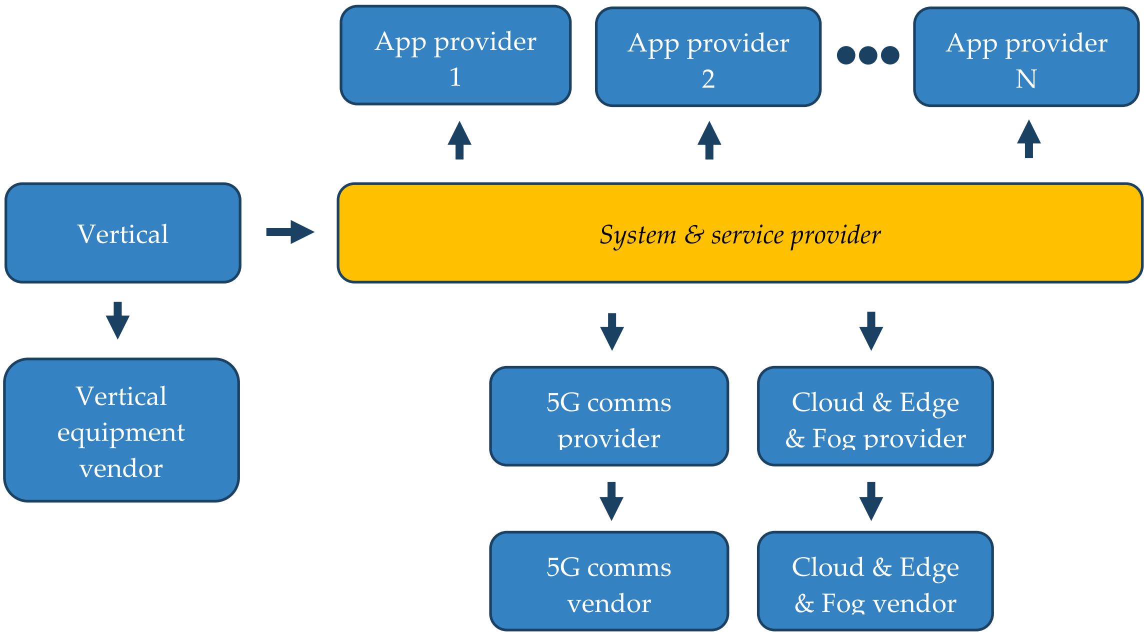

FIGURE 2-3: *SYSTEM & SERVICE PROVIDER* STAKEHOLDERS' FLOW

This type of stakeholder flow introduces a big change with respect to the one previously described. The vertical also establishes a business relationship with a vertical equipment vendor. However, in this case, it does not have any business relationship with any application provider but with the *System & Service Provider*. The *System & Service Provider* is the one owning the 5G-DIVE DEEP platform and the one that establishes the business relationship with any other provider.

This approach simplifies the flow for the vertical and determines a common set of 5G communications and Cloud, Edge & Fog providers with their respective vendors for all the possible applications that may compose the vertical service.

From here after, we will consider the *System & Service Provider* stakeholder flow as the one used in the 5G-DIVE project.

2.2.3. Overview of roles for identified stakeholders

In this section, we considered the following methodology. All the stakeholders represented in the *System & Service Provider* stakeholder flow in Figure 2-3 are considered as separate actors, with the objective of understanding later to what extent they can be combined for following the turn-key approach that we foresee for addressing those markets.

When analysing the different possible stakeholders' flows from the *System & Service Provider* perspective, there are several possibilities.

By embedding some stakeholders inside others, we followed an incremental analysis corresponding to the most feasible commercial approaches coming up with three possible stakeholders' flows *i) System & Service Provider*; *ii)* embedded vertical equipment provider; and *iii)* embedded 5G communications and Cloud & Edge & Fog provider.

2.2.3.1. *System & Service Provider* stakeholder's flow

First, we can consider the case with the biggest granularity possible in which each role is played by a different company and they establish a monetary and information flow among them. This was previously referred to as *System & Service Provider* stakeholder's flow and depicted in in Figure 2-3.

The most important benefit of this stakeholder flow is its appropriateness for projects that need multi-provider environments (e.g., public and private cloud), because it allows the change from one provider to another in a seamless way.

The most notable disadvantage is that having so many interactions can make the flow more complex and result in higher costs. This is due to the fact that when counting on different providers it is more difficult to optimize margins across all the stakeholders because of their individual profit-margin.

This stakeholder flow is the most appropriate for verticals that count with a highly skilled knowledge to cope with the technical complexity.

2.2.3.2. Embedded vertical equipment provider stakeholder's flow

Second, we can embed the vertical equipment vendor into the *System & Service Provider*. This can be the case for example of a vertical which plans to modernize its operation by introducing 5G communications and Cloud, Edge & Fog; or a *System & Service Provider* that commercialise a standard robotic solution for the Industry 4.0 that suits the factory owner.

It can be also the case of a drones' owner who needs a particular type of out-of-the-box drone fleet that can be obtained, configured, and operated through *a System & Service Provider*.

The stakeholder flow resulting from the previous description can be found in Figure 2-4.

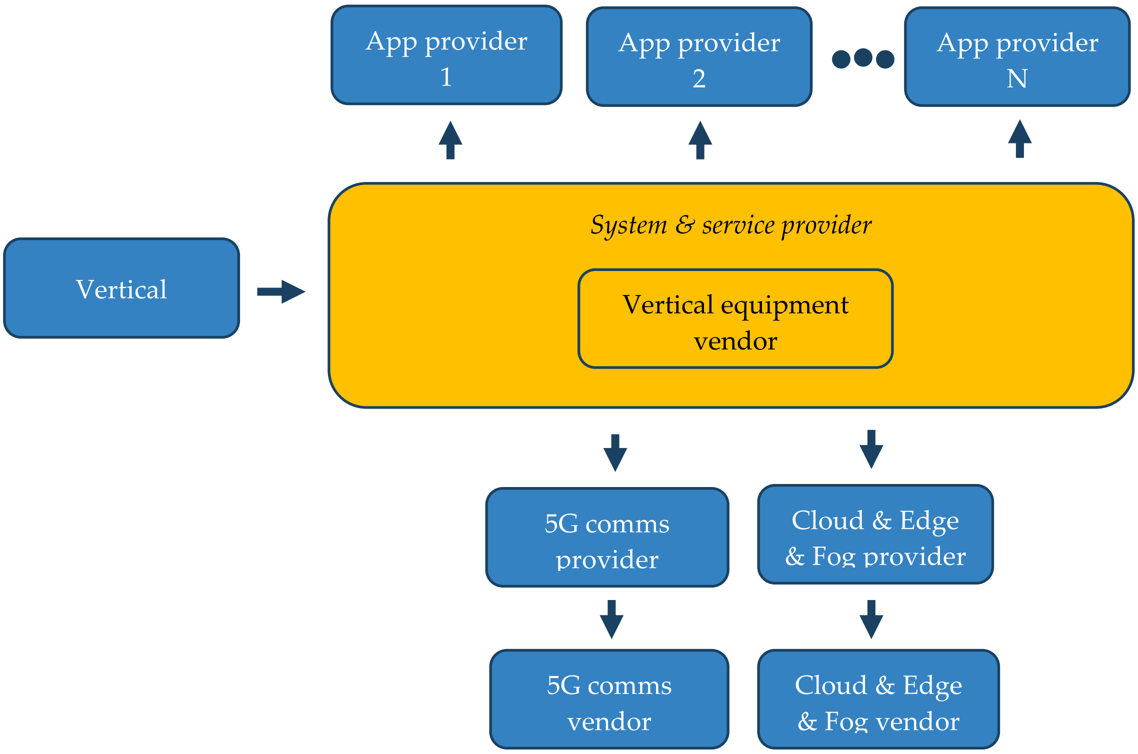

FIGURE 2-4: EMBEDDED VERTICAL EQUIPMENT PROVIDER STAKEHOLDERS' FLOW

The main benefit of embedding the vertical equipment provider into the *System & Service Provider* consists of allowing the vertical to outsource the equipment and simplifying the process by allowing the *system & service provider* to decide on which type of equipment is the most appropriate for the applications that the vertical wants to deploy to compose its service.

At the same time, the previous fact can be seen as a drawback as the vertical loses some short of flexibility. It is just a matter of perspectives.

This stakeholders' flow is designed for verticals who want to outsource everything to the *system & service provider* who will decide about the 5G communications and Cloud, Edge & Fog provider and the vendors in which these last two rely.

2.2.3.3. Embedded 5G communications and Cloud, Edge & Fog provider stakeholder flow

Third and finally, we consider a stakeholders' flow in which the 5G communications and Cloud & Edge providers are embedded within the *System & Service Provider*. This can be the case of a vertical demanding communication and computing capabilities for a service that it is deploying. The applications in this can be also embedded in the *System & Service Provider* or considered external to it as in the previous stakeholders' flows. The stakeholders' flow from the previous description can be found in Figure 2-5.

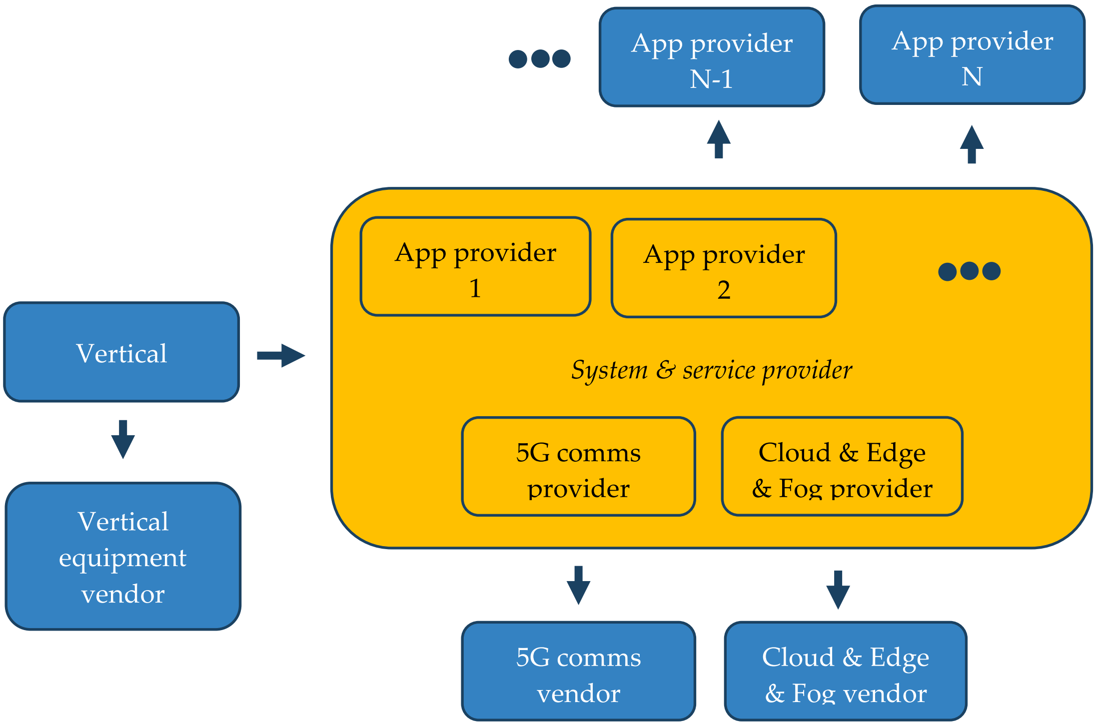

FIGURE 2-5: EMBEDDED 5G COMMUNICATIONS AND CLOUD & EDGE PROVIDER STAKEHOLDER FLOW

One clear benefit of this type of stakeholders' flow is possibility of taking advantage of scale economies for both 5G communications and Cloud, Edge & Fog. As a result, the margin can be compensated, and the cost reduced.

One possible drawback would be the limitation to the 5G communications or Cloud & Edge & Fog capabilities that the *System & Service Provider* possesses in case that the vertical wants to deploy a new service which can be covered with the *System & Service Provider* capabilities.

Finally, it can be said that this stakeholders' flow is designed for verticals that want to start a new operation from scratch. For such a purpose, they acquire the vertical equipment necessary for that operation and rely on a *System & Service Provider* for the 5G communications and Cloud and Edge & Fog capabilities.

2.2.4. Summary and selected stakeholders' flow

In the previous subsections, different possible stakeholders' flows were presented. In the 5G-DIVE project we have selected one stakeholder flow for each use case to be considered for the following sections. The selected stakeholder flow for each pilot and its reasons are the those that follows.

- *Industry 4.0*: Embedded 5G communications and Cloud, Edge & Fog provider stakeholder flow. In the 5G-DIVE Industry 4.0 pilot, we consider the case in which a factory owner outsources the equipment required to the Digital Twin, ZDM or mMTC use cases to a vertical equipment provider but relies on the *System & Service Provider* for obtaining the communication and computation capabilities. The factory owner can use, as a result of selecting this stakeholder flow, in-house applications, external applications and applications offered by the *System & Service Provider* for composing the factory owner service.

- *Autonomous Drone Scout*: Embedded vertical equipment stakeholders' flow. The most common business model of this pilot supposes public entities that establishes a business relationship with a *System & Service Provider* to deploy a full-operative solution for them, regardless the drone's equipment.

From here after, we will, when making reference to the stakeholder's flow in the following sections, we will be referring to those stakeholder's flow.

3. Business Model Canvas Analysis

In this section, we provide the business model canvases referred to the *System & Service Provider* and the application providers of the 5G-DIVE pilots, which showcase the points of view of the key stakeholders in the eco-system.

3.1. Business model canvas of *System & Service Provider*

As it was already introduced in section 2.1, it seems reasonable to assume that the solutions provided to vertical customers take the form of a turn-key project, justifying the use of the so-called *System & Service Provider*.

The Business Model Canvas corresponding to the *System & Service Provider* is presented in Table 3-1:

TABLE 3-1: *SYSTEM & SERVICE PROVIDER* BUSINESS MODEL CANVAS

<table>
<tr>
<td rowspan="2">Key Partners
5G communications provider
Cloud & Edge provider
5G communication vendor
Cloud & Edge vendor
Vertical equipment provider
Application providers</td>
<td>Key activities
Edge services deployment
5G NPN deployment
System Deployment and Integration</td>
<td rowspan="2" colspan="2">Value propositions
AI/ML capability provided by 5G-DIVE DEEP Platform
Pay-as-you-go subscription for deployed services
Common 5G communications and Cloud, Edge & Fog</td>
<td>Customer relationships
Evolution of wholesale services</td>
<td rowspan="2">Customer segments
Verticals</td>
</tr>
<tr>
<td>Key resources
Vertical equipment
Edge HW
5G Connectivity
Integration know-how</td>
<td>Channels
Account managers
Tailored deployments with strategic alliances
Integrators</td>
</tr>
<tr>
<td colspan="3">Cost structures
SW development
Communications
Personnel
5G, Cloud, Edge & Fog Hardware
Revenue sharing with application providers</td>
<td colspan="3">Revenue streams
One-time deployment fee
Pay as you go service subscription
Add-On services</td>
</tr>
</table>

The description of each of the components listed in the business model canvas can be found hereafter:

Key Partners

As defined in Section 2.1.

Key activities

- *Edge services deployment*: Deployment of Edge servers/datacentres with the Edge Cloud platform at the premises of the vertical customers.
- *5G NPN deployment*: 5G NPN network deployment may require the deployment of new small cells in the premises.
- *System Deployment and Integration*: Integration of the developed software in the physical components (e.g., robot manipulators, conveyor belt, cameras, drones), deployment of the virtualized applications in the Cloud and Edge datacentres, and overall integration with the 5G mobile communication systems.

Key resources

- *Vertical equipment*: Programmable robotic systems are required like robotic manipulators, conveyor belts and specific controlling interfaces adapted for each kind of robotic system.
- *Edge HW*: The hardware preferably owned by the Edge and Fog system providers, e.g., in case this role is performed by the telecom operator. When considering edge computing deployments on vertical premises, it is necessary to understand the proper dimensioning of the compute capabilities there. The current trend is to include Micro Edge Datacenters, which are low-consumption systems (<1MW) designed for IoT applications, autonomous vehicles, and smart cities applications [3].
- *5G Connectivity:* 5G-enabled CPEs and pluggable 5G-enabled network interface cards that can allow all the required devices to use 5G connectivity. This implies that 5G-enabled SIM cards are also required. In order to provide an NPN support on the vertical premises, it might be required to deploy 5G network locally in the vertical premises.
- *Integration know-how*: Know-how and skilled people regarding the design, deployment, operation, validation, and integration of all the building blocks that compose both 5G-DIVE use cases.

Value propositions

- *AI/ML capability provided by 5G-DIVE DEEP Platform*: Offering of the 5G-DIVE DEEP platform for introducing a new layer of artificial intelligence that improves the operation of the verticals.
- *Pay-as-you-go subscription for the deployed services*: The possibility of paying a subscription for the services the vertical consumes, according to the amount of usage.
- *Common 5G communications and Cloud, Edge & Fog*: A common 5G communication and Cloud, Edge & Fog infrastructure and platform for the applications developed by any application provider.

Customer relationships

- *Evolution of wholesale services*: The long-term trend is to evolve current services to provide new collaborative services in an end-to-end fashion. This will allow also to being able to engage new customers.

Channels

- *Integrators*: Integrators bring together different components and make them work, ensuring that those components function together.
- *Account managers*: Account managers help to keep B2B relationship alive. In this use case they will be in charge of contacting factory owners to showcase the portfolio of 5G, Cloud, Edge & Fog solutions that can be implemented under the 5G-DIVE scope.
- *Tailored deployments with strategic alliances*: Once that the solution has been designed, third parties can participate through strategic alliances in tailored deployments done in premises.

Customer segments

- *Verticals*: The *System & Service Provider* provides the turn-key Cloud/Edge solution with integrated applications to the vertical customers, like factories, public segments etc.

Cost structures

- *SW development*: Software development, including the costs related to the acquisition of software licenses.
- *Communications*: Deployment and maintenance of hardware required to provide 5G connectivity in the premises of the manufacturing site.
- *Personnel:* People for developing the software, deployment, and integration in the premises of the vertical site and managing the whole infrastructure.
- *5G, Cloud, Edge & Fog Hardware:* Hardware costs for the 5G, Cloud, Edge & Fog Hardware.
- Revenue sharing with application providers: Revenue sharing model is used between the *System & Service Provider* and application providers. Customer pays the subscriptions to the *System & Service Provider* for the applications running on the Cloud/Edge platform. Then a part of the subscription is shared to application providers.

Revenue streams

- *One-time deployment fee*: The initial deployment of the 5G-DIVE solution will imply a one-time fee with the objective of covering the deployment itself.
- *Pay-as-you-go service subscription*: A monthly fee is foreseen for covering the maintenance tasks of the deployment, which normally scales with the usages (e.g., system usage-time, number of devices served etc.).
- *Add-On services*: In case that additional capabilities or system improvement requests arise, they can be considered as a one-time or subscription fee (depending on the nature of the add-on services) also impacting the total revenue of the *System & Service Provider.*

3.2. Business model canvas for 5G-DIVE pilots

In this subsection, we begin with a general description of each of the 5G-DIVE pilots from the techno-economic perspective and then provide the analysis using business model canvases for Industry 4.0 and Autonomous Drone Scout pilots.

3.2.1. Industry 4.0 pilot

Industry 4.0, considered the fourth industrial revolution, aims to build the factories of the future. Shifting towards a smarter, fully connected, and automated paradigm, it combines smart objects and digital systems capable of autonomously exchanging information, triggering actions and controlling each other independently.

5G connectivity, IoT technologies, Fog/Edge/Cloud solutions, Big Data crunchers, and cyber-security arise as key components to realize this paradigm shift.

The goal is to create flexible and resource efficient production systems in manufacturing and to integrate industry, business, and internal processes through computer-based systems [4].

In the Industry 4.0 pilot of 5G DIVE, the following three use cases are considered:

- In the Digital Twin use case, physical assets, together with their processes, are replicated in a digital environment which can reproduce changes as they occur in the physical counterpart. In other words, a Digital Twin consists of mapping the physical and digital worlds (e.g., a physical machine with its digital replica) supported by a continuous exchange of data that ties the two worlds together. Such approach paves the way for novel ways for interacting with machinery within a manufacturing site, enhancing existing monitoring systems and enabling remote control either by a human or intelligent agent. The remote operation capabilities enabled by a Digital Twin will speed up task execution procedures by specialized technicians (e.g., maintenance, calibration, or task configuration), as they will not need to be physically operating the robotic system. This is expected to represent an improvement on the service response time as well as a reduction of the specialized technicians' travels, as well as a reduction on the failures.
- The ZDM use case explores M2M collaboration methods to ensure faster, more flexible, and less wasteful quality control processes. A set of video cameras are continuously monitoring a production line, which, together with enhanced objective recognition / image analysis algorithms, enables the detection of characteristic patterns that are recognized as defects. Upon detection, automated mechanisms are triggered to remove the defective piece from the production line. The sooner a piece is detected as defective and removed from the production line, the smaller is the scrap associated. The automation and M2M collaborative capabilities introduced by ZDM will allow an earlier detection of defects on manufactured pieces and, consequently, a potentially increase of the productivity with an improvement of the goods' quality and less wasted material. This is expected to represent an increase on the production throughput while reducing the cost of production, mainly due to the reduction on the customer visits for the quality assurance of the manufactured goods, the reduction on the scrap material, and the increase on the early detection of defects.
- The mMTC use case focuses on the replacement of wired connections in the factories, enabling wireless connectivity (e.g., cellular IoT, wireless sensor networks) for a massive number of small low-powered low-cost sensor nodes. The aggregation of data from sensor nodes provides

insights into the industrial workflows and plant operations enabling closed-loop control. In the context of Industry 4.0, one example is process and asset monitoring in the context of industrial production, which facilitates predicative maintenance with the monitored data available. Process monitoring connect critical industrial machinery with sensor nodes and actuators for providing insights into the current industrial workflows. These insights and analytics can be used for predictive maintenance using closed loop control. The current working environment inside a plant can be monitored through environmental monitoring, enabling a productive work environment for the plant workers and preventing dangerous situations like fire hazards.

In this sense, 5G and supporting technologies (e.g., Cloud/Edge/Fog computing and AI) are going to play a key role on accomplishing the envisioned functional and technical requirements and, ultimately, the technical and business requirements of both Digital Twin, ZDM and mMTC use cases.

Moreover, the fully realization of these use cases require the participation of different stakeholders (each providing different know-hows, technologies, equipment, software and hardware, connectivity, etc.) which will impact existing value chains and will result in new business models beyond connectivity.

The business model canvas corresponding to the Industry 4.0 is presented in Table 3-2. The canvas is drawn from the perspective of application providers using 5G-DIVE use cases (i.e., Digital-Twin, ZDM and mMTC).

The application providers of different use cases develop the corresponding applications (e.g., Digital-Twin, ZDM and mMTC) deployed on the 5G-DIVE platform which is, in turn, managed by the *System & Service Provider*.

Basically, the services of different use cases provided by the corresponding applications are offered to the vertical customers through a single provider; the *System & Service Provider*, as discussed in Section 2.

TABLE 3-2: BUSINESS MODEL CANVAS FOR INDUSTRY 4.0 APPLICATION PROVIDERS

Key Partners	**Key activities**	**Value propositions**	**Customer relationships**	**Customer segments***
Equipment provider (radio head vendor, robotic systems vendor) System & service provider Open-source community Software component	Software development Software test and verification Service deployment and orchestration Service management and maintenance	Software based Digital Twin and ZDM, providing remote control capabilities to robotic for quality control processes System resources instantiated dynamically and on-demand only whenever the	Customer support (online and offline) Feedback analysis	Factory owner

suppliers (e.g., OS, middleware, database, etc.)	**Key resources** Network connectivity Edge/Cloud platform Service software Service orchestration and management system Radio head infrastructure Robotic Systems hardware	Digital Twin and ZDM service is required Cloudified mMTC radio access infrastructure, providing efficient resource utilization with autoscaling, long term legacy support and future proofness. IoT device management, IoT data management and analytics, as well as possible AI/ML capabilities with data available in the system OpEx instead of CapEx following SaaS model System resources automatically scaled with the user traffic with autoscaling Network automation	**Channels** Through system & service provider Self-service (web) APIs APP store of the system & service provider Customer services (telephone, online)	

Cost structures		**Shared Revenue streams****	
Workforce for software development and maintenance Cost for sourcing in software components	Cost for system integration and tests	Subscription for Digital Twin, mMTC and ZDM services	Subscription for device management Additional subscription for providing IoT data management and analytics

* Indirect through the *System & Service Provider*.

** Revenue sharing with the *System & Service Provider*.

Key Partners

As defined in Section 2.1, there are several key partners of the application providers (e.g., Digital Twin, ZDM and mMTC) that develop the solution and provide the service to the customers. The *System & Service Provider* is the main partner which will provide the overall solution to the customers and integrate each service to its platform. Furthermore, as software developer, specific software components are sourced in from the open-source community and software component suppliers. For the Digital Twin and ZDM services, the Equipment provider is the robotic systems vendor who will produce the robotic system components to be deployed in the customer premises. For the mMTC service, the equipment provider takes the role of a radio head hardware vendor who will produce standard-compliant or certified radio head products to be deployed in the customer premise.

Key activities

The first key activities are the software development, integration, and tests. Then the developed software will be deployed to the Cloud/Edge/Fog platform and provide the Digital Twin, ZDM and mMTC services. After the service is started, it will be orchestrated, managed, and maintained.

Key resources

The SW resources are the developed Digital Twin, ZDM and mMTC software, Cloud/Edge/Fog platform (both HW and SW) and the orchestration and management system. Network connectivity (e.g., 5G) is essential to Industry 4.0. Other HW resources are application specific. For example, mMTC service needs of the radio head hardware infrastructure, while Digital Twin and ZDM services require robotic systems. This can be provided by the *System & Service Provider*. Factories or the *System & Service Provider* can order certified products from the market.

Value propositions

In this solution, the mMTC radio stacks, Digital Twin and ZDM applications are developed as software running on the Edge/Fog platform provided by the *System & Service Provider*. Factories do not need to acquire hardware-based mMTC base stations (or IoT gateways), even if they need to have compatible radio heads as indicated in the key resources. They neither need to have full-fledged robotic systems, allowing software components from the Robotic System to be offloaded to the Edge/Fog platform. The software solution can be easily upgraded and maintained using DevOps techniques originated from Cloud computing. Multiple mMTC RATs can be supported by SW in one system. This would reduce CapEx for hardware costs. The OpEx can scale with the network usage following the SaaS model (pay per use). Network automation and autoscaling make it the network operation more robust and efficient. The data can be stored at the edge, not going out of the factory.

Customer relationships

Like in any Cloud solution, the DevOps model would help improve the service quality continuously. Customer feedbacks can be digitally processed, to provide quick responses and maintain a good service quality. In general, this would help to maintain the relationship with customers.

Channels

Regarding the communication, distribution, and sales channels for the Industry 4.0 services, the first channel is through the *System & Service Provider* (e.g., its APP store, customer support, etc). Furthermore, self-service provisioning (e.g., dashboard) allows factories to start, stop, and change their service subscriptions by themselves. Through APIs, factories can integrate the subscribed services with their existing IT systems.

Customer segments

In Industry 4.0, the targeted customers are the factory owners. As examples, the factory owners may want to deploy mMTC networks and use IoT technologies to modernize their production processes and improve efficiency by leveraging the data collected from IoT devices, Digital Twin for robotic systems to modernize their production processes and enable remote control capabilities and ZDM solution to modernize their production processes and enable the automation of the quality control processes.

Cost structures

The main costs are related to software development, integration, tests, and maintenance, as well as the cost for sourcing in software components from suppliers.

Revenue streams

In this model, we assume that the application/service providers (e.g., Digital Twin, ZDM and mMTC) partner with the *System & Service Provider* with a revenue sharing model. The *System & Service Provider* will charge the subscriptions from the factories and then will share it with the application/service provider under agreement. There is a single type of subscription for the Digital Twin and ZDM: subscription of the Digital Twin services. In the case of mMTC there are mainly three types of subscriptions: *i)* subscription for the mMTC services, *ii)* subscription for IoT device management, and *iii)* additional subscription for providing IoT data management and analytics. All these services can be charged with SaaS per usage model, i.e., subscription (e.g., monthly, annually) according to the usage of the services or with a pay-per-use model (e.g., resources consumption).

3.2.2. Autonomous Drone Scout Pilot

Autonomous Drone Scout (ADS) is one of the modern technologies that can be applied to facilitate 5G networks.

It is becoming a promising technology to replace conventional technologies such as terrestrial base stations, fixed access-points and fixed-cameras, since these technologies mounted in the UAVs may be cheaper in the future and can be applied in the wider areas.

ADS is used to collect data (such as, GPS and visual datasets) in hazards' prone and congested areas. This technology is dominating the traditional approaches because of its cost-effective, fast deploy ability, safety, flexibility, and scalability. For example, in the case of a drone, it can be deployed by the firefighter department to scout a disaster area and give information about the possible victims.

ADS is efficient to collect required data in areas where data collection is challenging, which is then transmitted over different communication networks.

Additionally, drones can collect data in a base station from several locations across the city. Based on [3] and [5], it can be concluded that ADS can benefit from 5G-DIVE platform. For example, drone collision avoidance system and object detection services to the person in need of help can cop when the number of drones is scaled up.

In recent years, there has been a growing interest in drones and their applications to various sectors in the economy and, in particular, for applications on public safety.

The Autonomous Drone Scout pilot focus is on the need for a Public Safety agency to collected data and to transmit it to the edge of the network for cognitive processing and decision-making. According to D3.2, the ADS system is composed of a collision avoidance system that runs in the drone, and a navigation software that its executed at the edge. Together, the communication and the computing capabilities over different tiers of the platform facilitate the necessary means for low-cost and efficient rescue missions.

The ADS scenario will be used to evaluate two use cases, namely *i)* Drones Fleet Navigation and *ii)* Intelligent Image Processing for Drones. In the case of drone fleet navigation, the elementary rules for collaboration among drones are established. On top of that, intelligent image processing for drones can detect risks in disaster areas efficiently.

In the Drones Fleet Navigation use case, the fleet management model is key to the success of drone missions where drone fleet navigation allows performing horizontal flight avoiding obstacles, with characteristics of low speed and high precision in flight. Several models have been developed to meet the requirements for drone fleet navigation.

The coordination and the navigation of the drone fleet will be entirely autonomous through two main key technologies, 5G network and edge computing.

In the Intelligent Image Processing for Drones use case, images from drones are processed in real-time edge applications for emergency detection and response.

The result of the image processing and cognitive techniques is utilized to autonomously update the trajectory for each drone. Also, a joint operation of the resources deployed on the drone and in the ground fog, edge, and cloud are utilized based on latency and computing requirements. The respective resource tier will be used to execute the designed algorithms to achieve the targeted result.

In summary, 5G and supporting technologies (e.g., Cloud/Edge/Fog computing and AI) will play a key role in accomplishing the envisioned functional and technical requirements and, ultimately, the business requirements ADS use cases.

This will open the door to more automation in the scouting processes, creating a new value chain of services, which can be used to provide more services to the drone customers.

The Business Model Canvas corresponding to the Autonomous Drone Scout pilot can be found in Table 3-3:

TABLE 3-3: AUTONOMOUS DRONE SCUOT APPLICATION PROVIDER BUSINESS MODEL CANVAS

Key Partners	**Key activities**	**Value propositions**	**Customer relationships**	**Indirect Customer segments***
Equipment provider (Drones vendor) ***System & service Provider*** Open-source community Software component suppliers (e.g., OS, middleware, database, etc.)	Software development Software test and verification Service deployment and orchestration Service management and maintenance Drone configuration and calibration Drones inspection and maintenance	Increase safety using drones to inspect dangerous areas Allow Remote Operation of Drones, saving costs, faster, secure, accurate Decrease the time for the detection of risks to humans in danger (social welfare)	Public safety events Public bidding	Drones owner
	Key resources Network connectivity Edge/Cloud platform Service software Service orchestration and management system Drones Hardware Drones Software		**Channels** Integrators Account managers	

Cost structures		**Shared Revenue streams***	
Workforce for software development and maintenance Cost for sourcing in software components	Cost for Drones Cost for Drones deployment and tests	Subscription for Drones services System maintenance services	Subscription for Drones management Add-On services

*Indirect through the *system & service provider* in public and private sector.

**Shared with the *system & service provider*.

Key Partners

Same as defined in Section 3.2.1. In this case, the equipment provider is the drone's vendor who will produce drones to be deployed in the customer.

Key activities

Most are the same as defined in Section 3.2.1. In the ADS pilot there are two additional key activities. The first one is drone configuration and calibration related to the activities done by the drones' owner after the equipment acquisition. The second one is the drone's inspection and maintenance.

Key resources

Most are the same as defined in Section 3.2.1. In this pilot the drone's hardware (e.g., drones, remote control, etc.) and the drone's software as developed by the application provider are considered also key activities.

Value propositions

The value propositions for both use cases are very promising. They promise to increase safety using drones to inspect dangerous areas by reducing data collection time and the time of the staff hours. In addition, to allow remote operation of drones, saving costs and making the operation faster, more secure, and more accurate. Finally, to decrease the time for the detection of risks to humans in danger also known as social welfare.

Customer relationships

Two customer relationships are considered here. First, in public safety events, seminar and talks to present ADS solution to public safety agencies such as fire department, emergency management, law enforcement, and national security activities. Second, the public bidding consists basically of a bidding on public safety software and hardware system replacement.

Channels

- *Integrators*: Integrators bring together different components and make them work, ensuring that those components function together.
- *Account managers*: Account managers help to promote ADS business model. In particular, they will be in charge of contacting public safety agencies to showcase the portfolio of 5G, Cloud & Edge solutions that can be implemented under the 5G-DIVE scope.

Customer segments

It is integrated by the private sector composed by companies for disaster relief edge command centre solutions which aim to improve the efficiency and productivity of decision making in disaster relief effort and by the public sector, mainly public safety agencies.

Cost structures

Similar to section 3.2.1, the main costs are related to drone software development, integration, tests, and maintenance, as well as the cost for sourcing in software components from drone suppliers. In particular, the cost for Disaster Relief Edge Command Centre solutions for improving the efficiency and productivity of decision making in disaster relief effort.

Revenue streams

- *Subscription for Drones management*: subscribing or selling for the complete integrated solution to public safety agencies.
- *Subscription for Drones services*: subscribing for services of the integrated solution to public safety agencies.
- *Add-On services*: In the case that additional services request arise, they will be considered as a one-time fee also affecting the total revenue of the system & service integrator.
- *System maintenance services*: The cost of regular maintenance especially for drone software and hardware.

4. Methodology for the CapEx and OpEx evaluations

In this section, we propose a methodology for complying with the three main objectives associated with the 5G-DIVE techno-economic analysis:

1. Identify the key issues impacting on the overall Capital and Operation Expenditure (CapEx/OpEx) due to the different use cases in the project
2. Provide insight on the economic and operational feasibility of the 5G-DIVE approach from different angles.

In order to fulfil the previous objectives and to validate the business models proposed in Section 3, a common methodology for both 5G-DIVE Industry 4.0 and ADS pilots is proposed taking into account all the involved stakeholders.

Commonly, techno-economic analysis focus on the difference in expenditures between the traditional solution of the customer and the innovative one provided in the comparison. Following that idea, the methodology envisaged by the 5G-DIVE techno-economic analysis considers the cost-reduction approach and the newly developed products or services taking into consideration their associated revenue streams as described in Section 3. Some of the reductions are often long-term savings that should be annualized to be compared. As indicated in [3], by adding all the values (annualized when required) we obtain the Yearly Total Value (YTV), which is the parameter that allows us to compare between the traditional and the innovative solution:

$$YTV = \sum_{i=1}^{I} \frac{CAPEX_i}{AP_i} + \sum_{j=1}^{J} OPEX_j + \sum_{k=1}^{K} B_k$$

EQUATION 4-1: YEARLY TOTAL VALUE

where:

- ***CAPEX****$_i$* refers to each capital expenditure of the total I capital expenditure for the 5G-DIVE pilots.
- ***OPEX****$_j$* refers to each operational expenditure of the total J operational expenditure for the 5G-DIVE pilots.
- ***B****$_k$* refers to the benefit of the solution that can be due to a new revenue or a cost efficiency of the total K benefits that may arise as a result of implementing the 5G-DIVE solution.
- ***AP****$_i$* refers to the amortization period of the *CAPEX*$_i$ item.

It is important to highlight that in order to homogenize the YTV, each CapEx item has to be annualized by dividing it by its appropriate AP. Thanks to that, it is possible to neglect inflation and cost derived from investment (e.g., interests on outstanding debts like bonds, bank loans, etc.).

This methodology is devoted to understanding the economic advantages of the adoption of 5G-DIVE solutions.

4.1. Solution point of view

5G-DIVE value proposition is on the automation and intelligence features incorporated in the project's platform allowing vertical industries to develop, run, and manage applications and services without the complexity of building and maintaining the supportive infrastructure. Taking into account both the heterogeneous and distributed nature of the edge and fog environment and the variety of vertical industries and associated use cases, it is essential to provide the necessary tools for streamlined and flexible management, thus concealing the underlying complexity.

As described in Section 2, we will follow an approach where the main stakeholder, named *System & Service Provider* provides a turn-key solution for vertical customers offering the 5G-DIVE platform. In doing so, it integrates complementary capabilities such as applications, communications or computing, either owned or from third parties.

In that regard, we will account for the benefits provided from the solution point of view to the vertical to the benefits B_k in Equation 4-1.

4.2. Technical point of view

The 5G-DIVE project is supported by three main technological pillars, namely:

- 5G, as communication technology enabling not only new network capabilities but also a different way of consuming them. Namely, by vertical sectors that can fully exploit the new functionalities (high bandwidth, low latency, the massive number of connected devices, etc) for improving productivity or developing emerging applications in their digitalization process. 5G is being positioned as a catalyst for the creation of an innovative ecosystem, as reflected in [2].
- Distributed compute capabilities, contribution to reduced latency, bandwidth savings, locality and proximity, context information, etc., especially in the form of cloud, edge and fog computing, permitting the flexible composition of services and deployment of applications tailored to the specific needs of the vertical industries.
- Artificial Intelligence, Machine Learning and Data Analytics, allowing smart decisions on the control and management of resources and assets in order to improve the performance and efficiency of the network. The development of advanced algorithms will allow the network to be adaptive to different scenarios and network events. In the 5G-DIVE project, intense use of both AI/ML is aimed, as described in Section 3.2.1 for Industry 4.0 and Section 3.2.2 for the Autonomous Drone Scout.

Each of these pillars contributes to the techno-economic dimension of the project from a different angle. On one hand, the introduction of these technologies will provide productivity efficiencies with respect to the present mode of operation for a given vertical industry. On the other hand, the deployment of these novel technologies will imply some costs. This analysis precisely intends to elucidate what is the proper balance of all those contributions (in terms of CapEx and OpEx) to support sustainability followed by 5G-DIVE. All this process should be framed in the context of the stakeholders previously defined to ensure the viability of the business models in consideration.

4.2.1. 5G Networks

5G networks have been conceived to support the needs of a hyper-connected society, demanding simultaneously very high data rate access, very low latency, and wider coverage for an increasing number of almost permanently connected devices.

5G will accommodate simultaneously a mix of different service typologies with very distinct needs on top of the same physical infrastructure. 5G services can be grouped into three main categories, namely enhanced Mobile Broadband (eMBB), ultra-Reliable and Low Latency Communications (uRLLC), and massive Machine Type Communications (mMTC). Each of them presents different inherent characteristics spanning from ultra-low latency to high bandwidth and high reliability.

Apart from that, 5G strongly leverages the introduction of three new technological paradigms on provider's networks: network virtualization, network slicing and network programmability.

On the one hand, virtualization of network functions enables the separation of the execution of a given network function from the specific physical device where those functions are executed, breaking the rigid capacity restrictions that traditionally conditioned the deployment of functions in the network. Thanks to the virtualization there is flexibility at the time of deploying and scaling network functions in terms of temporal and geographical delivery, allowing at the same time the commoditization of the devices on top of which those functions run.

On the other hand, the programmability of the network facilitates an easier reconfiguration of the transport substrate and the topologies interconnecting compute execution environments, making possible the automation of operations in the network and its integration with intelligent mechanisms of management and control.

As in the previous point, we will account for the cost resulting from the introduction of 5G to the Capital Expenditure $CAPEX_i$ (annualized when required) and the Operational Expenditure $OPEX_j$ in Equation 4-1.

4.2.2. Cloud, Edge & Fog

Service and cloud providers, as well as vertical industries, are in the process of deploying computing capabilities across the network for hosting network functions and applications. All that computing substrate will form an interconnected mesh on which compose services dynamically and flexibly. Such distributed infrastructure, across multiple providers and several substrates, can complement each other by extending the services in multi-domain orchestration scenarios.

Such compute mesh can be extended from large data centres, in the internals of the provider's networks, up to the far edge close to the vertical industries and end-users, that is, the edge and the fog environments.

On the one hand, Cloud has powerful resources, but they are centralized.

On the other hand, when moving towards the edge of the network (Edge & Fog) nodes are distributed but less powerful.

However, the previous assumptions increase the heterogeneity of the resources, introducing different benefits such as the bandwidth savings across the network, the reduction of latency, the increase of security, privacy and accessibility, control and management and the easiness to scale up or down according to the service needs.

In the upcoming analysis of 5G-DIVE, we will account for the cost resulting from the introduction of Cloud, Edge & Fog to the Capital Expenditure $CAPEX_i$ (annualized when required) and the Operational Expenditure $OPEX_j$ in Equation 4-1.

4.2.3. AI & ML solutions

The application of artificial intelligence and machine learning on top of data collected from the service and the network will permit us to anticipate situations or take better decisions, particularly when the input data is too complex and there are many conditions. This fact is especially true in a Fog environment which is very heterogeneous, dynamic, mobile and volatile. In doing so, AI and ML will allow the implementation of corrective measures pre-emptively, such as a faster reaction to events, trigger scaling actions, etc. All of them can be translated into a more efficient operation, especially when integrated with automation mechanisms for service and network adaptation.

For obtaining the best of the AI and ML solutions, two are the pieces to take into consideration: *i)* the definition of advanced algorithms that could capture the complexity of the situation to be monitored and subject of optimization; and *ii)* the quality of the data collected which form the base of the data analytics that permit obtain substantial information for feeding those algorithms.

(i) The evolution of Industry 4.0 will be focused on industrial automation, opening completely new avenues for business. Some examples are predictive quality and maintenance, human-machine interaction, generative design or market adoption and supply chain. Autonomous Drone Scout Autonomous use the computer vision technology to hover in the air avoiding the objects to keep moving on the right path. This process is enhanced by the use of artificial intelligence.

(ii) The quality of the data collected will include historical data collection, live capturing of new data via sensors, data aggregation, dashboards for monitoring and analysing and new applications, machine learning algorithm and other techniques.

We will also account here the cost resulting from the introduction of AI and ML solutions to the Capital Expenditure $CAPEX_i$ (annualized when required) and the Operational Expenditure $OPEX_j$ in Equation 4-1.

5. CapEx & OpEx evaluations

This section identifies the key issues impacting on the overall Capital and Operation Expenditure (CapEx/OpEx) in the different 5G-DIVE pilots and use cases and provides an insight on the economic and operational feasibility of the 5G-DIVE approach.

Please note that all the prices in this section are given in Euros. For other currencies indicated in the literature, the following change rates has been used:

- *United States dollar ($)*: 1USD=0,85€[1].
- *New Zealand dollar ($)*: 1NZD=0,59€[2].

5.1. Pilots' evaluation

Before analysing both pilots separately, we would like to introduce some elements that are common for both the I4.0 and the ADS pilots.

5.1.1. Savings & incomes

5.1.1.1. *Service & System Provider*

Profit margin applied to the *System & Service Provider*

All the reported costs should be satisfied by the *Service & System Provider* in order to deploy the 5G-DIVE solution for a vertical. The *Service & System Provider* will include some margins on top of the cost for generating profits. As a reference, we take the value of 17% as the average net profit margin for companies in the telecommunications sector [6].

5.1.1.2. Vertical

AI

In order to account for the potential benefits brought by the third pillar of the project, we consider the case study by the GSMA in [7], where AWTG, an end-to-end engineering services and technology solutions provider, deploys an AI-based solution named "Service Assurance and Service Creation Platform" for TOT, a public company expanding its business to different areas, including Industry 4.0

[1] As of 23.11.2020.

[2] As of 23.11.2020.

(smart manufacturing, smart factory, industrial IoT, etc.). Thus, TOT can be assimilated as playing the role of Service and System Integrator according to the previously defined 5G-DIVE stakeholders.

Such study considers the automation achieved by the introduction of AI-based solutions in several time-intensive tasks, such as full automation of network monitoring and management, fault and alarm management, customer support, etc. The operational savings are achieved through lower cost of operational HW and SW licenses, reduced human resource requirements and less management and supervision.

Figure 5-1 presents the high-level AI framework implemented in the referred case study for the service assurance component.

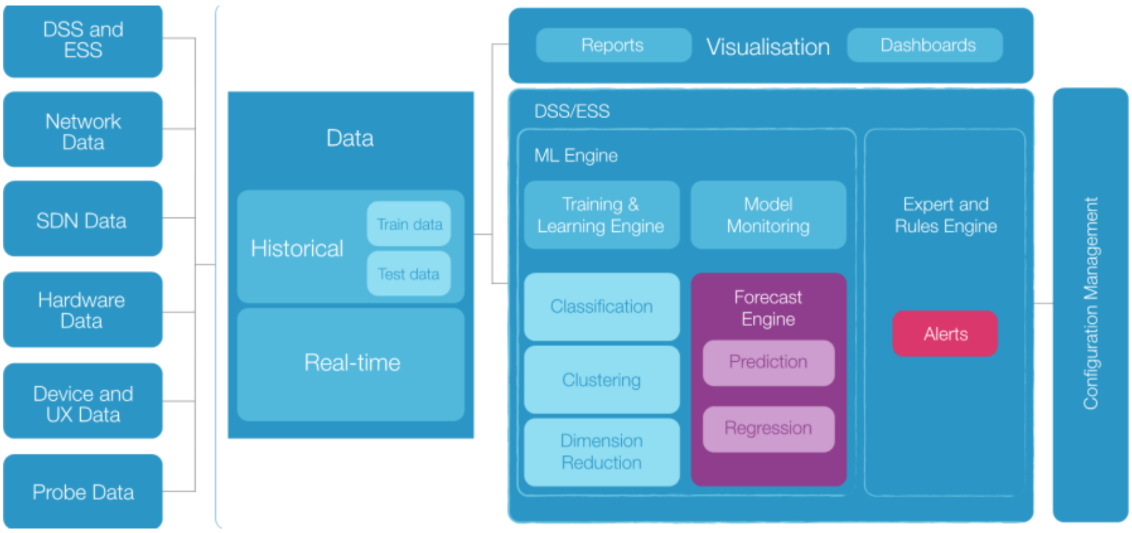

FIGURE 5-1: HIGH-LEVEL AI FRAMEWORK FOR SERVICE ASSURANCE [7]

The case study describes several benefits emerging from the application of AI techniques calculated based on the existing cost of technical operations, engineering resources and customer care resources of TOT. Even though the referred benefits are provided from the perspective of the public company TOT, some of them can be assumed that will be directly translated to the vertical customer (the factory owner in this case), which will become equally benefitted from this novelty.

The following are considered as the main benefits for the vertical:

- *Lower cost of licenses, hardware and software used to operate the network*: 50%.
- *Use of AI for automation of time-intensive and repetitive tasks such as network management, fault, and alarm management*: 20%.
- *Less engineering resources due to AI-led fault management, service monitoring, reporting and optimization*: 18%.
- *Use of device-based AI-customer agent, reducing the number of human customer care agents*: 24%
- *Automation of customer service processes*: 24%.

- *Lower cost of site maintenance and operation from better monitoring of site operations, power usage, and fault management*: 2%.
- *Use of AI for predicted maintenance with sensors that monitor the health of the physical sites*: 2%.

In summary, the benefits of using AI-based mechanisms can be summarized as *i)* operational benefits, such as the automation items listed above, and *ii)* optimization savings, like the lower costs due to better usage of resources. From the two previous mechanisms we assume that the operational benefits are the ones directly translated into vertical benefits since those will be the ones impacting the productivity of the factories. As reference value, we assume an overall improvement of 15% as conservative value, to be applied on top of the savings and incomes for both Industry 4.0 and Autonomous Drones Scout 5G-DIVE pilots.

5.1.2. Costs

5.1.2.1. System & Service Provider

Spectrum

The coverage in the plant will require the usage of an auctioned radio spectrum. According to the analysis in [3], the cost associated with a factory environment can be less than 5k€ with an amortization time of 20 years, so the cost is negligible. Thus, for the Digital Twin, ZDM and mMTC manufacturing use cases the total cost associated with the SIM cards necessary per scenario is below 100€.

5.1.2.2. Vertical

AI

It is extremely difficult at this stage to predict what could be the cost of an AI-based system as the one designed within 5G-DIVE. We have scanned public sources for obtaining a reference of what could be a reasonable cost for it, to make some estimations.

In [8] the estimation of the cost for developing AI/ML systems for businesses is from 84760€ to 254294€, depending on the complexity, size, and customer requirements. For [9] the cost of an AI Minimal Viable Product (MVP) varies between 25430€ and 84760€ depending on the size of the project and its complexity. Finally, for the particular case of chatbots, the cost estimated in [10] and [11] ranges between 5086€ and 254294€ in the first case, and 25430€ and 211914€ in the second. It should be noted that those costs are referred to the cost of the entire solution. In addition to that, it can be assumed that it will be possible to reuse a given solution with adaptations for different verticals, thus the cost should be allocated proportionally to the expected number of customers. Furthermore, it can be also considered a period of amortization for the AI/ML platform (e.g., 5 years).

With these inputs, for the analysis here we will consider a cost per vertical customer of 16910€ per year, that would rise a total value of 84760€ during the 5 years of amortization.

5.2. Industry 4.0 Pilot evaluation

This subsection describes the references followed to elicit the analysis in terms of CapEx and OpEx for a realistic Industry 4.0 use case. The data has been collected from multiple sources as shown hereafter.

With respect to improvements in the productivity on the vertical side, which generates savings for the present mode of operation, two aspects are considered:

- Cost reduction in vertical customers due to the usage of 5G and edge computing capabilities. For this analysis, we have considered the study performed [3].
- Cost improvements due to the introduction of AI in the productivity environment of factories. For that, we have followed the reference use case detailed analyzed by the GSMA in [7].

In turn, with respect to the costs of the service and system to enable the aforementioned savings, related to each of the pillars of the value proposition from 5G-DIVE, the following aspects are considered:

- Costs of 5G communication system, considering different reported values:
  - Cost of radio spectrum consumed. For that, we follow the same analysis performed in [3] taking as reference the values of spectrum auctions in Europe.
  - Cost of network slices fitted to the vertical service. Also, as in [3], we take as reference the study in [12].
- Cost of edge computing facilities. Again, we depart from the [3] analysis in this respect, collecting public information from manufacturers for the dimensioning exercise and applying costs from [13].
- Cost of AI systems. For this, we have performed an analysis of public references for the cost of AI systems [14] establishing some realistic hypotheses for the case of 5G-DIVE.

The next subsection describes in more detail the reference values considered. The approach followed is to focus on the cost/benefits for a single vertical and then extrapolate it to a potential number of verticals in the geographies of interest.

Please note that for this CapEx and OpEx evaluation we decided to focus on the Digital Twin and ZDM use cases, not analyzing the mMTC use case.

5.2.1. Savings & incomes

5.2.1.1. Vertical

[3] details several sources for savings due to the introduction of 5G communications complemented by edge capabilities, which form two of the three pillars of 5G-DIVE. We depart, then, from the same analysis. The list of saving sources described is the following:

Travel reduction

According to he rationale for this source of savings is the reduction of travelling required to provide maintenance services for internal tools in the factory. The tool referred, named Coordinated Measuring

Machine (CMM) is used for measuring point positions to calculate geometries of physical objects by sensing discrete points on the surface of the object with a probe. The reduction of costs claimed reports an OpEx saving of around 150k€ per year. The rationale for the calculation is described in TABLE 5-1.

TABLE 5-1: ESTIMATION OF OPEX SAVINGS DUE TO TRAVEL REDUCTION [3]

Trip duration (days)	Average cost	Trips per year	Estimated Trips reduction	OpEx Savings per year
3 to 7	2,5 k€	100	60%	150 k€

Availability of experts

The trips referred before imply having an expert on the productivity tools being unable to work during some periods, such as the time for travelling or the idle periods on those trips during which the tools are being calibrated or performing some other tasks. According to the estimation in [3], an average of 50% of the maintenance time is waiting time. Thus, when remoting the maintenance actions, it is possible to make better usage of the working time of the experts. Increasing the availability of the experts in 2 days of work per trip, by transforming 60% of the maintenance trips into remote actions, means increasing availability in 120 days per year. Considering an average cost per day of an expert to be around 800€, this implies a saving of 95k€.

5.2.2. Costs

5.2.2.1. System & Service Provider

Cloud, Edge & Fog computing

For the characterization of the edge computing environment, the assumption is that a micro-data centre is deployed on the factory premises. Such micro data centres are usually referred to as Micro Edges, consisting of computing facilities in few racks (even in single-rack form factor) with low-consumption systems (<1MW).

The assumption of cost for a Micro Edge taken here is based on the calculations performed in [13] when modelling a NFVI infrastructure. The modelling details are specified in Table 5-2, resulting in a monthly cost of 2308€ assuming a depreciation of 36 months. Maintenance costs are not included as these are supposed to be part of the cost paid to the *System & Service Provider*.

TABLE 5-2: DESIGN ASSUMPTIONS AND COST CHARACTERIZATION OF A MICRO EDGE

Concept	Units	Capacity	Units
Leaf switches	1	vCPUs	288
Management switches	1	RAM	756
Controller nodes	1	Block Storage	21600 (GB)
Compute nodes	2	Energy	2,6 kW

Block storage nodes (HDD)	2	Cost	2308€

Network Slices (URLLC and eMBB Network Slices)

At the time of provisioning services for vertical customers, it can be assumed that the differentiation and isolation of those services will be ensured employing the provision of network slices.

For pricing calculation, we take as reference the cost evaluation performed in [12] which consider the cost of 21€ per Mbps and 53€ per user. Considering that the dimensioning in a factory follows the same criteria as the Industry 4.0 case in [15] then the total cost is 63487€. TABLE 5-3 summarizes the calculations, where the hypothesis followed is that an uRLLC slice costs twice an eMBB one.

TABLE 5-3: NETWORK SLICES YEARLY COSTS

Use case	Slice	Formulation	Final cost
Digital Twin	eMBB	(65x 21€) + (100x 53€)	6665€
	uRLLC	[(65x 21€) + (0,4x 53€)] x2	2772 €
ZDM	eMBB	(50x 21€) + (1000x 53€)	54050 €
		Total Cost	63487 €

Video platform

In order to perform the supervision actions of the production environment, a video platform is required. Considering the cost of off the shelf broadcast cameras, a high end 4K video camera with H.265 real-time encoder profile with around 1102€ (170€ camera, 509€ encoder chip, 424€ NR modem) for the industrial scenario.

5.2.3. Summary of the Industry 4.0 analysis

In order to project the economic contribution of 5G-DIVE for a particular deployment, the savings, incomes and costs analysed before are summarized in the following tables.

Table 5-4 and Table 5-5 summarizes the analysis reported in the previous sections, annualized by applying an amortization time, from the perspective of the vertical industry.

TABLE 5-4: INDUSTRY 4.0 VIEW OF SAVINGS & INCOMES

Economic item	Value [k€]	Amortization [yrs]	Annual value [k€]
Travel reduction	150	1	150
Availability of experts	95	1	95

Subtotal	245
Efficiencies in the production due to AI	+15%
Total	281,75

TABLE 5-5: INDUSTRY 4.0 VIEW OF COSTS

Economic item	Value [k€]	Amortization [yrs]	Annual value [k€]
Spectrum	5	20	0,25
Network slices	63,5	1	63,5
Edge computing	27,48	1	27,48
Video platform	1,102	1	1,102
AI system	84,76	5	16,95
Subtotal			109,58
Average profit margin			+17%
Total			128,20

With this analysis and the hypothesis taken, it can be concluded that the 5G-DIVE approach shows sustainability. The net benefit for the vertical industry in this example will be of 153,55k€ per year and per vertical customer.

5.3. Autonomous Drone Scout pilot evaluation

ADS case is difficult to be addressed in economic terms since it is conceived for emergency and safety purposes. There is however an analysis that helps to provide such economic insight. The study in [16] provides some prospective figures for the usage of drones in public safety and security in New Zealand.

5.3.1. Savings & incomes

5.3.1.1. Vertical

Annual impact on the savings per site

According to [16], a sensitivity analysis is included assuming different uptake rates (speed) and scale of uptake (size) in the adoption of drones, being this paired with a discounted cash flow analysis modelling three discount rates (4%, 6% and 8%), calculating gains for 25 years. We take as a basis also for our analysis the base or average values, as described below. For simplicity, we will assume that the estimated gains are linear over the 25 years.

Two situations are evaluated. First, the usage of drones for Search and Rescue (SAR) which is exactly 5G-DIVE ADS use case, and second, the usage of drones for firefighting. Here we will consider only the SAR case, as being more related to the 5G-DIVE project use cases.

In the case of SAR, two areas of usage are considered: *i)* lives saved, rescued or assisted, and *ii)* avoided fatalities. For each of them, considering 1% anticipated events avoided, with a discounted cash flow of 6%, the gains are accounted respectively in 150,76m€ and 2,4m€. This would imply an annual impact on the savings of 6,13m€.

5.3.2. Costs

5.3.2.1. System & Service Provider

Industrial Computer

For the Autonomous Drone Scout pilot, we consider the use of an industrial computer HPE ProLiant DL580 Gen10 Server [17] with a total cost of 12,34K€ and an amortization time of 5 years.

5.3.2.2. Vertical

Drones

For calculating the cost of drones needed for achieving those figures, it is necessary to take some assumptions on how many of them could be deployed. The document [16] details that there are 74 Surf Life Saving Clubs in the country and around 60 Land Search and Rescue volunteer organizations [18] in case of having similar numbers of governmental SAR stations, and counting at least two drones per site, the total number of drones can be stated in around 400 for a total of 200 SAR sites. Averaging the gross benefit among the 200 SAR sites, we could obtain an average contribution per site to the overall benefit 30,68k€ (6,13m€/200=30,68k€).

In 5G-DIVE a cost of 5,7k€ is considered per drone according to DJI Store [19]. In the calculations shown bellow we are only considering the cost per one site, consisting in two drones 5,7k€*2=11,4k€.

Apart from the drones' cost, in this use case, we can consider the costs for the edge computing facilities, the spectrum and the AI system. All the processing will be performed on the site, leveraging on the edge capabilities deployed.

5.3.3. Summary of the Autonomous Drone Scout analysis

In order to project the economic contribution of 5G-DIVE for a particular deployment, the savings, incomes and costs analysed before are summarized in the following tables.

Table 5-6 and Table 5-7 summarize the calculations.

TABLE 5-6: ADS VIEW OF SAVINGS & INCOMES PER SITE

Economic item	Value [k€]	Amortization [yrs]	Annual value [k€]
Annual impact on the savings per site	30,68	1	30,68
Subtotal			30,68
Efficiencies in the production due to AI			+15%
Total			35,3

TABLE 5-7: ADS VIEW OF COSTS PER SITE

Economic item	Value [k€]	Amortization [yrs]	Annual value [k€]
Spectrum	5	20	0,25
Industrial Computer	12,34	5	2.47
Drones	11,4	5	2,28
AI system	84,76	5	16,95
Subtotal			21,95
Average profit margin			+17%
Total			25,68

In this case, with the assumption and hypothesis taken, the ADS use case results also sustainable with a net benefit of 9.61k€. However, it should be highlighted that the main purpose of the use case is not looking for economic profits but general social welfare.

6. Conclusions

This deliverable has reported the work done under Task T1.2-T*echno-economic analysis and business model validation* resulting in a preliminary and quantitative economic evaluation of the 5G-DIVE pilots.

The preliminary and quantitative economic evaluation has been done by analysing, on one hand, the different stakeholders participating in each pilot as in Section 2, and in the other hand, by applying the methodology proposed in Section 4.

The stakeholders' flows have described the 5G ecosystem composed by the different stakeholders (such as, factory owners, system integrators, communication providers, cloud providers and other entities) that efficiently interact between them with the objective of providing a novel service. We have analysed the different 5G-DIVE use cases to understand how the market could address the business demand coming from this kind of vertical customers. In this respect, it seems reasonable to assume that for these verticals the solutions would take the form of a turn-key project, giving room for companies that can assume more than one stakeholder role and resulting in a new role referred to as *System & Service Provider*. Based on this reasoning, we identified, in Section 3, the business models for both the *System & Service Provider* and the application providers that enable the benefits to the verticals.

The methodology proposed in Section 4 allows us to understand for each pilot what are the economic benefits that result in savings or increase on revenues as well as the different costs associated to the implementation. To consider expenses encompassing more than one year, we introduced the "Yearly Total Value" in order to obtain annualized items. Finally, and after applying the methodology to the 5G-DIVE pilots, in section 5, we reported the techno-economic analysis of both pilots in the form of a table, showing the economic viability of the Industry 4.0 use cases as well as the viability of the Autonomous Drone Scout use cases in terms of lives saved and social welfare. According to what was written here, it can be said that the work reported in this document has successfully achieved the objectives proposed in Section 1: *i)* the techno-economic analysis of the 5G-DIVE project has been elaborated; *ii)* the key issues impacting on the overall Capital and Operation Expenditure (CapEx/OpEx) in the different use cases have been identified; and *iii*) an insight on the economic and operational feasibility of the 5G-DIVE approach from different angles.

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