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Deliverable D5.1

Ecosystem analysis and specification of B&E KPIs

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Abstract

This document provides suggestions for actor roles for the 5G-VINNI facility and the complex 5G ecosystem. Based on this the document elaborates on implications for 5G business relationships and business models.

The results of a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the 5G-VINNI facility are reported. By systematically combining the SWOT input it is possible to suggest both forward leaning strategies, and more defensive ones.

The document contains an overview of the verticals' innovation potential that the 5G-VINNI facility can enable.

Furthermore, it provides the basis for enabling business validation of the 5G-VINNI facility by establishing Business and Economic KPIs concerning topics such as cost efficiency, value creation, and entry barriers.

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Executive summary

In the 5G community, 5G is not only perceived as a technology but also an ecosystem, signalling an expansion of parties involved in value creation and innovation, and expectations to new growth. Two approaches from the innovation and business management field are helpful to analyse 5G as an ecosystem, namely the value network and platform ecosystem approaches. Both encompass the complex interdependency in 5G value creation and capturing. The value network approach provides a more detailed analytic view on how an interconnected system is organised; the platform ecosystem approach emphasizes business relationship prerequisites when an ecosystem platform creates and capture value together with complementors and enterprise customers. The approaches help to suggest relevant business roles (actor roles) and their business relationships in 5G-VINNI and 5G in general. The approaches are also the foundation for a SWOT analysis of the 5G-VINNI facility, carried out by the project, and an accompanying online survey to vertical enterprise customers.

The suggested 5G-VINNI actor role model contains five main actor roles relevant for 5G-VINNI: Customer, NSaaS (CS) Provider, Network operator, Virtualization Infrastructure Service Provider (VISP), and Data Centre Provider. In addition three aggregator roles were identified for the last three main roles. This model indicates important business relationships; however, it is limited by its emphasis on measuring and validating technical feasibility. Thus, the 5G-VINNI actor role model is complemented by a detailed actor-model for 5G in general, using the value network approach for value creation in a complex system. In total, we suggest 23 key actor roles for the 5G ecosystem, grouped into nine role clusters.

This complexity of providing 5G services is hidden when we discuss 5G as a platform ecosystem. Instead we reveal the many-faceted business relationships between the 5G platform, the firms that complement the platform in developing and providing complete solutions, the enterprise customers, and end-users. We assume that the actors taking on a role as network operators providing Network-Slice-as-a-Service (NSaaS) and other value-added services constitute the platform. An intuitive understanding of NSaaS is that enterprise customers are provided with their seemingly separate slice of the network. The complementors which the platform enables to innovate with NSaaS and supporting interfaces are the other IT providers in the market. The enterprise customers are firms in a specific vertical which actually purchase NSaaSs and are served by NSaaS provider(s). We also introduce the end-user, or the user equipment (UE), which needs to be connected to an NSaaS purchased by a specific enterprise customer.

Based on our different 5G actor role models we introduce concepts and concrete examples of new business relationships, business models and some potential revenue streams. Before proceeding, it is necessary to emphasize the possibility for one UE with a SIM-card provided by one operator, to be allowed access to an NSaaS provided by a second operator. We will also emphasize the possibility for UE connected to an NSaaS provided by one operator to communicate with UE in an NSaaS provided by a second operator. We suggest several examples where this may be demanded; we claim that interoperability between logical networks (with their connected UEs) pertaining to different NSaaS contracts provided by different operators is a widely held requirement. Interoperability is technologically feasible, and mostly subject to limitations in the business relationship between the operators and in the way technologies are currently deployed.

We suggest that handover, (national) roaming and federation schemes (for example when UEs serviced by different operators) are candidates to manage interoperability between networks and geographies. Furthermore, we present a preliminary suggestion for how 5G interconnection must cater to device end-points, edge end-points, core end-points, and international backbone cloud in both the home and remote geographies.

We suggest that mobile network operators (MNO) may capture future 5G revenues in three ways. First, one MNO may get connectivity revenues from all end-users and UEs that are connected to the

logical network associated with the NSaaS contract, including compensation for equipment visiting from a different MNO. Second, an MNO may have revenues from managing an NSaaS contract, both the initial implementation and the administering of connections, facilitation of supporting services, and potentially administration of applications. Third, the interconnection between logical networks pertaining to different NSaaS contracts (provided by different MNOs) is a potential revenue stream. An MNO's revenues are not restricted to these revenue streams, however, in our analyses we emphasize the importance of sharing both value creation and capturing with the complementors in the 5G ecosystem. The significance of sharing of roles, predictability, and trust is confirmed in the responses to our Strengths-Weaknessess-Opportunities-Threats (SWOT) survey; to engage in adjacent actor roles currently held by complementors may hinder the growth of the whole ecosystem and thus the demand for 5G platform services.

The SWOT analysis and accompanying survey, carried out by the project, provide us with potential strategies for succeeding at different stages in the 5G evolution: from internal experimentation with the 5G-VINNI facility to future commercialized 5G services. The strategies suggested for the *initial stages* fall into the categories attack, reinforce, develop and avoid.

> Attack: a) The (expected) technical performance superiority of the 5G-VINNI facility allows exploitation of high interest of some vertical industry sectors for offering value-added/assured quality services to their customers; b) Private networks (defense, emergency, health) are expensive/challenging for non-ICT actors to handle, and opens opportunities for providers of high performance, professionality and ability to exploit new technologies.
>
> Reinforce: a) Current geographical limitations for the 5G-VINNI facility must be mitigated by expanding to additional customer segments; b) Vertical enterprise customers are familiar with and expect access to trials and experimentation, and must be carefully catered to.
>
> Develop: a) 5G-VINNI has to devise and validate novel collaborative business models and "all-win" mechanisms that increase market stability and accelerate the innovation in later stage; b) 5G-VINNI should use its standing to push important standardization processes in Europe.
>
> Avoid: Opportunities are driven by verticals' and partners' eagerness to digitalize. In case of limited culture for collaboration and trust between 5G actors, high performance and acceptable cost levels is not sufficient to build the market. The innovation capacity must be reinforced in early phases due to the limited set of 5G-VINNI customers.

We have organized our exploration of the 5G-VINNI facility's innovation potential in a framework according to the Oslo Manual 2018 (OECD/Eurostat, 2018). We structure innovations in product and business process innovations. In order to be an innovation, the Oslo Manual suggests requirements on novelty and ownership, assessed according to characteristics such as durability, observability or decision-making abilities. The businesses' objectives from innovations can be everything from creating new markets, reduce labor costs, absorbing knowledge, to improve well-being. According to this structure, we have suggested almost 60 business innovation examples across nine verticals and shown that all verticals examined can benefit from innovative 5G use-cases.

In order to evaluate the impact of the 5G-VINNI facility on the vertical industries, we have specified a set of business Key Performance Indicators (KPIs). These KPIs can be seen as proxies for understanding how vertical industries innovate, as these may be computed based on measurements collected while experiments are hosted or via online questionnaires. Furthermore, we defined several KPIs for evaluating the business potential of the 5G-VINNI facility. The Economic KPIs can be decomposed into two categories, namely cost efficiency and value creation. Business KPIs are mostly used for understanding how vertical industries innovate. Together they form the 5G-VINNI B&E KPI repository.

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Abbreviations

Abbreviation	Meaning
5G	Fifth Generation (mobile/cellular networks technology)
5G PPP	5G Infrastructure Public Private Partnership
API	Application Programming Interface
AR	Augmented Reality
B&E	Business and Economic
B2B	Business to Business
B2B2X	Business to Business to “unknown”
B2C	Business to Consumer
BaU	Business-as-Usual
BS	Base Station
BSS	Business Support Systems
CAPEX	Capital Expenditure
COTS	Common-of-the-Shelf
CS	Communication Service
CSP	Communication Service Provider
DSM	Digital Single Market
DSP	Digital Service Provider
E2E	End-to-end
EC	European Commission
eMBB	Enhanced Mobile Broadband
ESB members	External Board members (5G-VINNI)
GST	Generic Slice Template
HW	Hardware
ICT	Information and Communication Technologies
IoT	Internet of Things
IT	Information Technology
KPI	Key Performance Indicator
LTE	Long Term Evolution
MANO	Management and Network Orchestration
MEC	Multi-access Edge Computing
ML	Maturity Level
mMTC	Massive machine type communication
MNO	Mobile network operator
MVNO	Mobile Virtual Network Operator
NEST	NEtwork Slice Type
NFV	Network Function Virtualization
NFVI	NFV Infrastructure
NSaaS	Network slice as a service
NSI	Network slice instance
NSSAI	Network Slice Selection Assistance Information

Abbreviation	Meaning
NST	Network slice template
OPEX	Operational Expenditure
OTT	Over-The-Top
P-NEST	Operator specific NEST
PPDR	Public Protection and Disaster Relieve
PV	Present Value
QoE	Quality of Experience
QoS	Quality of Service
R&D	Research and Development
RAN	Radio Access Network
RRV	Rapid Response Vehicle
SA	Service Aggregator
SDN	Software Defined Networks
SIM	Subscriber Identity Module
SLA	Service Level Agreement
S-NEST	NEST with industry accepted slice characteristics
S-NSSAI	Single Network Slice Selection Assistance Information
SW	Software
SWOT	Strengths, Weaknesses, Opportunities, Threats
TCO	Total Cost of Ownership
TOWS	Threats, Opportunities, Weaknesses, Strengths
UE	User equipment
URLLC	Ultra-reliable and low latency communication
V2X	Vehicle-to-“unknown”
VAF	Virtual Application Function
VaP	Value-adding Partnership
VIPS	Virtualization Infrastructure Platform Supplier
VISP	Virtualization Infrastructure Service Provider
VNF	Virtual Network Function
VR	Virtual Reality
VSP	Vertical Service Provider
VSPU	Vertical Service Provisioning User
VSPU CSP	VSPU Communications Service Provider
VSRU	Vertical Service Requesting User
VSRU CSP	VSRU Communications Service Provider
WACC	Weighted Average Cost of Capital
WAN	Wide Area Network

Definitions

Network Slice as a Service (NSaaS) and NSaaS contract

In this deliverable NSaaS is understood as the service offered to the enterprise customer, which in turn make use of the service to serve own end-users or customers, confer 5G-VINNI D3.1 (5G-VINNI Deliverable 3.1, 2019a). In D3.1 this service is also called a Network slice service or Network slice service (instance). In this deliverable a service provided to a specific enterprise customer (instance) according to the NSaaS model is called a NSaaS contract.

Logical network

In this deliverable, we understand that a logical network (service) pertains to the specific NSaaS contract for a specific enterprise customer. A network slice or logical network as offered to an enterprise customer (NSaaS instance) might not map 1:1 to a network slice as operated in the MNO network, as often many instances of the former may be mapped onto an instance of the latter.

Interoperability

In this deliverable, we understand interoperability according to the New European Interoperability Framework (European Commission, 2017b). Interoperability has technical, semantic, organizational and legal sides. Technical interoperability includes e.g. interface specifications. Semantic interoperability is about shared format and meaning of data. Organisational interoperability concerns documenting, integrating or aligning business processes and relevant information exchanged. Legal interoperability is about ensuring that organisations operating under different legal frameworks, policies and strategies are able to work together.

1 Introduction

This document addresses business aspects of 5G. It takes as a starting point that 5G will alter current business models and mechanisms, and the term ecosystem is suggested to capture such market changes. Following this assumption, we have studied how 5G providers may interact with other actors in the market, both with regards to joint innovation and in delivering services. This includes a thorough analysis of actor roles and business relationships in the 5G ecosystem. Based on this, we have started the discussion on 5G business model implications, while implications for the business layer will be elaborated upon in the next project phases. A major share of this document reports a SWOT analyses for the 5G ecosystem as well as suggested innovation potential for verticals. We have also suggested business and economic KPIs for evaluating and monitoring 5G success.

1.1 Objective of this document

This document concerns the 5G-VINNI project objective 5: Develop a viable business and ecosystem model to support the life of the 5G-VINNI facility during and beyond the span of the project. Given that a forward-looking approach is needed, the deliverable D5.1 addresses the following sub-objectives:

- perform business and economic analysis of the 5G ecosystem in general
    - analyse the complex value chain of the 5G ecosystem, including but not limited to precommercial settings
    - identify potential business opportunities, threats, strengths and weaknesses, focussing on the envisioned end-to-end use cases and verticals
- specifying and evaluating business and economic KPIs that complement 5GPPP technical KPIs

1.2 Structure of this document

Section 2 presents the background for 5G-VINNI and motivation for carrying out the analyses.

Section 3 first reviews ecosystem and value networks as business concepts, enabling analyses of the 5G-VINNI facility and 5G as ecosystems. Actor roles in a 5G ecosystem are introduced, from a high-level model with focus on the 5G-VINNI facility, to a general and many-faceted 5G actor role model. By applying the platform ecosystem concept to 5G, the analysis reveals significant business relationships and potential revenue streams. This is followed by a more detailed value network analysis of some 5G scenarios. The section is concluded by some first suggestions on characteristics of business relationships in 5G platform ecosystems, and how the evolution of such relationships affects innovation and growth over time.

Section 4 first reviews the SWOT analyses as a business tool, and then applies it to 5G-VINNI. The project suggests 5G strength, weaknesses, opportunities and threats from MNOs and 5G-VINNI's perspective, and pairs these factors to reveal the strategic room. The foundation to this thorough SWOT analysis is a survey involving vertical actors. The results are presented in the section. The section also describes a method for measuring innovation potential from 5G for different verticals, and applies the method when suggesting specific benefits for a set of verticals.

Finally, Section 5 suggests business and economic KPIs for 5G and the 5G-VINNI facility.

2 Background

2.1 Digital single market

To address the fact that the global economy is rapidly becoming digital, and Information and Communications Technology (ICT) is no longer a specific sector but the foundation of all modern economic systems, the European Commission (EC) adopted the Digital single Market (DSM) strategy (European Commission, 2015).

Through the DSM the EC is set to ensure free movement of goods, persons, services and capital and enable individuals and businesses to seamlessly access and exercise online activities under conditions of fair competition and high level of consumer and personal data protection, irrespective of their nationality or place of residence. The DSM will ensure that Europe maintains its position as a world leader in the digital economy serving a market of over 500 million people and helping European companies grow globally. Completing the DSM can contribute EUR 415 billion per year to Europe's economy. The DSM Strategy is built on three pillars (see also Figure 1):

- Better access for consumers and businesses to online goods and services across Europe
- Creating the right conditions for digital networks and services to flourish
- Maximising the growth potential of our European Digital Economy

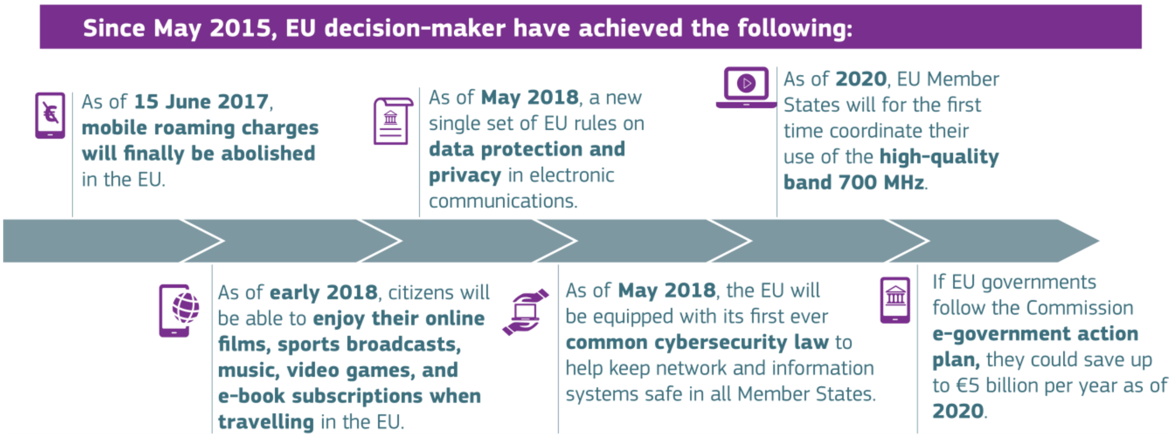

Figure 1: DSM achievements
(European Commission, 2017a)

A study, prepared for the EC (European Commission, 2014), identified four verticals (automotive, healthcare, transport and utilities) and four environments (smart cities, non-urban areas, smart homes and smart workspaces) for its forecast. Figure 2 illustrates the framework to conceptualise the key benefits and impacts from using 5G capabilities in such contexts.

Based on the framework presented in Figure 2 we analyse the expected impact of 5G-VINNI from different perspectives:

- Specific impacts of 5G-VINNI related to the expected impacts in the call ICT-17-2018.
- The impact of 5G-VINNI on the implementation of the 5G for Europe Action Plan (European Commission, 2016a).
- Further impacts, like strategic impact for Europe, commercial/ market impact, scientific and technological impact as well as socio-economic impact.

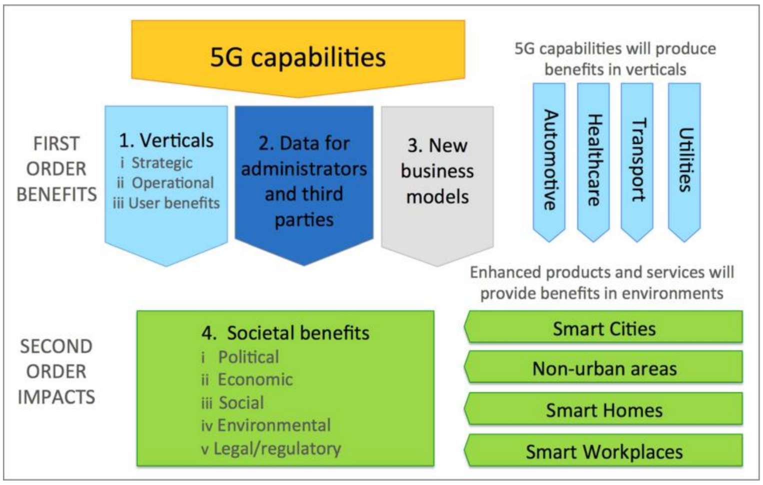

Figure 2: Framework to identify 5G benefits and impacts (European Commission 2014)

5G should cover 60 to 70% of most advanced European countries by 2025. Enhanced mobile broadband will dominate in the early stages of 5G services; however IDATE[1] expects around 15% of connected devices and 25% of IoT connections to rely on 5G. IDATE forecasts that 5G revenues from service subscription should reach €31.7 billion in EU 28 and close to 300 billion EUR worldwide. Figure 3 gives the forecasted number of 5G subscriptions worldwide until 2025 (in billions).

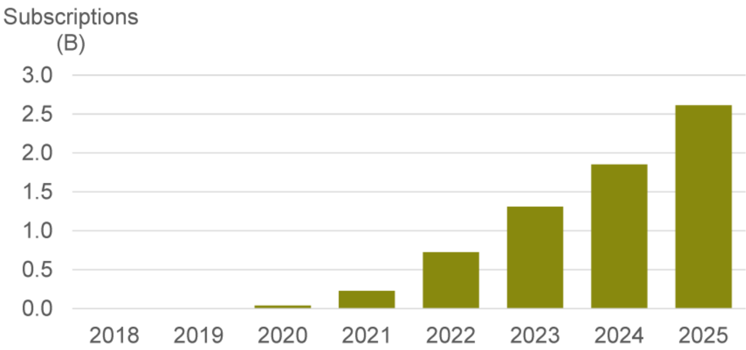

Figure 3: 5G subscription forecasted until 2025[2]

2.2 5G for Europe action plan

5G-VINNI supports and contributes to the 5G Action Plan (European Commission, 2016a; European Commission, 2016b), which sets out an ambitious introduction timeline to enable Europe to take early advantage of the new market opportunities enabled by 5G in the whole economy and society. This action plan sets out a clear roadmap for public and private investment on 5G infrastructure in the EU. To achieve that, the Commission proposes the following measures:

- Align roadmaps and priorities for a coordinated 5G deployment across all EU Member states, targeting early deployment in 2018, and commercial introduction by the end of 2020.
- Make provisional spectrum available for 5G ahead of the 2019 World Radio Communication Conference (WRC-19), to be complemented by additional bands, and work towards a recommended approach for the authorisation of specific 5G spectrum bands above 6GHz.

[1] https://en.idate.org

[2] Figure sourced from CCS Insight, retrieved 28th June 2019, https://www.ccsinsight.com/press/company-news/3240-ccs-insight-predicts-1-billion-users-of-5g-by-2023-with-more-than-half-in-china/

- Promote early deployment in major urban areas and along major transport paths.
- Promote multi-stakeholder trials to turn technological innovation into full business solutions.
- Facilitate an industry-led venture fund in support of 5G-based innovation.
- Unite leading actors in working towards the promotion of global standards.

The following 5G-VINNI actions directly respond to the 5G Action Plan:

- Establish a facility to conduct trials and pilots in Europe. The facility provides the substrate for cross-border trials and experiments leveraging and complementing national efforts to develop and deploy 5G infrastructures.
- National plans for spectrum for testing have been identified and will be leveraged. Participants work with the national authorities to secure the necessary spectrum and comply with the requirements attached thereto.
- Develop and deploy the facility thereby collecting feedback on the progress of the roll-out and the effectiveness of the administrative conditions that are setting the rules for cells' and other infrastructure components' deployments.
- Align with 3GPP timeline for finalisation of Rel. 15 and 16. The work plan is geared towards developing and deploying a 3GPP compliant facility. Support the quality improvement of standards by providing feedback through its participants to 3GPP and other SDOs.
- Respond to verticals' industry requirements through direct engagement of relevant actors in the stakeholder board. Plans to release the facility for external access facilitating pre-commercial trials.
- Test 5G PPP network KPIs, which also meet the requirements of Public Protection and Disaster Relief (PPDR) services.
- Engage large industry participants in the project. The leverage effect of EU funding on private investment in R&D for 5G systems is in the order of 5 to 10 fold according to Euro-5G (Euro-5G, 2016).

2.3 5G PPP program

2.3.1 5G-VINNI creates impact in several areas of importance to the 5G PPP programme

Performance KPIs impact: 5G infrastructures exceed the performance of 4G and LTE for capacity, ubiquity, speed, latency, reliability, density of users, location accuracy, energy efficiency, service creation time, and network management Capital Expenditures (CAPEX)/Operational Expenditures (OPEX). 5G-VINNI will investigate these parameters across the set of applications scenarios.

Impact on innovative radio spectrum use: The planned 5G-VINNI end-to-end facility sites will operate on several frequencies simultaneously. In some of the facility sites, new frequency ranges – such as the 26 GHz band – will be used to experiment with their role in delivering 5G services.

Impact from validation of the end-to-end architecture: The 5G-VINNI E2E facility sites will be based on the evolution of the 5G PPP network architecture as presented in the 5G PPP white paper (see 5GPPP Arch. WP (2017)). This reference architecture contains the key design recommendations identified by the Phase 1 5G PPP projects and is offered as the baseline architecture for the 5G PPP phase 2 and 3 projects. 5G-VINNI will perform architecture validation activities on a representative E2E 5G architecture from a technical and business perspective.

Impact on 5G SDOs and open source: SDOs and open source initiatives are used to facilitate rapid adoption of 5G-VINNI solutions. In 5G-VINNI, multi-stakeholder demonstration, testing and validation of the 3GPP Rel. 15 features will be performed against 5G vertical use case requirements. Through such tests, gaps of Rel. 15 will be identified, followed by requirements and technical proposals delivered for the Network Slicing (e.g., eMBB/URLLC/mMTC) features in 3GPP Rel. 16/17. In particular, 5G-VINNI will validate and optimize multi-slice UE operation in various vertical use cases for Rel. 16/17, which are currently not well covered in Rel. 15. Protocol tuning and optimization (e.g. E2E multi-party testing) will be performed, so that corresponding proposals will be generated for CT WGs for Rel.17. 5G-VINNI will impact the new ETSI ZSM ISG on zero touch networks and service management, as well as a number of open-source communities such as ETSI OSM, OpenBaton, OPNFV, and ONAP amongst others.

Impact from the availability of the 5G-VINNI end to end facility: The approach allows for expansion of the facility in two dimensions: scalability to include more vertical applications from third parties and repeatability to deploy new sites as necessary based on a well-documented procedure. The 5G-VINNI E2E facility is planned to be inclusive, facilitating technology innovations, and innovations around new 5G business models, 5G disruptive applications and the complete value-chain/ecosystem development.

Finally, four (4) facility sites and three (3) experimentation sites will be made available by 5G-VINNI, offering trial and validation possibilities for a variety of use cases and KPIs:

- The Norway facility site has a strong ecosystem of vertical industries such as shipping, logistics and public safety. The facility is expected to remain operational after the project ends.
- The Greece facility site in Patras targets Smart City pilots, scenarios that maximize spectrum usage and scenarios that involve mobility in the city fabric.
- The UK facility at Adastral Park – BT's main research and development centre is a large business park and can therefore support a wide variety of use cases that illustrate 5G services offered over both small and larger geographic scale.
- The Spain facility site will be located at 5TONIC an open innovation laboratory, with the goal of facilitating open collaboration in the development of 5G technologies.
- The Portugal experimentation facility in Aveiro is shared with other 5G-related activities, such as Aveiro 5G City, a joint effort of Altice Labs with the Aveiro Municipality and local academic institutions.
- The Munich experimentation facility site consists of 5G RAN in the city centre of Munich and the core network at the Huawei premises. It facilitates trials for V2X and eHealth use cases.
- The Berlin experimentation facility site provides 5G core, IoT core and functionality related to interworking of orchestrators. It also provides satellite connectivity to the Rapid Response Vehicle (RRV) acting as a mobile experimentation facility site for satellite integration with 5G.

2.4 5G Challenges in the H2020 Work programme

5G-VINNI responds to the challenges described in the H2020 work programme related to 5G by:

- The 5G-VINNI facility sites will be set up to allow and support concurrent use cases and trials under a variety of load conditions to validate realistic usage situations. 5G-VINNI plans to be in the forefront of implementing new 5G solutions and functionality that will enable performances well beyond early 5G trials.
- The 5G-VINNI facility will be set up to support deployment and orchestration of vertical projects' own application functions and provide services to advance the use cases further. The business and ecosystem models addressed by 5G-VINNI will ensure the feasibility of the 5G-VINNI facility as well as helping vertical projects with business layer and ecosystem innovation.
- The business and ecosystem models address by 5G-VINNI will address a multitude of stakeholders and actor roles, including anticipated innovative business roles such as VNF as a Service, VNF Deployment and Operation as a Service, and a variety of 5G vertical ecosystem platform integrators and service providers.
- The 5G-VINNI consortium brings together main industry players in Europe both at the vendor side as well as at the network operator side. The 5G-VINNI partners complement each other

and the objectives and activities will strengthen the industry players both within and outside the consortium, for instance by means of our dissemination and exploitation commitments.

- The 5G-VINNI customer facing E2E service orchestration approach and supporting capabilities will address new business roles and innovation opportunities related to for instance VNF as a Service, VNF Deployment as a Service, and VNF Operation as a Service, Cloud Application Providers, and a variety of 5G vertical ecosystem platform integrators and service providers.
- By putting emphasis on business models and ecosystems 5G-VINNI will analyse how 5G is a part of an ongoing transformation in the telco industry. Based on in-depth insights and anticipated effects of industry transformation 5G-VINNI will ensure that technical requirements are taken into account and anticipate short, medium and longer term business requirements and mechanisms to support innovation and transformation also within vertical sectors.
- The trials and testing campaigns performed by 5G-VINNI or the hosted vertical projects will generate new insights into spectrum usage and policies through relevant and realistic network scenarios.

3 5G value networks and ecosystem

The 5G community has introduced the term ecosystem to signal an expansion of involved parties in 5G value creation and innovation, and new growth[3]. As of now, the authors of this report have the impression that there are many different understandings of what a 5G ecosystem will imply. In this section we examine closely the origins of the term, and other business concepts that aim to capture the systemic nature of the telecommunication industry. Rightly, telecommunication market has been the empirical source and example of market models that are more systemic and networked in nature. The modular and re-composable 5G architecture reinforces its systemic characteristics. Thus, by scrutinizing such concepts and adapting them to 5G use-cases, this section reveals new business relationships and potential revenue streams. This will be the foundation for further business model investigation in the next phases of the project.

In this section we first introduce the basic concepts of value networks and platform ecosystems, and suggest some basic concepts for describing business relationships. Second, we suggest a basic 5G actor role for 5G-VINNI. This is our starting point for a general, still more finely grained model for 5G actor roles using the value network approach. This is followed by an analysis of 5G as a platform ecosystem, which enables us to emphasize important business relationships in a future 5G platform ecosystem. Here we also elaborate on examples of how such business relationships may play out, using the value network as analytic tools. Based on a taxonomy of potential business relationships, we suggest implications for 5G business models and revenue streams. The section is concluded by a first suggestion of the capabilities of business relationships, and how these may evolve over time.

3.1 Ecosystem, value networks and Business Relationship Concepts

Telecommunication technologies and markets are understood to be systemic and networked where components are linked and interdependent in their operation. Telecommunication has been the empirical foundation for developing new business concepts for networked industries (Stabell & Fjeldstad, 1998), and is used as example of ecosystem concepts (Jacobides, Cennamo, & Gawer, 2018) and concepts such as information infrastructures (Hanseth & Lyytinen, 2010).

In recent years, the mobile telecommunication sector and 5G community has adopted the term ecosystem to signal the systemic nature of the technologies and markets, however, rarely referring to existing sources in the field of business management, innovation and technology evolution. The industry uses the term ecosystem in two slightly different ways. Firstly, GSMA and ITU (GSMA, 2019a; ITU, 2018) apply the term mobile ecosystem to broaden the market beyond mobile operators, including for instance device manufacturers, equipment vendors, retail operators, software companies, and organizations in adjacent industry sectors. Also the term 5G ecosystem signals that many types of firms are involved in value creation and capturing (ESOA, u.d.; NGMN, 2015). Secondly, the term ecosystem is used for more specific cases where a platform enables surrounding firms to innovate and create value in order to grow the total market; Apple's App Store is often used as an example of this concept (GSMA, 2019b; 5GPPP, 2017).

In the following we relay on two recognized ecosystem concepts from the business management and innovation literature: a) the value network (Stabell & Fjeldstad, 1998) and b) the platform ecosystem (Gawer & Cusumano, 2014). While both of them capture the complex interdependency of value creation, the former is a more detailed model that usually focuses on a single industry such as telecommunications, utilities, transportation, etc. The latter pays particular attention to composite

[3] E.g. 5GPPP, 2016, 5G - empowering vertical industries; 5GPPP, 2017, 5G - innovation for new business opportunities. Retrieved 28th June 2019: https://5g-ppp.eu/roadmaps/

services enabled by one key market player and supported by several satellite entities that may span several industries. These concepts could be instantiated in the 5G context as follows:

5G value network, introvert view: a 5G ecosystem is a complex network or interconnected system, with focus on how 5G services are provisioned seen from within. Such models reveal the internal complexity of a platform, and hide the complexity of the interaction with customers and external partners.

5G platform ecosystem, extrovert view: a 5G ecosystem is an interconnected system, where the focus is on how one 5G platform interacts with external partners and customers. This can be illustrated as a platform with complementors or a keystone with niches. Here, the model hides the internal complexity of a platform, and reveal the complexity of interactions with customers and external partners that can belong to other industry domains.

The vision of 5G as an ecosystem for certain include the extrovert view, referring to platforms, interdependency with partners, increased innovation, open interfaces and growth. In addition, the new 5G architecture requires that we consider how the internal value network of 5G may be affected. Thus, these approaches can be seen as complementary and both of them will be important to understand the 5G market. At the same time these two views will also affect each other and we will provide an integrated model in Section 3.2.2 that departs from the traditional narrow view of value network concept and borrows ideas from platform ecosystems. In the following we elaborate on both concepts.

3.1.1 Value networks

Organisations are naturally related to each other. They are dependent on each other's production, distribution, use of goods and services. They have direct relationships with customers, distributors, suppliers and even competitors, and indirect relations with all suppliers, customers, competitors and other stakeholders. These relationships are important because in today's world it is rare to have firms that can exist as self-supporting businesses. Partnerships may reduce transaction costs of individual organisations, develop further their core competencies, help them reach broader audience, increase the value taking advantage of the synergies between the consortium members, share risks and promote development of knowledge. That is why firms need to establish and develop sustainable cooperation, alliances and possibly joint ventures to guarantee the quality and quantity of goods and services exchanged and the demanding response times.

As will be shortly described, organisations are moving from linear and omnidirectional models to multi-directional and more complex structures. For example, money flows may not always flow in the opposite way of the related product/service, as advertisers can subsidise the customer's experience in exchange of end-users' personal data. Furthermore, value proposition to end-user can be increased by considering additional complementary activities from strategic partners and influencers, or even substitute ones by competitors. In this subsection we will briefly describe this research strand that led to the value network concept.

Earlier management theory tried to explain how disruptive innovation happens from the individual organisation's perspective, for example by examining its resources, or management and leadership, as possible causes for success or failure. As will be described in the following, the literature gradually have put more emphasis on the environment (e.g., end-users' requirements or the behaviour of suppliers, strategic partners, competitors and organisations from adjacent industries) in order to identify new business opportunities for collaborative value creation.

Understanding how innovation takes place is important for profit and non-profit organisations alike. The former are interested in creating value in ways that differentiate them from competitors and develop core competencies effectively and faster than rivals. The latter, even though they do not aim at generating value surplus (e.g. new products) per se, they can seek innovative ways to fine-tune their operations for improving effectiveness and efficiency. Furthermore, having a visual representation of intra and inter organisational relationships is useful for communicating the vision internally (e.g., new employees) and externally (e.g., investors).

In particular, starting with descriptive analysis of the current state, which provides insight and contribution to our understanding of inter-organizational relationships, they are moving to prescriptive analysis to optimize outcomes during the supply chain planning and execution phases. The role of descriptive analysis is to estimate the sensitivity of key performance indicators, like profitability or volumes sales, to different assumptions about external aspects (such as customers' willingness to pay for existing offerings, suppliers' price dynamics). Similarly, prescriptive analysis focuses on a set of candidate future scenarios and aims to find the proper aggregate of activities that a company should internalise in order to maximize its value proposition towards the end consumers (and usually its share of profits). This is done by exploring how external aspects will have evolved in each of the future scenarios and eventually their impact on the performance of the actor. The activities selected will eventually define the business model of the organization and suggest the mutual agreements that should be in place. For example, descriptive and prescriptive analyses could suggest that Mobile Network Operators should a) build interoperable systems, b) enable the creation of a large market by exposing interfaces to other actors and c) build trustworthy relationships with other actors by asking a fair share of the revenues.

In 1985, Porter used the term "value chain" for the value producing activities of one organisation (Porter, 1985). In his model a firm is disaggregated into its strategically relevant activities, so that the behaviour of cost and the existing and potential sources of differentiation can be understood. While Porter's main objective has been analysing individual firms, he explicitly recognised the need to consider value creation more broadly. Indeed, Porter defined "value system" as a set of consecutive activities, where each actor adds successively value to the product. All these activities are interrelated and there exists linkages between value activities within a firm's own value chain but also between value chains in the value system.

A rather standard value system is the "value stream" (Brown, 2009), where organisations (and their core competencies) are horizontally connected with each other. In such a stream, raw materials (including information, resources) are formed into single components that are assembled into final products, distributed, sold to end-users and maybe serviced. Each firm provides what they can do best and deliver it to the next organisation in the stream, while money flows in the opposite direction. Furthermore, a single organisation can participate in multiple steps, or even in all of them. Thus, the value stream can be defined as the processes of creating, producing, and delivering an offering and may be controlled by a single entity or a network of organisations. A special case of the value chain concept, named "Value-adding Partnership" (VaP) has been defined, where the main difference is that organisations form a coalition whose total profits are shared in a fair manner and that they trust each other (Johnston & Lawrence, 1988). The value stream concept (or "broader value chain") when applied to entities, like lawyers, physicians, and consultants, who deliver a customer service in a iterative manner, has been described as "value shop" (Stabell & Fjeldstad, 1998). The main difference to the previous concepts is that a recurring cycle of activities (i.e., analysis, action, and evaluation) may be required for value to be delivered (for example when a management consultant has identified the most promising business model). We will come back to this aspect in Section 3.2.3 where the innovation and operation phases will be defined.

This next concept, called "value grid", emerged by noticing the entire economy can be viewed as the superset of all value streams (Pil & Holweg, 2006). The grid approach allows companies to move beyond traditional linear thinking and industry lines and map out novel opportunities and threats. Thus, we move from linear graphs to more complex networks.

Interestingly, the notion of "value network" was described to be composed of "nodes or positions (occupied by firms, households, strategic business units inside a diversified concern, trade associations and other types of organizations) and links manifested by interaction between the positions" (Thorelli, 1986). Since then several researchers gave their definition of what constitutes a value network. Probably the first official definition of a value network is attributed to Christensen (1997) as the: "context within which a firm competes and solves customers' problems". A value network is defined as: "complex dynamic value exchanges between one or more enterprises, its customers, suppliers, strategic partners and the community" (Allee, 1999). She also stressed that the value flows in general are not simply one directional, but are interwoven, interdependent and multi-directional and highlighted the existence of non-monetary exchanges of knowledge and benefits within a value network.

Furthermore, several concepts that are closely related to the value networks were proposed, such as "Networks and organizations", "Strategic alliances", "Value constellation", "Strategic networks" and "Business ecosystems". The latter model stresses the interdependency of a single entity's success with the success of the rest organisations.

Table 1 summarises the key strategic management models and concepts and their differences based on desk research performed by 5G-VINNI members. We observe that most of the approaches deal with multiple organisations that belong to a single business domain and assume sequential customer-provider relationships. The "Value network" concept is a notable exception as it involves multiple organisations connected in arbitrary ways and operating in multiple domains. This is why we believe that this modelling framework is suitable for analysing the 5G ecosystem.

Table 1: A 5G-VINNI taxonomy of key strategic management models (source 5G-VINNI elaboration)

	Number of organisations interacting	Number of business domains / industries / markets	Type of relationships
(internal) value chain (Porter, 1985)	1	1	Sequential
value system (Porter, 1985)	N	1	Sequential
Value stream	N	1	Sequential
Value-adding Partnership	N	1	Sequential
Value shop	N	1	Sequential, but with several iterations
Value grid	N	M	Sequential (for each domain)
Value network	N	Typically 1 (but can be extended to multiple domains)	Arbitrary/mesh

Given the complexity of the existing or foreseen real world relationships, including all relevant activities and exchanged outputs will probably result in a "spaghetti" diagram that is hard to read. Figure 4 illustrates a value network for the smart grid domain (Rafael, Thanos, Kanakakis, Fearnley, 2019). The complexity is high even though key functionalities are grouped into roles (the blue boxes) and several supporting steps/roles (such as Communications providers like Communications Service Providers and Financial institutions like banks) were omitted.

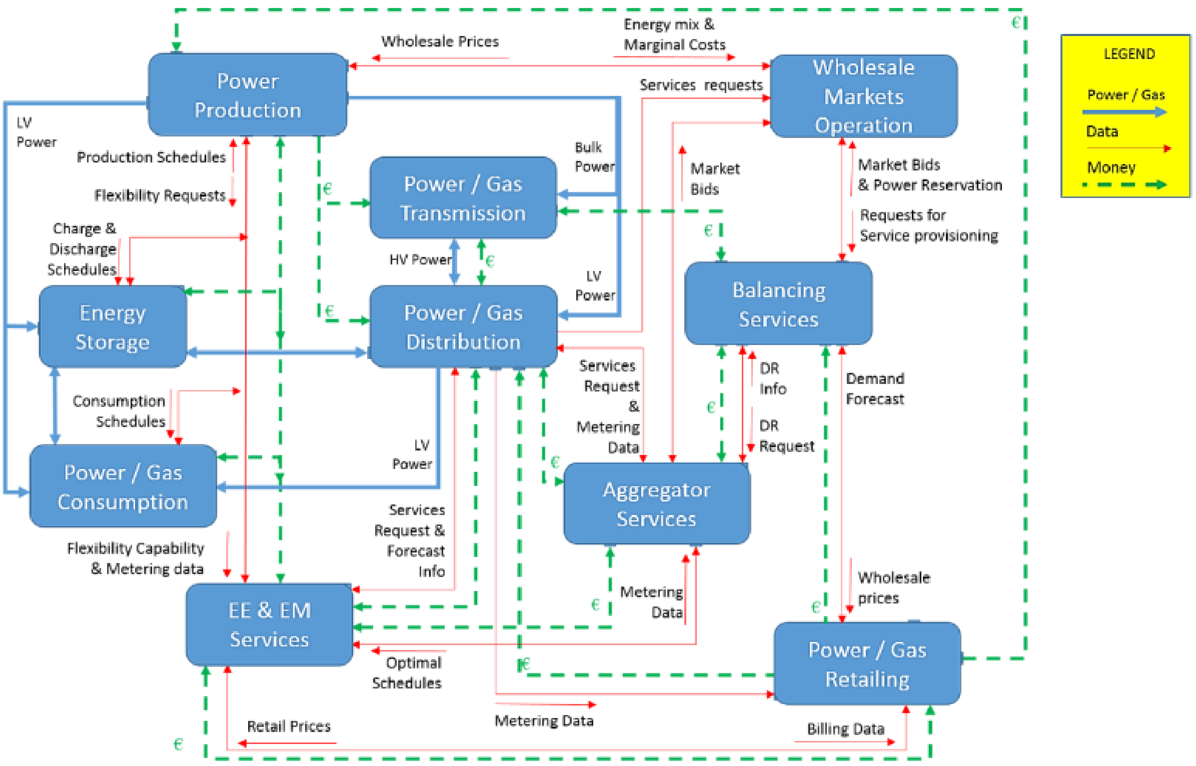

Figure 4: An example of a value network for the energy domain that demonstrates the level of detail that is usually sought after by market analysts

Thus depending on the purpose and scope of the analysis, some activities may be aggregated, represented with less detail, or even omitted. In general, activities should be:

- Separate or detailed enough, to enable choices on what to do internally, externally or together with collaborators.
- Focused on the important ones to improve readability.

3.1.2 Platform ecosystems

Historically the term "Digital Business Ecosystem" was introduced to describe self-organizing business communities that leverage Information and Communication Technologies (ICT) to achieve the grand challenges (growth, job, inclusion) as of the Lisbon Strategy[4]. This resembles the technological innovation systems perspective (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; Hekkert, Suurs, Negro, Kuhlman, & Smits, 2007) which explains socio-technical structures and processes for technology diffusion.

At the core of these understandings is the interdependence between actors and processes in a system, and how positive self-reinforcing effects drive the evolution of technologies. The non-technical aspects of technology diffusion that are emphasized are such as knowledge building and sharing, legitimation and institutions, incentives for experimenting, and for financial gains. Together with technological factors such as standards, these processes may take technology evolution into one path. The notion of self-organising points at the challenges with managing or controlling an ecosystem by one actor, however, it is still suggested that it is possible to manoeuvre strategically in such systems. Jacobides et al. (2018) have elaborated on ecosystem theory, and suggested

[4] Confer the Information Resource about the European approach on Digital Ecosystems, http://www.digital-ecosystems.org/

ecosystems are correlated to technologies that are modular and interdependent, implying complementarities in consumption and production. That is, the value in consumption is higher and increasing when technological modules are used together; likewise production and quality of modules are mutually dependent. 5G is used as an example of as a technology which has the characteristics that could lead to a market with ecosystem characteristics.

Relying on the same dynamics as described above, the platform ecosystem is a concept where the technology already has taken a certain path and a platform has become a centre for innovation and delivery in the ecosystem. A definition of a platform in an ecosystem is “products, services, or technologies developed by one or more firms, and which serve as foundations upon which a larger number of firms can build further complementary innovations and potentially generate network effects” (Gawer & Cusumano, 2014). There are two main takeaways from this. First, many complementing firms are engaged and enabled to invest in and carry out the innovation activities in the market. Second, because the focal firm is dependent on other complementing firms and technologies this is the only way to spur high growth in the market. Thus, to share the total revenues across the market is necessary; the platform has to aim for growth through its share of a bigger cake. To succeed with building such a market is not only a question of technological complementarity. Drawing on advices from the concepts of platform ecosystem (Gawer & Cusumano, 2014) and technological innovation systems (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008), successful growth is dependent on the building of legitimacy, ability to experiment, and sharing of risks, revenues, and knowledge.

The firms who build complementary innovations to a platform, often called complementors, are not the final customer in the ecosystem. Complementors are all those other firms which the platform is dependent on in innovation and operation; only together do they provide a complete service. In the case of advanced ICT-solutions firms are typically providing: system integration, consulting, software, data hosting (data centres), cloud services, devices, and sensors. If we assume that the 5G is the platform, all these types of firms would be complementors. It is also possible to define software or hosting service as a platform, and all other actor roles as complementors. We would even suggest that vertical specific platforms could evolve within vertical domains, for instance in the automation sector. However, in our case, we discuss 5G as the platform.

At the core of an ecosystem and systemic innovation is uncertainty and inability to control and plan it. On the other hand, actors can still be assigned with at least the intention to strategically manage an ecosystem. In our approach, we assume that an actor, for instance a 5G platform provider, acts strategically however under high degree of uncertainty. Thus, providers can aim to position build an ecosystem and position as platform provider. One example of such strategies is how GSMA (2019b) suggests that a financial service ecosystem could grow around a mobile money platform.

The next subsection elaborates on the business model concept and introduces related terms such as actors and stakeholders.

3.1.3 Business Modelling Concepts

This section proposes business modelling concepts that enable the definition of business models and their association to actor roles. We do this by defining relevant terms and how these terms shall be used to describe the business roles/actor roles and business models. It contributes to helping the determination of:

- who the stakeholders are,
- who the actors are,
- which actor roles each actor plays, and
- how trust relationships among stakeholders/actors are.

This is important as refinement of the network slice requirements currently found in TS 22.261 (ETSI TS 22.261, 2018) and may be discerned from considering the business role models that will apply with slicing. Business role/actor role models used in previous generations were centered on the relationships between MNOs and their subscribers as well as between MNOs (e.g., roaming, RAN sharing). The concept of network slices introduces the possibility to support additional new business role models in 5G, including models supporting multi-tenancy, vertical markets, and service optimization.

3.1.3.1 Actor roles motivation and separation

There are mainly three reasons for actor role separation:

- Economic: Actors which are considered users and producers of services could be assigned to different actor roles
- Technical: 1) areas of different development speed of technology could be placed in different business/actor roles; 2) technical interfaces are different from business/actor roles and should be kept apart, and; 3) technology can trigger the creation of new business/actor roles or render existing ones obsolete
- Regulatory: regulatory constraints mat lead to certain separations of business/actor roles

The duality of the *user/provider* concept pair is maintained for the description of the relationship between the business/actor roles. A *contract* governs the *user/provider* relationship.

The following concepts are used in the remainder of the section:

- *Stakeholder:* A party that holds an interest or concern in the 5G ecosystem.
- *Actor:* A party or business administrative domain that either consumes services or contributes to the service provisioning.
- *Actor role:* A well-defined function. An actor may hold several actor roles/business roles, while an actor role can be adopted by several actor instances.
- *Business relationship:* An association between two actor roles or their instances.
- *Contract:* The context defining constraints for one or more interfaces to operate under. The legal document that governs the relationship between two actors/business administrative domains.
- *Interface (Reference Point):* The manifestation of a business relationship in the telecommunications system. An interface consists of several related specifications governed by a contract.

3.1.3.2 Identification of interfaces (reference points)

Communication services are realised with a set of complementary functions. Each function is atomic and could be offered by a single actor. The concept can be used in a virtualised or non-virtualised context. In the context of 5G, such an atomic network function will usually refer to a VNF (Virtual Network Function).

The separation of actor roles and a clear definition of network function responsibilities enable the functional modularisation of the architecture. Even more, it could imply that the functional modularisation of the architecture should be defined by business models.

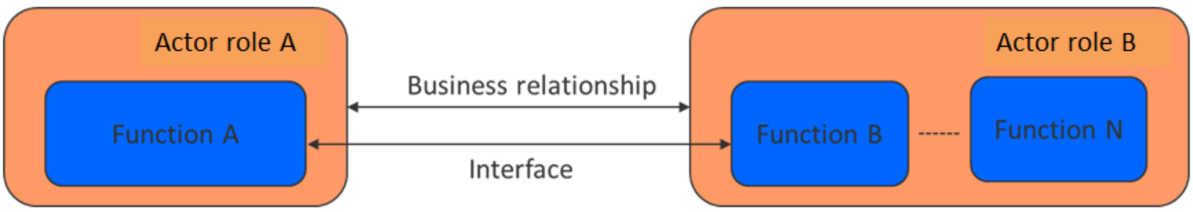

Figure 5: Identification of interfaces

Figure 5 illustrates two business roles, A and B, whereas actor role A provides Function A (e.g. VNF A) and actor role B provides other functions, such as Function B … Function N. A technical interface can be identified between Function A and Function B (also called reference point) that allows the exchange of information between the two functions. The information flow is depending on the user/provider assignment of the functions.

The interface is the manifestation of the business relationship between actor role A and actor role B. In Figure 5 the actor roles are independent of the actors /administrative domains being present in the ecosystem (see next sub-section).

3.1.3.3 Mapping of business roles to business administrative domains

Figure 6 shows the relationship between business administrative domains/actors and business roles.

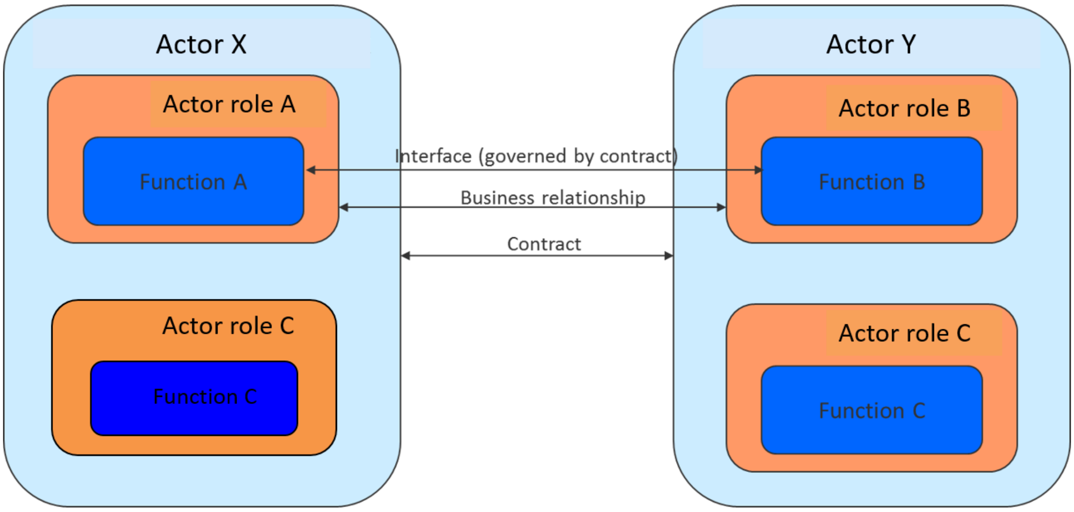

Figure 6: Mapping of business roles to business administrative domains

In particular the following relationships apply:

- Each actor role is performed by one or more administrative domains/actors. For example Actor role C (e.g., Network Service Provisioning) is shown to be taken by both Actors X and Y.
- Each actor, such as X, can assume one or more actor roles for instance roles A and C.
- A contract exists between actors (e.g., network operators)
- The contract governs the business relationship and the technical interfaces between the functions performed by the actor roles that are assumed by the actors

3.1.3.4 Usage of Services

One of the actors will offer service usage to the customer which will be realized as a reference point to the application. Figure 7 expands on the previous concepts and includes a third actor (Z) running an (application) function D, which through a technical interface consumes the services of Function B (offered by actor Y assuming the actor role B).

Note that the technical interface of Function B (assuming a provider role for Function B) may be the same as that provided:

- to Function A, which lies in the foreign business administrative domain X, or
- to Function C, which is owned by the same business administrative domain Y as Function B, but in the context of a different business role C, as well as
- to the function D

In its manifestation as an intra-actor reference point (between Function B and C), it is not governed by any contract, yet it is a useful conformance point regardless of whether it is used inter-domain or intra-domain.

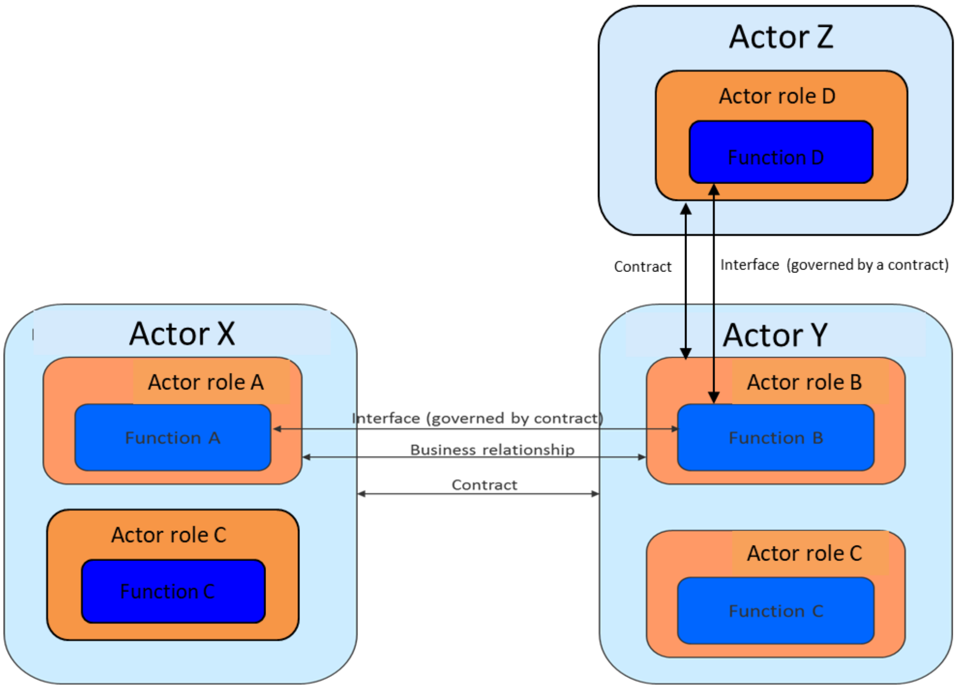

Figure 7: Usage of services

3.1.4 Summary concepts

While both value network and platform ecosystem methodologies are focusing on analysing the relationships that take place in a certain context, these typically differ on the level of detail and the ecosystem structure (i.e., the presence of a central role). Furthermore, key concepts, such as functions, actor roles, business models and stakeholders, were defined in order to clarify the relationships/interfaces between technical roles, business roles/actor roles, business models and the entities that have a vested interest.

In the following we define two actor role models of varying complexity; a simple one that is suited for 5G test-beds (such as the 5G-VINNI) whose purpose is pre-commercial validation of 5G technologies deployed and managed by a limited set of stakeholders. We also define a detailed model for the 5G ecosystem in general where a large set of stakeholders interact in the delivery of advanced network services to vertical industries. These actor role models will help us in identifying and analysing abstract 5G business models.

3.2 5G actor role models

This section introduces different sets of 5G ecosystem actor role models. These models will reveal different important business relationships with different implications for revenues streams and business layers. First, we suggest an actor role model to 5G-VINNI. Second, we elaborate on a general actor role model for 5G. Third, we elaborate on actor roles seeing 5G as a platform ecosystem. This allows us to suggest three families of important business relationships.

3.2.1 An actor role model for 5G-VINNI

This section aims to identify the actor roles that we can consider in the environment of the 5G-VINNI experimental facility, building on the models already suggested in the literature (see Annex A.1 for more details), and taking into account four main concrete aspects related to the nature of this environment. First and foremost, the fact that during the project lifetime 5G-VINNI will not be an operating 5G network infrastructure, but an environment for experimentation and measurement by vertical industries. As a direct consequence of the former, we must not forget the services provided by the experimental facility are different from the longer-term ones foreseen for a running 5G network infrastructure. In the former case, the services offered fulfil customer goals related to the measurement and validation of ICT solutions under varying network conditions rather than continuous and reliable communication services: for example, consider that service consumers will be allowed to request measurements suitable to interfere network operation, or that service providers are expected to cause intentional service disruptions to enable the validation of recovery mechanisms. In the latter case, the long-term communication services and accompanied support for Service Level Agreements (SLAs) offered after 5G-VINNI has completed and for at least one year, shall allow enterprise customers to perform business trials with actual users if they so desire[5]. In consequence, the types of the potential business roles and opportunities differ, according to the essential goals of the facility, and how these are fulfilled. Finally, the service model defined for the 5G-VINNI facility (5G-VINNI Deliverable 3.1, 2019a) implies the provision of network slices, spanning one or more sites, as the service unit to be delivered to customers.

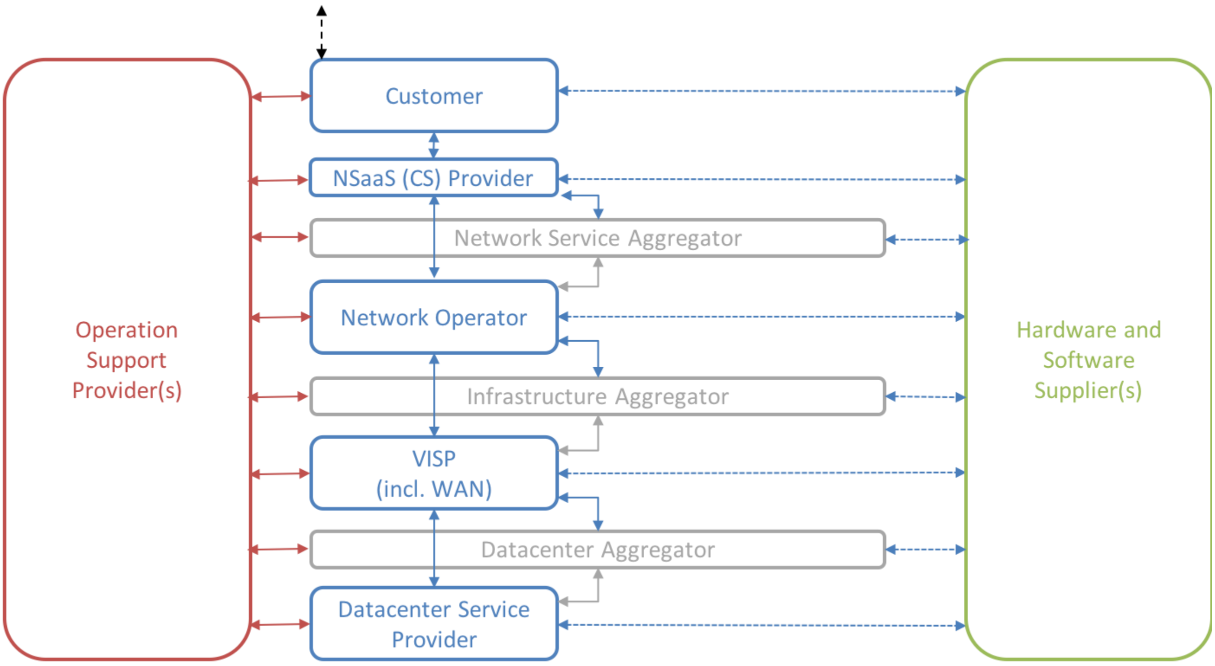

Figure 8: The actor role model for the 5G-VINNI facility services. The main actor roles and relationship in 5G-VINNI are depicted in blue. Other actor roles are assumed to be ancillary

The proposed 5G-VINNI actor role model is derived from the 3GPP model (3GPP TR28.801, see Annex A.1 for a detailed description), incorporating the considerations made there and the constraints discussed above, translated into the general diagram shown in Figure 8, and discussed in the rest of this section. These roles are generic enough to be applicable to any 5G experimentation facility[6], and even to any experimentation service dealing with advance networking services of practically any nature.

First of all, the diagram includes a number of ancillary roles, relevant for the provisioning of services but not considered part of the core of the 5G-VINNI ecosystems. They are related with supply, support and aggregation activities.

[5] More details about the short vs long term services and how these are mapped to different releases of 5G-VINNI appear in Section 4.1.

[6] This concrete model is focused on the relationships between the actors within the 5G-VINNI environment, i.e. not including for instance third parties. Confer the next sections for more general models.

- Suppliers of all hardware and software required for running the 5G-VINNI infrastructures and the experiments on it are grouped into a single, general role to abstract all the potential vertical and transversal relationships among them and with the different core roles. This abstraction is intended to acknowledge suppliers is key for actual experiment running, but this does not imply additional business models beyond the reliance of each of core roles on them. 3GPP identifies three individual supplier roles, namely Network Equipment Provider, NFVI Supplier and Hardware Supplier.
- A similar abstraction has been applied to the concept of operation supporters, a role identified in some earlier projects (5GEx Deliverable 2.1, 2016) and essential in our view in any realistic network service provisioning scenario. These supporters would be, in many cases, connected to the suppliers discussed above, and focused on the integration and control of specialized elements. Their role can be considered instrumental in all those cases where such elements are key to the execution of the experiments.
- The role of aggregators has been identified by recent projects exploring slice-based service provisioning (for more details see Annexes A.2 and A.3) and it is essential for considering federation schemas, especially when federated services are provided by the aggregator themselves to consumers, abstracting the individual services of the federation components. The diagram depicts aggregator roles above all core roles, with the exception of the top one, directly connected to customers. While nothing precludes in principle a customer to take an aggregator role by itself, it would be beyond the 5G-VINNI scope. Finally, it is worth noting that the aggregator roles at the different roles allow for different levels of collaboration among the 5G-VINNI sites and the integration of external infrastructures, in addition to the top-level service integration supported by the slice federation mechanisms discussed in Section 3.2.3.

The core roles basically correspond to the stack of roles in the 3GPP diagram, though certain aspects have to be examined to clarify their precise implications in an experimentation facility like 5G-VINNI:

- Data centre service providers (or Data Centre Service Provider according to 3GPP TR28.801) can be of any nature, from the so-called public cloud infrastructures to highly-specialized sites focused on a particular sector or network segment. The multi-site, multi-cloud capability of current network orchestration platforms allows for an implicit aggregation without a concrete entity playing that role.
- The virtualization infrastructure service provider (VISP) role is equivalent to the Virtualization Infrastructure Service Provider (3GPP TR28.801), adjusted to include the provisioning of data forwarding services across WAN infrastructures (what is usually referred as transport services in 3GPP documents) as these cannot be considered out of the scope of experimentation services. Following the current trend in standardization regarding the necessary convergence of NFV and SDN techniques, and the consolidation of intent-based interfaces, all network infrastructural services are considered with a common role providing general orchestration services.
- The term Network Operator has been kept for maintaining consistency with the 3GPP terminology, though it should be clear that a network operator in the 5G-VINNI context is associated to a site operator, exposing the experimentation services for a particular site, either aggregated or not through supporting aggregator layer(s).
- The communication services provided by 5G-VINNI are network slices, provided as a service, for experimentation. These services are offered by Communications Service Providers in full conformance with 3GPP 5G actor role model (3GPP TR28.801). The model does not assume a single communication service provider in the 5G-VINNI facility, so this role can be played by

one or several centralized or localized sites of any nature, though some kind of common or per-site portal seems the most likely instantiation of this role.

- To conclude, Communication Service Customers (3GPP TR28.801), or simply customers, are expected to focus on measurement and evaluation rather than on general network service consumption, and therefore their requirements in terms of types of service and SLAs will differ from the usual practice in network service provisioning, though they will likely include direct references to those common types and SLAs.

3.2.2 A general actor role model for 5G

This section aims to identify the actor roles emerging on the 5G ecosystem in general, rather than to 5G-VINNI (or any other 5G experimentation facility) that focuses on validating the technical feasibility of the proposed solutions to meet verticals' requirements. We argue that in order to validate the business potential of 5G experimentation-as-a-service offer, business trials and pilots with actual users, need to be considered. Furthermore, the collaboration of some satellite actor roles need to be secured. For example, mobile network operators (MNOs) are requesting access to lampposts and other tall structures in cities in order to deploy a dense network of base stations (McKinsey, 2018). This suggests that a broader view in terms of actor roles and their relationships is needed compared to the actor role model presented in subsection 3.2.1.

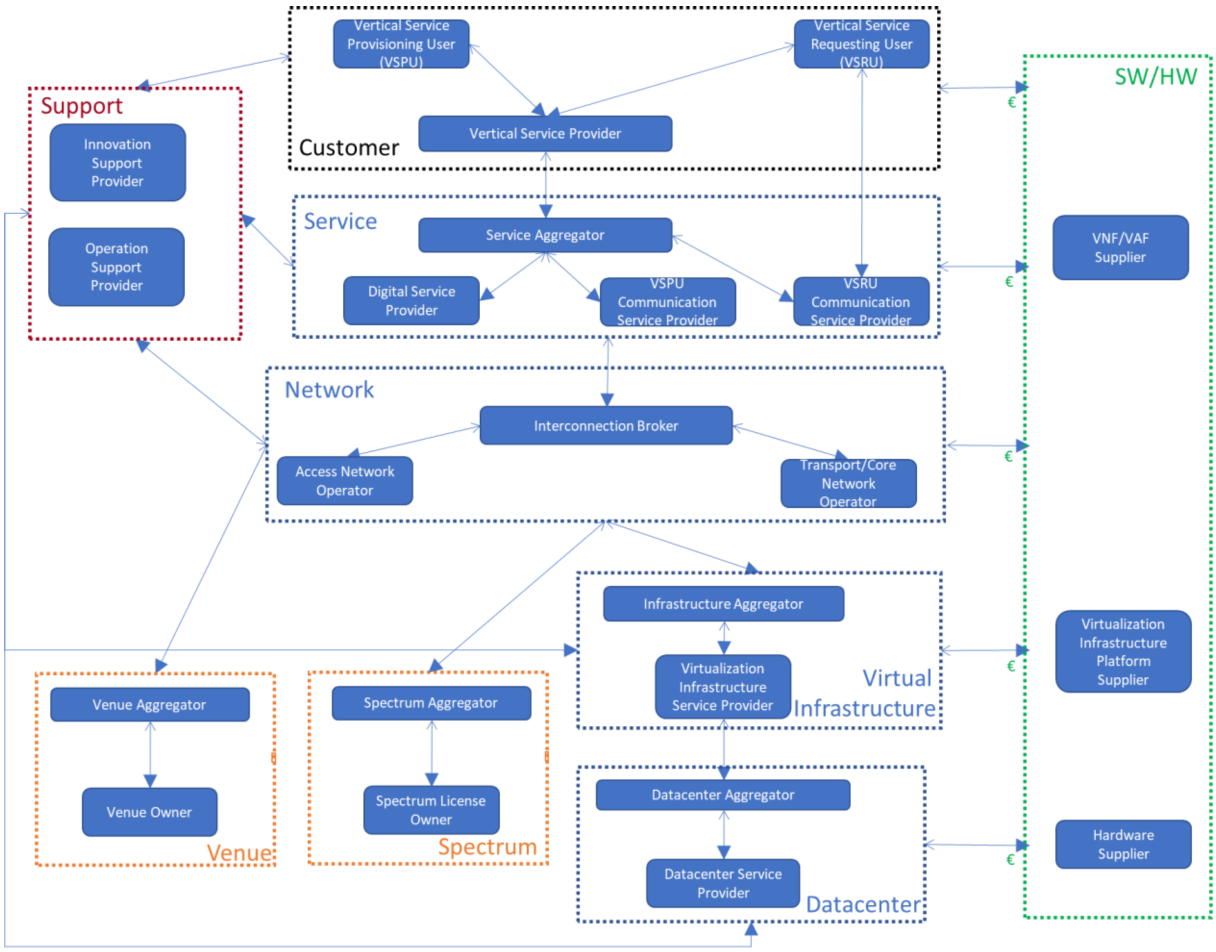

Figure 9: The general actor role model for 5G ecosystems

Figure 9 presents an actor role model for the 5G ecosystem that is inspired by 3GPP (3GPP TR 28.801). 5GEx and SLICENET have defined a number of actor roles and their client-provider relationships (see A.2 and A.3).

For better readability, roles (blue boxes) are grouped into “role clusters” and represented by dotted boxes of several colours. Blue lines represent relationships in general. Solid arrows refer to money, while open arrows refer to products, service outcomes, data, etc.

These roles are:

- Vertical Service Provider (VSP), which represents a vertical company/organisation that buys the required communication and application services (i.e., vertical service) and allows qualified users to have access to this service according to the policies. Thus this role is disconnected from the role of Vertical Service Users (either those provisioning or requesting). In the most common scenario this role is adopted by an SME doing business on a specific vertical, a large service provider that offers online application services, or even an end-user. This role is also commonly referred to as tenant (5GPPP Arch. WP., 2017).
- Vertical Service Provisioning User (VSPU), which refers to those consuming the resources of a vertical service in order to facilitate this service. This role is envisaged to be played by actors (or devices) that belong to the Vertical Service Provider (VSP), such as employees, servers, sensors, etc.
- Vertical Service Requesting User (VSRU), which refers to those consuming a vertical service because they find it valuable (i.e., a customer), or even to facilitate this service (e.g., a subcontractor). In other words the Vertical Service Requesting User (VSRU) and Vertical Service Provisioning User (VSPU) are the two (or more) end-nodes that need to communicate. This is similar to the caller (the one who starts a phone conversation) and the callee (the recipient). The main difference from the Vertical Service Provisioning User (VSPU) role is that members of this role need to have a contract with the Vertical Service Provider (VSP).
- VSPU Communications Service Provider (VSPU CSP), which offer communications services through own/leased[7]/brokered network to a VSPU (according to its contract with the VSP).
- VSRU Communications Service Provider (VSRU CSP), which offer communications services to a VSRU. The reason for distinguishing this role from the VSPU CSP is that different users can choose different communications providers for their everyday communication needs (calls, Internet access, etc.). We will be using the term CSP in the following subsections when referring to any of these instances. In general, a communication service can be considered either as B2C, B2B or B2B2X.
    - B2C (business to consumer) communications services refer mostly to services offered by a vertically integrated provider toward end users (VSRUs/VSPUs), e.g. mobile data, voice and messaging.
    - B2B (business to business) communication services are offered to enterprises, e.g. an uLLC slice connecting a factory with a remote operations centre.
    - B2B2X (business to business to “undefined”) communication services refer to services offered to other CSPs (e.g. Roaming, RAN sharing). While B2C and B2B services are expected to be rare in the future due to regulatory conditions, competition from rival companies or cost efficiencies due to collaboration, B2B2X is more representative of the complex value networks already present today.
- Digital Service Provider (DSP) or Over-The-Top (OTT) Service Providers, which offer online application/information services to VSPs. These services are specific to vertical industries, such as transportation, entertainment, eHealth, public safety, etc. For example, a company

[7] E.g. Virtual Mobile Network Operators who do not have their own billing system.

offering a real-time video analysis service that utilises Artificial Intelligence (AI) techniques for identifying public safety incidents would fall into this category. In the example above the Vertical Service Provider would be a Public Safety organisation, such police. Similarly to communication services, application services can be B2C, B2B or B2B2X. An example of the last case is Vertical Service Providers and Service Aggregators (see below).

- Service Aggregator (SA) or System Integrator, who bundles several communication and application services and sell these to customers (or intermediaries). An example of the last case is a OTT Service Provider that integrates communication services (e.g. mMTC slices in order to connect a large set of IoT sensors) and application services for analysing data collected and resells as an integrated, value-added service.
- Access Network Operator, who designs, builds and operates a network (e.g., a Radio Access network - RAN) for offering Layer 2 or Layer 3 services to CSPs and their serviced users. Furthermore, instances of this role can expose functionality via Application Programming Interfaces (APIs) to other trusted entities (i.e., complementors) for network monitoring, traffic shaping etc. in real time. This network programmability is key for SAs to build innovative systems that suit the communication needs of vertical industries, as well as for Interconnection Brokers (see below) to provide end-to-end connectivity and Operation Support Providers (see below) for analysing run-time performance.
- Transport/Core/Backbone Network Operator, who builds and operates a backbone network interconnecting remote access networks together, as well as, with the rest of the Internet. Members of this role can expose functionality to complementors, also.
- Interconnection Broker, who has agreements with other Network Operators (either Access or Transport/Core) and offers end-to-end connectivity when more than one CSPs need to interact. This entity is also known as the customer-facing provider (5GEx Deliverable 2.1, 2016). Network Operators (Access or not) are well positioned to take on this role and we expect that such instances could enable the 5G platform ecosystem that will be further described and motivated in Section 3.3.4. Nevertheless, independent third parties running BSS/OSS (or non-operators) can act as customer-facing providers.
- VNF/VAF Supplier, who provide virtual network functions (such as vCPE, vEPC, vRAN, VoLTE, vADC, vRouter) as well as virtual application functions (like Video Traffic Manager, etc.).
- Virtualization Infrastructure Service Provider (VISP), which provides virtualized infrastructure services. Designs, builds and operates its virtualization infrastructure(s). Virtualization Infrastructure Service Providers may also offer their virtualized infrastructure services to other types of customers including to Communication Service Providers directly, i.e. without going through the Network Operator. VISP offer virtualization infrastructure services ranging from multi-purpose VMs/Containers to complete virtualized infrastructure management solutions on compute, storage, network, IoT, etc.
- Virtualization Infrastructure Platform Supplier (VIPS), who supplies network function virtualization infrastructure to its customers.
- Infrastructure Aggregator, who aggregates virtualized infrastructure services from multiple providers.
- Data Centre Service Provider that invests in Computing, Storage, Networking or IoT resources for using locally or making these available to other members of the ecosystem.
- Data Centre Aggregator, who aggregates physical infrastructure and associated services from multiple Data Centre Service Providers.

- Hardware Supplier, who supply hardware, such as Common-of-the-shelf (COTS) servers, IoT sensors, etc.
- Venue Owner, who manages the venue where an infrastructure (such as base stations) needs to be established.
- Venue Aggregator, who has business relationships with several venue owners and simplify the process of finding the appropriate locations for deploying infrastructure.
- Spectrum License Owner, who has the right to use or resell the spectrum that she was awarded (most probably by means of market forces).
- Spectrum Aggregator, who has business relationships with several Spectrum License Owners in order to share spectrum more cost efficiently or, even, more flexibly (e.g., on demand).
- Innovation Support Provider, who offers technical, behavioural, economic, and legal consultancy services to several actor roles in order to adopt 5G technologies and services, e.g., assist during the on-boarding and integration process of a certain slice, performing stress tests before service roll-out.
- Operation Support Provider, who offers highly-focused ancillary operational services such as monitoring service performance and conformance to Service Level Agreement (SLA) terms.

While the two actor role models defined serve different purposes, the one on 5G-VINNI focuses on the architectural implications while the generic one pays attention to future business relationships in the 5G ecosystem. Nevertheless, one can draw parallels between the actor role model for 5G experimental facilities (such as 5G-VINNI) and the broader one for the 5G ecosystem. In particular all roles present in the 5G-VINNI actor role model appear on the generic one, albeit not always with the exact same name. For example, the following roles appear verbatim: “Datacenter service provider”, “Datacenter aggregator”, “Infrastructure aggregator” and “Operation Support Provider”. While trying to reuse names as much as possible, some “5G-VINNI” actor roles were broken down into more detailed ones. Table 2 provides a mapping between the actor roles whose names differ.

Table 2: Mapping the actor roles between the 5G-VINNI and general 5G models

5G-VINNI actor role name	5G actor role name
VISP	Virtualization Infrastructure Service Provider
Network Operator	Access Network Operator, Transport/Core/ Backbone Network Operator
Network Service Aggregator	Interconnection Broker
NSaaS (CS) Provider	VSPU Communication Service Provider, VSRU Communication Service Provider
Customer	Vertical Service Provider
Hardware and Software Providers	VNF/VAF Supplier Virtualization Infrastructure Platform Supplier Hardware Supplier

Furthermore, the following roles were introduced for completeness:

- Venue Owner
- Venue Aggregator
- Spectrum License Owner
- Spectrum Aggregator

- Digital Service Provider
- Service Aggregator
- Vertical Service Provisioning User (VSPU)
- Vertical Service Requesting User (VSRU)
- Innovation Support Provider

In sum, we have identified 23 key actor roles for 5G ecosystems that can be grouped in 9 role clusters. These actor roles are expected to be sufficient for describing most of the business models in the future 5G ecosystem. In the next subsection we will argue about the importance of the 5G platform ecosystem and distinguish between the platform operator, complementors and customers. Assuming that actors taking on the Network Operators' roles are the ones to act as platform operators, the rest non-customer roles would be seen as "complementors" (either in the innovation or the operation phase).

3.2.3 5G as a platform ecosystem

This section elaborates on the aspects of an ecosystem that involves all the non-telco actors engaged in providing composed digital solutions (including 5G) to a vertical enterprise customer. It also elaborates on the business relationships that emerge between the different enterprise customers' 5G contracts and UE. As suggested above in the description of platform ecosystems, the firms who build complementary innovations to a platform, often called complementors, are not the final customers. The complementors are all those other firms which the platform is dependent on in innovation and operation; only together they provide a complete service. For instance, advanced ICT-solutions firms typically provide: system integration, consulting, software, data hosting (data centres), cloud services, devices, and sensors. Here we assume that the 5G is the platform.

For 5G platform ecosystems we need to emphasize a distinction between the innovation phase and the operation phase. This is because the actor roles that are most active in driving the innovation and thus growth of a service are different from those that are most involved in delivering the service. For instance, consulting firms, system integrators or SW providers are supporting an enterprise customer in elaborating on pain points, and identifying, designing and testing solutions. They are often being technology agnostic, and have the task to experiment with solutions towards other actor roles in the ecosystem. Eventually, this innovation phase ends up in a recommendation for some services. In operation, the customer has chosen a solution, and IT and telecommunication firms are delivering services and products directly to the customer: for instance professional SW is delivered as a cloud service on tablets connected via Wi-Fi and 4G. All these different complementors have their separate relationship with the customer. Thus, the above-mentioned types of firms fall into two main groups of complementors, active either in innovation or operation. These business relationships are all illustrated in Figure 10: the innovation phase is illustrated with awareness and experiment; the operation phase is illustrated with implement and operate.

Mark that this is a model where we for the sake of clarity make a distinction between the innovation and operation phases and the different actors that are involved. However, we acknowledge that for instance telecommunication and data hosting actors could act as a facilitating part also in the innovation phase.

In the case of 5G and more especially 5G-VINNI, we often assign the customer – i.e. the vertical enterprise customer – to be in charge of its innovation process working directly with the telecommunication provider. However, the core idea of engaging the ecosystem for growth is to get all other complementors to work with innovation with enterprise customers, which in turn will lead to increased demand for telecommunication services. Thus, we need to emphasize this alternative. Still, we recognize that the vertical enterprise customer itself, or an entity on behalf of customers, can take on the lead role in innovation – i.e. being the innovator working directly with telecommunication providers. Remember, with ecosystems we are taking a step away from the act of MNOs selling products directly to an enterprise customer.

Instead we are aiming at enabling innovative processes for complementors that in the next instance lead to demand for MNO services. However, there is always a tension in such situations, where the NSaaS platform provider is competing with its complementors. It is recognized that the motivation to invest for actor roles' in an ecosystem decreases when they risk competing with their powerful provider at the same time (Gawer & Cusumano, 2014; Reuver Vershuur, Nikayin, Cerpa, & Bouwman, 2014; Iansiti & Levien, 2004). On the other hand, the NSaaS provider may take on an important role to invest in and build knowledge in a specific vertical, and pave the way for other firms to join at a later stage. In any case, predictability and trust between the actor roles are important prerequisites for innovation and growth to happen.

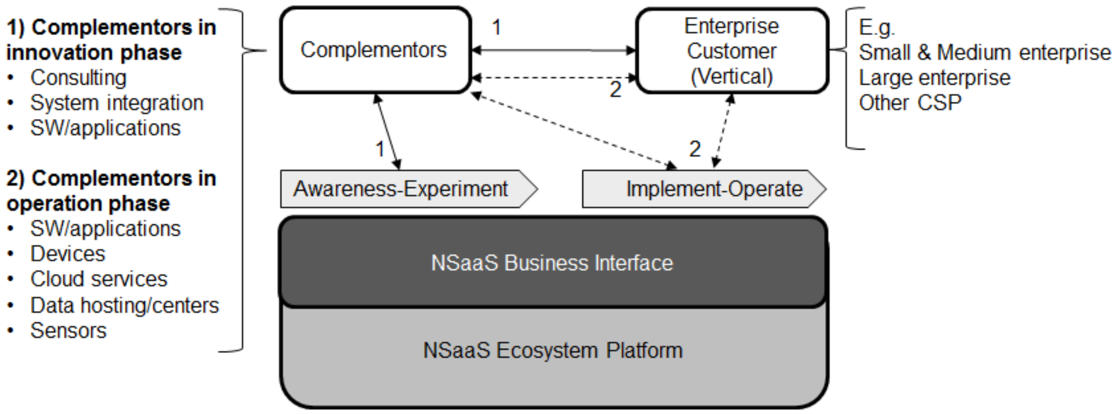

Figure 10: Type of firms that are complementors to the NSaaS platform in the ecosystem

The model in Figure 10 depicts foremost the main types of business relationships - i.e. not technical relationships - in an imagined 5G ecosystem, i.e. involving selling, advising, revenues, and contracts. However, such business relationships also rely on the existence of APIs. This is to enable sufficient levels of experimenting with the 5G platform as well as enabling operational automation and higher business efficiency. The API capability is indeed appointed an important role for driving innovation and delivery of services among the platform and complementing firms in the ecosystem, together with social aspects such as building of identity and community, legitimacy, reputation, and sharing of risk and profit. Put in concrete terms, such “social” aspects may be achieved through documentation, contracts, predictability in sharing of risk and profit, and sharing of information and knowledge. The platform in question “orchestrates” all the complementary firms through its many-faceted interface turned towards customers and complementors.

We assume that the technical interfaces, APIs, are somewhat different in the innovation and operation phase. Over time the APIs will change and evolve. We will however, emphasize that the platform will have to provide APIs to complementors also in operation – that is, it does not only provide services directly to the customer or vertical when innovating. For instance, a professional SW package delivered to a utility vertical may require a continuous flow of updates from the network.

In Figure 10, the NSaaS involves only one provider, although an NSaaSs can be provided by several operators together; this complexity is hidden in the model in order to emphasize the business interface towards the complementors and enterprise customers.

The provisioning of NSaaS implies to assign a specific set of network capabilities (specific to a slice) to one application that is installed on a UE. Thus, different applications on a UE can be assigned to either different or similar network slice capabilities based on the application requirements or operator’s policy. UEs’ multiple connections to network slices and application specific network capacity is illustrated in Figure 11. For example, there is an enterprise customer who owns or purchases the right to use an application from an application provider. Assuming that each of these applications is handled by a contract between the enterprise customer and the NSaaS provider; the holder of the UE has a relationship to the enterprise customer which provides the application and/or the NSaaS provider. In the case where one application is assigned with certain network capabilities, this does not mean that the UE or subscriber freely can access the same network capabilities with any application. In general, network capabilities provided through NSaaS are reserved for specific applications on the UE. In the following we call the provisioning of application specific network capabilities for NSaaS contracts, which are held by one vertical enterprise customer. There may be a high volume of NSaaS contracts, and thus enterprise customers. The operator networks use admission control to manage which slice/S-NSSAIs the UE is allowed to access w.r.t the specific requests (e.g., application).

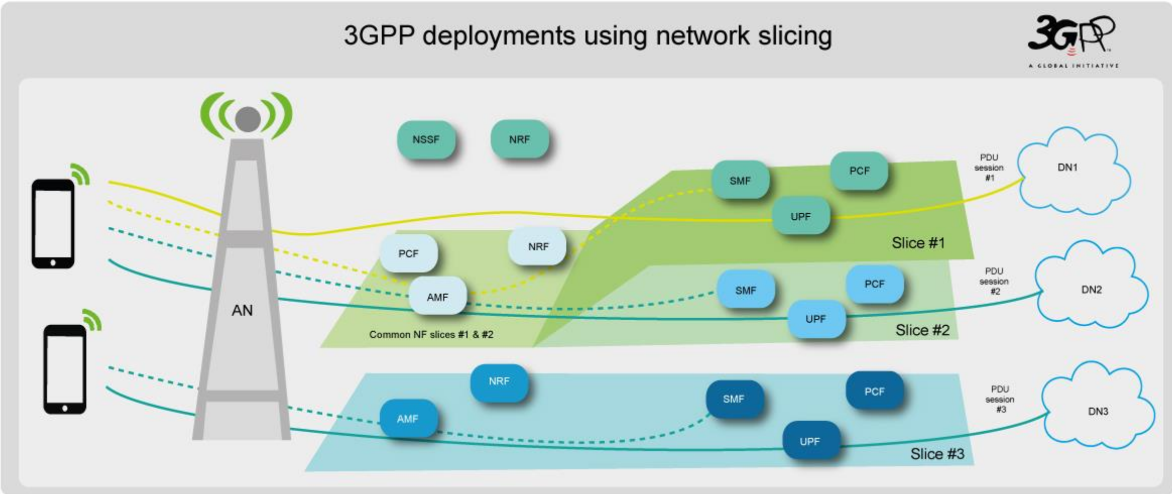

Figure 11: Illustration of how devices connect to different NSaaS contracts (Mademann, 2017)

In telecom, multiple ownerships of the different platform segments have often been solved with standards, interconnection and roaming – or also aggregation and exchange mechanisms. In an ecosystem delivering a complex and interdependent solution to an enterprise customer, we must assume that the requirements on these traditional ways of achieving interoperability will be evolved, beyond basic federation schemes (see 5G-VINNI Deliverable 1.2, 2019c). In Figure 12 we provide a simple illustration of how an NSaaS contract provided to an enterprise customer, must ensure that UE with primary broadband subscriptions at other operators can access the NSaaS contract and get privileged access to the application belonging to the enterprise customer. For instance, a hospital, providing a health critical application to patients must cater to that patients have subscriptions from all operators.

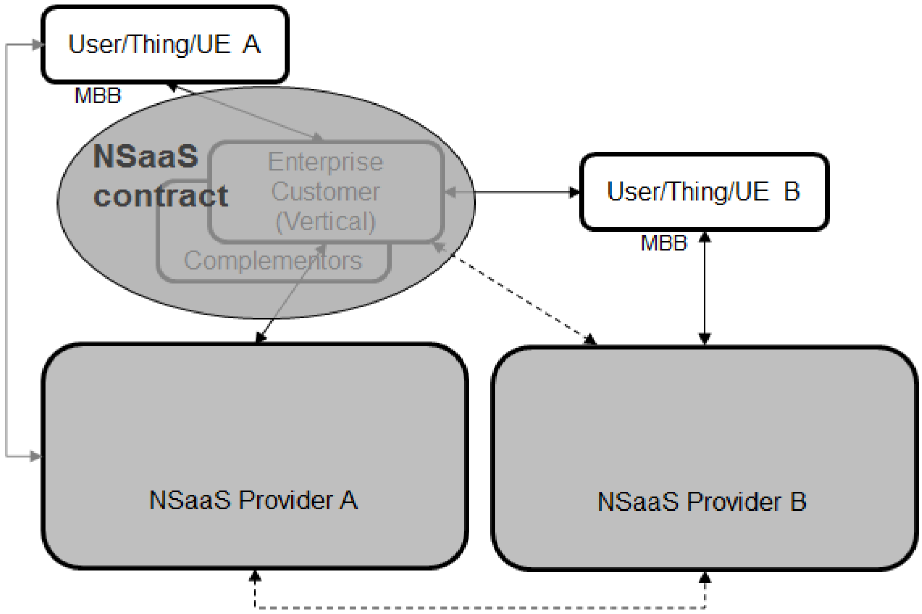

Figure 12: Users and things originating in different operators, accessing NSaaS contracts

The above example points at how one UE may access several network slices or NSaaS contracts with one ID, or one SIM-card[8]. Here we take the opportunity to also suggest that one UE can be connected to the mobile network via a SIM-card or alternatively a downloadable operator profile working as a SIM on the UE. Multiple profiles from multiple operators on one UE can enable its connection into many different NSaaS contracts. However, it is also possible to allow one SIM profile from a home mobile operator to be the identifier also into other NSaaS contracts (visited networks), i.e., to roam between NSaaS contracts using the same SIM profile from the home operator. We expect both the models with roaming and multiple operator profiles on one UE to be present, however, emphasize the case with one home SIM from one home MNO.

Both instances will trigger off a payment to the provider of the NSaaS contract, however, may imply different business relationships between the operators involved.

National and international handover, roaming and interconnection, via a wide range of federation schemes, may answer to these concerns in different ways. Again, handling of interoperability may be left to aggregators and exchange mechanisms, which take care of the multiple relationships with operators in order to ensure that enterprise customers in turn reach all their end-users, even when they have a SIM-card from different operators. Anyhow, this is just as much a question of business relationships and models, as technical specifications. In Table 3, we have systematised how handover and roaming between NSaaS networks pertaining to different contracts may be managed, and how enterprise customers can be managed within a MNO's footprint, and in a remote geography.

We specifically address the cases of UEs belonging to the enterprise customer moving across radio access networks either in: 1) the home geography, or; 2) a remote (visiting) geography of the primary MNO. In both these cases we consider the case of handover within the primary MNO's network scope (or an MVNO network established on-demand by the primary MNO) vs. the case of roaming (national roaming as well as roaming into a remote geography). For more details, see Table 3.

[8] This is in accordance with the discussion addressing S-NSSAI and NSSAI in D1.2 (5G-VINNI Deliverable 1.2, 2019c). The core message remains the same: one UE/user/thing can connect to many network slices/NSIs, even simultaneously

Table 3: Overview of different ways to manage interoperability

<table>
<tr><th></th><th colspan="3">Home net – MNO-A</th><th colspan="3">Visiting MNO-B</th></tr>
<tr><td rowspan="3">Same/Home geography:

Geography X
(e.g. Country X)</td><td colspan="3">Handover in MNO-A's own network
(device moving from one Base Station BS (A) to another BS (B) where the two BSs has different slice capability set)</td><td colspan="3">National Roaming between slice of RAN A in MNO-A
and
slice of RAN B in MNO-B

Roaming agreement necessary</td></tr>
<tr><td colspan="3">Slice/BS (A) with capability set 1 (CS1), and

Slice/BS (B) with capability set 2 (CS2)</td><td colspan="3">Slice/RAN A with capability set 1 (CS1)

Slice/RAN B with capability set 2 (CS2)</td></tr>
<tr><td>(CS1 = CS2)</td><td>CS1 > CS2</td><td>CS2> CS1</td><td>(CS1 = CS2)</td><td>CS1 > CS2</td><td>CS2> CS1</td></tr>
<tr><td rowspan="4">Remote geography:

Geography Y
(e.g. Country Y)</td><td colspan="6">How to solve handover/roaming outside MNO-A's footprint?</td></tr>
<tr><td colspan="3">MVNO - handover
MNO-A in Geography X establish (on-demand) MVNO-A' in Geography Y.

Purchasing NFVI and Network resources from e.g. MNO-B in Geography Y, i.e. a tenant of MNO-B.

Similar to the above. However, the BSs are managed by MNO-B on behalf of MVNO-A</td><td colspan="3">Roaming
Roaming between slice of a RAN A in MNO-A Geography X into slice of RAN B in MNO-B in Geography Y[9]

Roaming agreement necessary</td></tr>
<tr><td>Slice with capability 1</td><td colspan="2">Slice with capability 2</td><td>Slice with capability 1</td><td colspan="2">Slice with capability 2</td></tr>
<tr><td></td><td>Same as 1</td><td>Different from 1</td><td></td><td>Same as 1</td><td>Different from 1</td></tr>
</table>

Finally, enterprise customers will be provided with NSaaS contracts from different NSaaS providers. Thus, there will be many different market implementations of these. Even within specific sectors, e.g. the health sector, we can easily predict the presence of many NSaaS contracts serving hospitals, municipalities, and health equipment providers. On the other hand there will also be forces to simplify and reduce cost. Hence, common or shared NSaaS contracts can also be an option to consider, as network service providers evaluate cost-benefit of slice design, offering and operation.

In any case, these different enterprise customers will demand interoperability between the different logical networks pertaining to their NSaaS contracts, for instance in order to provide complete patient processes across hospitals and home healthcare. That is, one device in one logical network needs to establish e.g. a video session with a device in a different logical network. For efficient resource allocation, expert resources residing in one logical network must be accessed from resource users in another. Managing these relationships becomes even more complicated by considering that applications (and consequently the NSaaS contracts used) will be deployed asynchronously.

The business relationship between two NSaaS contracts is depicted in Figure 13, reusing the graphics from the previous figures. We regard this as different from providing an End-to-End solution which needs federation as described in the 5G-VINNI Deliverable 1.2 (5G-VINNI Deliverable 1.2, 2019c) which also will need different business agreements. In the current 4G regime, interconnection between different networks is possible by default. For interconnection between logical networks pertaining to different NSaaS contracts, in a home geography and between geographies, will be subject to same type business agreements as current regimes. However, the complexity of the cases to be considered will increase.

[9] Device from slice in home network MNO-A in Geography X, moves into slice in visiting network MNO-B in Geography Y

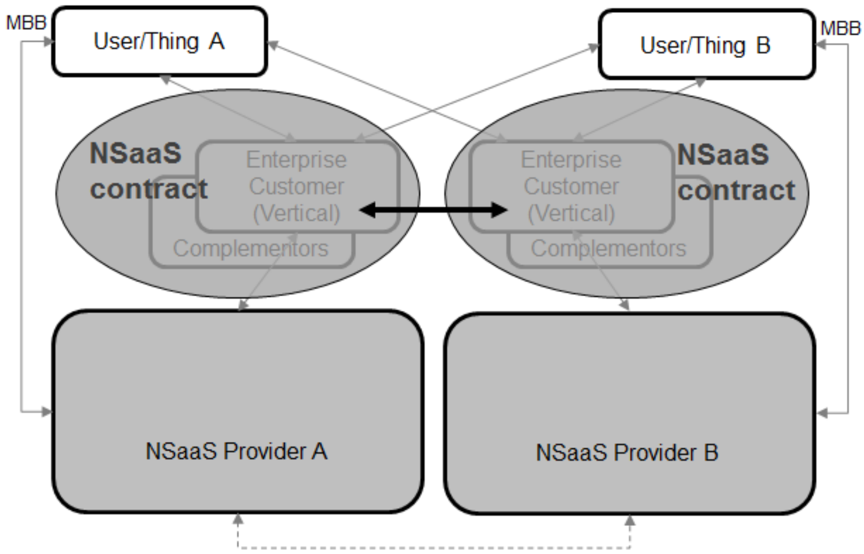

Figure 13: Interconnection between NSaaS contracts

In Table 4 we have started to consider the various cases of interconnection, where the device or data centre end-point of the enterprise customer need to connect to an end-point (i.e. a device or a data centre end-point) in a different network. This is a preliminary table which currently only contains overview cases and their combinations (non-exhaustive), however, still revealing important business implications. Note that the device or data centre end-point of the enterprise customer might be one in a different network than the network operated by the primary CSP. The data centre end-point can be one in an international backbone data centre, a Telco core or a Telco edge data centre. In the further work on analysing and filling in or even extending the table we have to consider for instance: whether the interconnected end-point is owned by the enterprise or not, a customer of the primary CSP /MNO; whether the other end-point (i.e. not-owned by the enterprise or not a customer of the primary CSP / MNO) is in the same geography as the home geography. In case the end-point of the enterprise customer (or serving the enterprise customer) is in a remote geography we have to consider whether this is enabled by the “MVNO on-demand” approach or by (outbound) roaming. In all these examples there are several cases of where and what are the other interconnected end-points. Moreover, the question of who is the initiating party can have business impact.

Table 4: Ways to manage 5G interconnectivity

End-points owned by (or serving) the Enterprise customer		**Interconnected end-points i) own end-point in remote geography (i.e. MVNO or roaming case) ii) other end-point in same or remote geography iii) initiating party: own end-point / other end-point**			
		Device end-points	Edge cloud	Core cloud	Backbone cloud, Int.
Same geography	Device end-points (mobile and fixed?)				
	Edge data centre end-points				
	Core data centre end-points				
Remote geography	Device end-points (mobile and fixed?)				
	Edge data centre end-points				
	Core data centre end-points				

3.2.4 Summary - 5G actor roles and implications for business relationships

Above we have adapted different ecosystem/system views to 5G actor roles. From this, we suggest that we are dealing with three families of business relationships:

Family 1: Complementor/Vertical enterprise customer facing NSaaS platform

Family 2: Interoperability among MNOs within and across geographies, including interoperability with regards to 1) NSaaS contract of one operator and UEs/things of other operators, and 2) between NSaaS contracts of different operators

Family 3: Infrastructure (suppliers, to establish "internal" capabilities, including resources in other operators' domains)

The first family concerns the external ecosystem, the second deals with MNO peers, while the third is addressing how a MNO decides how to source, control and operate its resources used to deliver NSaaS contracts.

In the 5G-VINNI actor role model described above we are foremost concerned with the Family 3 type of relationship, and that part of Family 1 that concerns the enterprise customer/vertical. In our elaboration of the future 5G ecosystem and business models, the two first families are important. These business relationships are elaborated upon in section 3.3.

3.3 Business relationships in 5G ecosystem

3.3.1 Describing Business relationships in 5G ecosystem using the 5G Value network

As explained above , value networks describe the key actor roles of the ecosystem under study and their interactions in terms of physical resources exchanged, money and information. Figure 14 presents a detailed value network of the 5G ecosystem, building upon the 5G actor role model presented in the previous subsection. We observe that these interactions appear as customer-provider relationships, where service provisioning is represented with open arrows and in exchange for money , represented with solid arrows. Note that information flows are omitted for better clarity.

We can use the value network in Figure 14 for describing candidate business models, which document how each actor adds value in the broader ecosystem and at the same time pursues its sustainability. This is one of the first steps when performing the prescriptive analysis and appears in Figure 15 where we propose "baseline"[10] business models of the key actors in the 5G ecosystem, which are represented by different colours (Patient as a Vertical Service Requesting User, Hospital as the Vertical Service Provider, Digital Service Provider, System Integrator as Service Aggregator, Consultant, Operation Support Provider, Mobile Network Operator A, Mobile Network Operator B, VNF/VAF Supplier, Virtualization Infrastructure Platform Supplier, Virtualization Infrastructure Service Provider, Hardware Supplier and Infrastructure Provider).

We observe that in the proposed baseline case, a single entity takes on one or more 5G ecosystem roles. We assume that two Network Operators operate in a (national) market and have adopted exactly the same roles; for example each one of them:

- owns the spectrum used internally;
- owns the venues where infrastructure (e.g., set of base stations, data centres, etc.) is deployed;
- owns data centres where physical resources are deployed

[10] This value network and related baseline business models is illustrative only. One could sketch several variants as will be shown later.

- aggregate data centres (especially when Mobile Edge Computing at customer premises is considered);
- runs virtual machines on top of physical resources;
- aggregates virtual machines running on different administrative domains;
- manages access, transport/core and backbone networks;
- acts as the Interconnection Broker in order to provide end-to-end services and
- acts as a Communication Service Provider (i.e., selling contracts to non/enterprise customers).

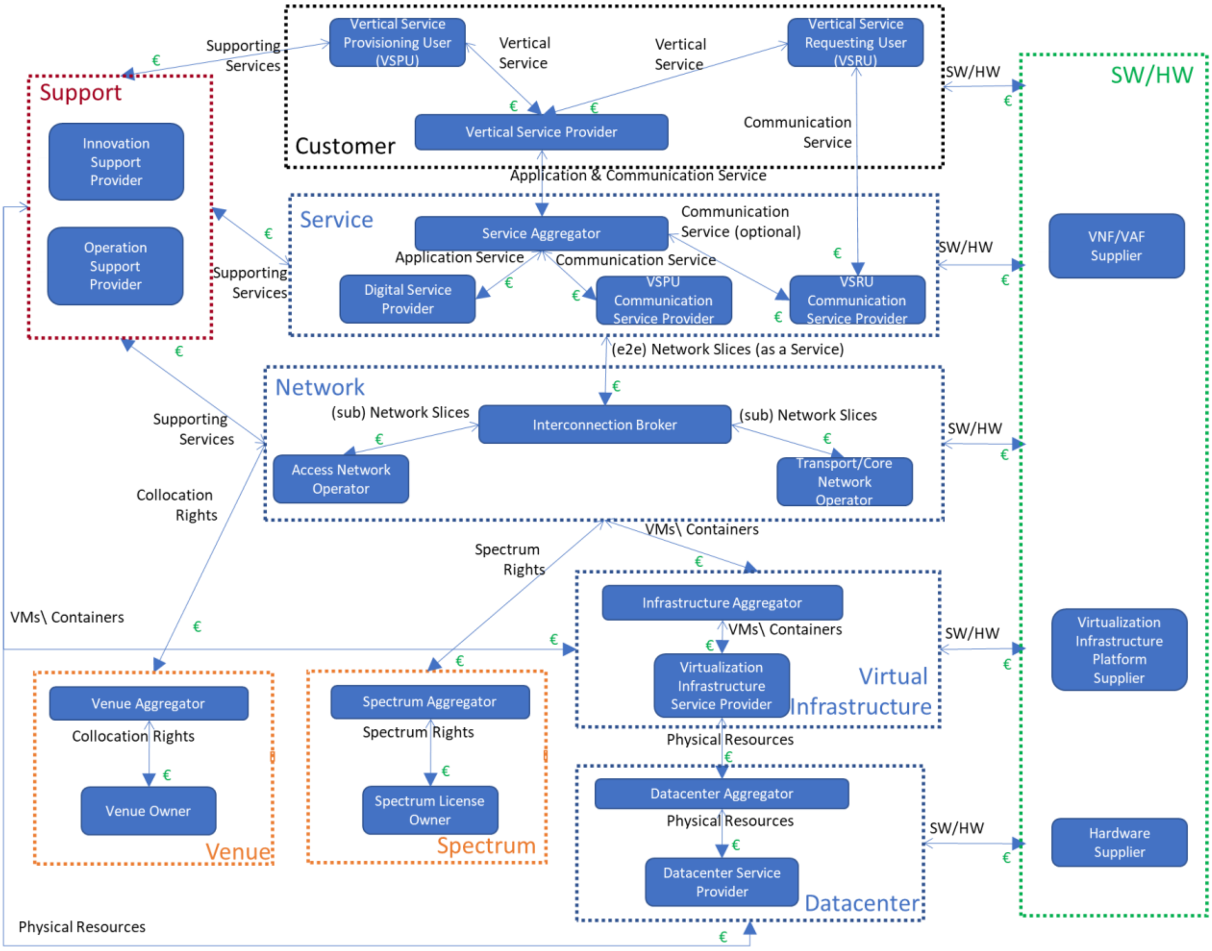

Figure 14: The generic value network for 5G

A Service Aggregator integrates communication and application services in a way that meets the requirements of the vertical industry where a certain Vertical Enterprise operates. This particular Service Aggregator will probably choose one of the two competing Mobile Network Operators (A, B) for end-to-end network slice provision. Suppose that the Hospital (i.e., a Vertical Service Provider) offers an advanced health service, such as a real-time health monitoring application that informs doctors when needed. In order for such a service to be delivered, both Patients and members of the hospital or equipment need access to the communication and application service(s). Since they belong to different providers, interoperability is crucial for the economic viability of such a service (or similar ones like providing a specific quality for an autonomous vehicle).

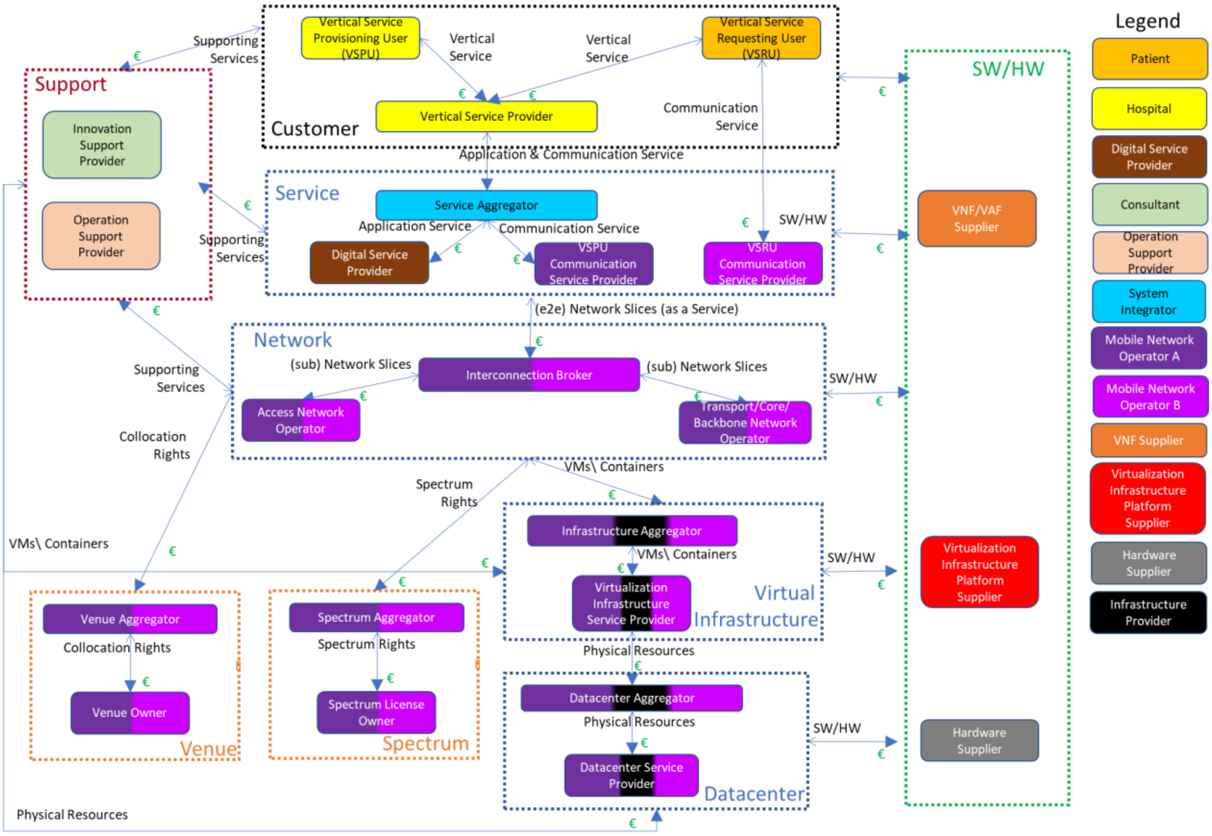

Figure 15: Candidate value network and involved business models for 5G where interoperation is achieved by slice federation

There are several ways to achieve interoperability amongst providers:

1) "consensus-based" where all parties agree to have a business relationship and depending on the user location (or network coverage respectively) can be realised with: a) network slice federation (national/international), or b) roaming (national/international);

2) "unilaterally" where interoperability is enforced, which can be realised with redundancy (i.e., redundant slices) if "adaptors", like dual-SIM or eSIM devices, exist.

In case of network slice federation, each MNO would offer network slice instances for each slice template (e.g., eMBB) and the Interconnection Broker would set-up the end-to-end slice. This is why both MNOs appear as active in Figure 15.

The case of (national) roaming is described with the value network diagram in Figure 16. Note that for better clarity the roles that are not directly relevant to roaming are excluded. We observe that the roles of the Interconnection Broker, Access Network Operator and Transport/Core Network Operator are taken on by Mobile Network Operator A only. Using network slices of Mobile Network Operator A is attributed to lack of coverage by MNO B. This could be also attributed to the admission control policy set by MNO B or other operational reasons.

These models illustrate three important managerial issues:

1. the resources a Network Operator must source and manage within own market/footprint in order to provide a complete service;
2. the resources a Network Operator must source and manage in other operators' market/footprint in order to provide a complete and continuous service and
3. the resources a Service Aggregator must provision for making sure that end-to-end network slice provision is not restricted to one operator's clientele.

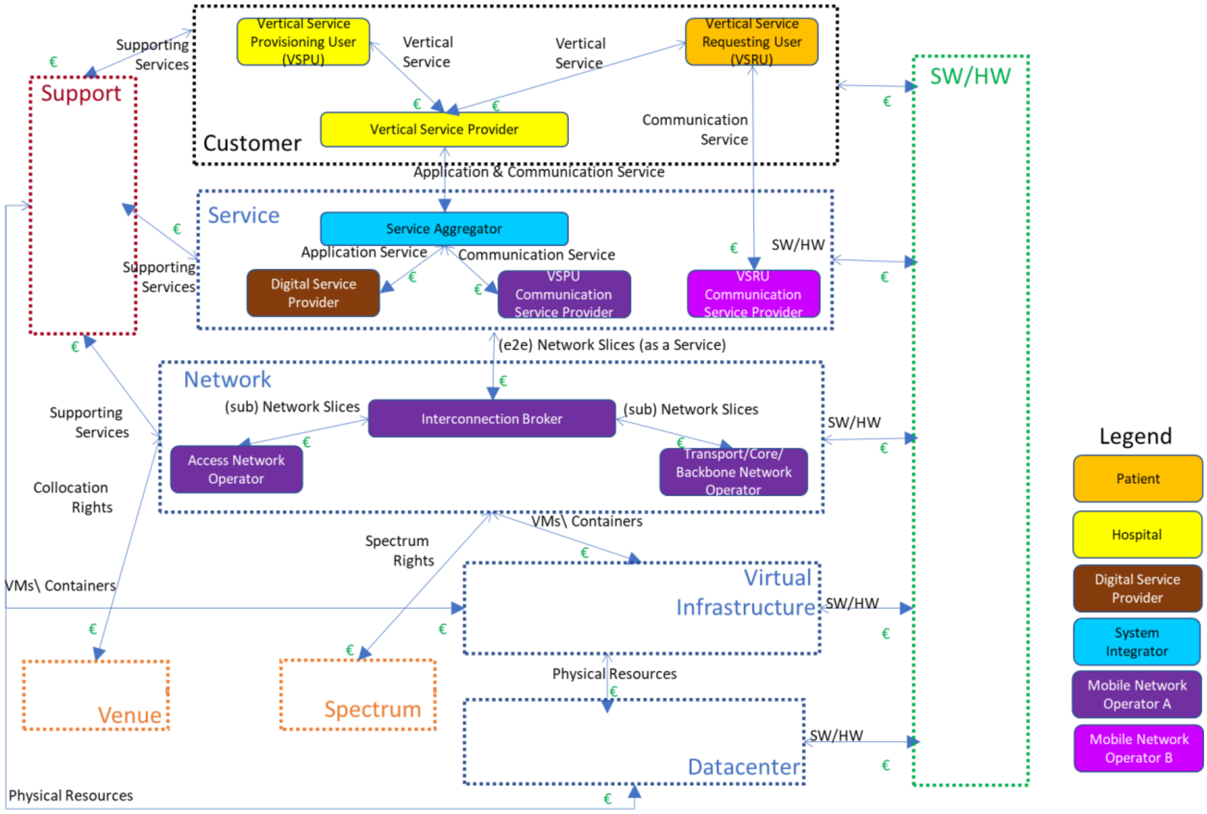

Figure 16: A candidate value network and involved business models for 5G where interoperation is achieved by roaming

The first issue is not new in the 5G ecosystem, as this is the main function of network operators regardless of technology. Nevertheless, 5G technologies such as SDN and NFV allow them to perform these tasks efficiently and effectively.

The second issue is related to the need for providing interoperability despite the varying requirements posed by different use-cases of interest to vertical industries. This challenge is specifically addressed by industrial associations, and suggested to be solved with establishing 1) NEtwork slice Types (NEST) with industry accepted slice characteristics, across operators (S-NESTs), or 2) Private NESTs provided by one operator (P-NEST) (GSMA, 2018). In the first example it will be possible to use national/international roaming to ensure a continuous service, while in the second example there must be private/specific agreements on replication of the P-NEST with other operators. Based on these options, an operator can sign a contract which is the set of resources customized to accommodate the performance requirements of a particular customer enterprise.

While the GSMA paper above focuses on roaming, such slice types could be also used for one operator to extend a NEST into other operators' network. In 5G-VINNI such solutions are described as Network slice federation in (5G-VINNI Deliverable 1.2, 2019c). Here, a seamless slice availability for enterprise customers and UE is foremost solved by enabling the re-creation or expansion of a given network slice into a visited network. Slice federation could involve S-NESTs whenever vertical/enterprise customers have typical requirements, or could require pre-established contracts (i.e., P-NESTs) between operators. While an operator is not required to instantiate S-NESTs, incentives to comply with industry-wide standards will be strengthened if/when Interconnection Brokers and Service Aggregators attract significant market share.

For the third issue, in case neither slice federation nor (national) roaming are offered (e.g., due to failure in agreeing upon the revenue sharing policy) then the Service Aggregator would have to consider choosing both Mobile Network Operators (A, B). This scenario is illustrated in Figure 17, where the only difference compared to the slice federation case is that the Service Aggregator has a contract with all MNOs (A, B) for any Hospital's VSRU to have ubiquitous access to the health service.

In all cases above we have assumed that the Vertical Service Requesting Users (VSRU) pays the Vertical Service Provider (e.g., a hospital) for the complete service (both communication and application elements). In other words the communication service is part of the vertical service (i.e., Vertical Service Requesting Users (VSRU) will eventually pay the hospital for using that slice). We should note that there are cases where Vertical Service Requesting User's access to the service is subsidised by the Vertical Service Provider (e.g., an invited doctor needs to use the slice as any other local infrastructure).

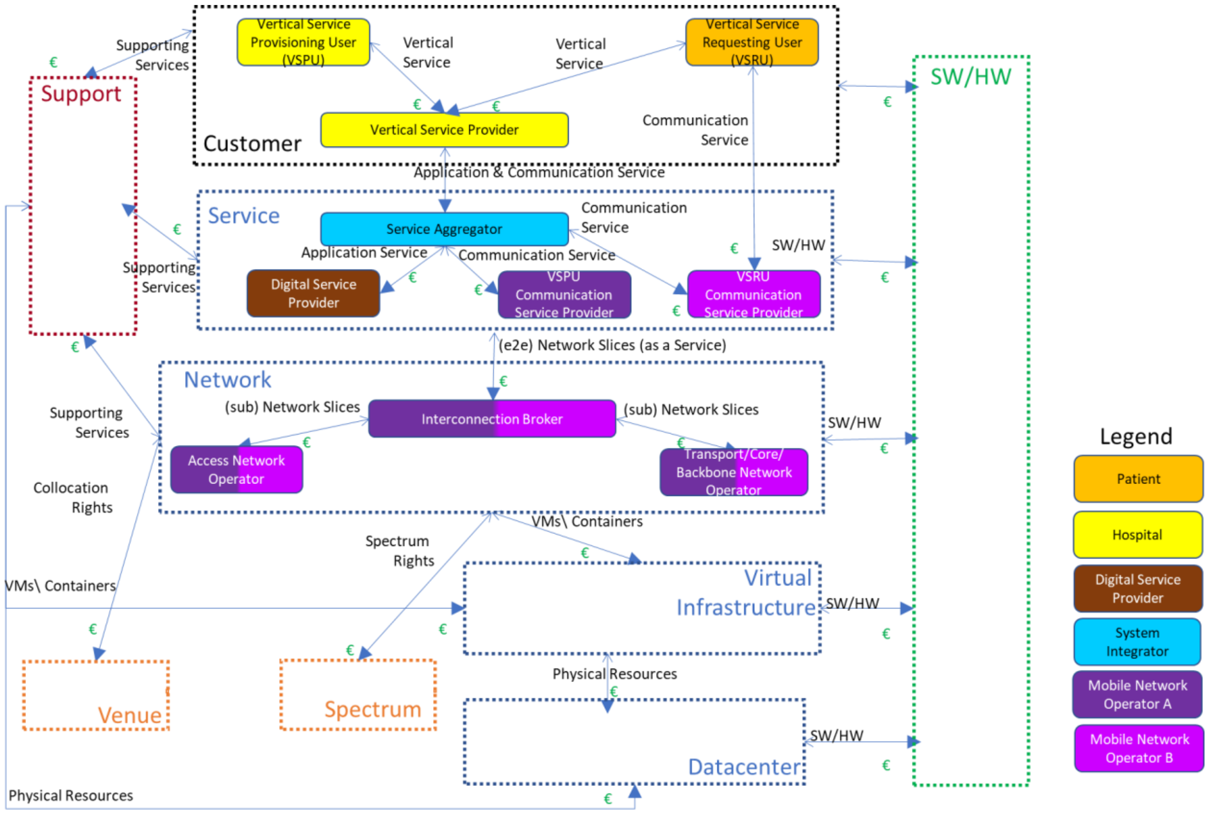

Figure 17: A candidate value network and involved business models for 5G where interoperation is achieved by Service Aggregators having contracts with all network operators

Figure 18 presents a value network for 5G-VINNI. We observe that ICT-19 consortia take on several roles; namely:

- all roles belonging to the Customer cluster
- all roles belonging to the Support cluster
- several roles being part of the Service cluster
- all roles related to Virtual Infrastructure cluster
- all roles related to Data centre cluster
- the venue owner role (especially for those use-cases where MEC will be needed)
- the VNF/VAF Supplier role (part of the SW/HW cluster)

On the other hand, 5G-VINNI members perform the functions of the following roles[11]:

[11] For more details on the roles that each of the 5G-VINNI members take on (per facility site) the interested reader is redirected to D3.2 report (5G-VINNI Deliverable 3.2, 2019b).

- several roles belonging to the Service cluster with no overlap with ICT-19 consortia
- all roles that make up the Network cluster (namely each of the 5G-VINNI facility site)
- all roles belonging to the Venue cluster (namely each of the 5G-VINNI facility site)
- all roles belonging to the Spectrum cluster (namely each of the 5G-VINNI facility site)
- all roles belonging to the Support cluster all roles related to Virtual Infrastructure cluster (namely each of the 5G-VINNI facility site)
- all roles related to Data centre cluster (namely each of the 5G-VINNI facility site)
- the VNF/VAF Supplier role (part of the SW/HW cluster)

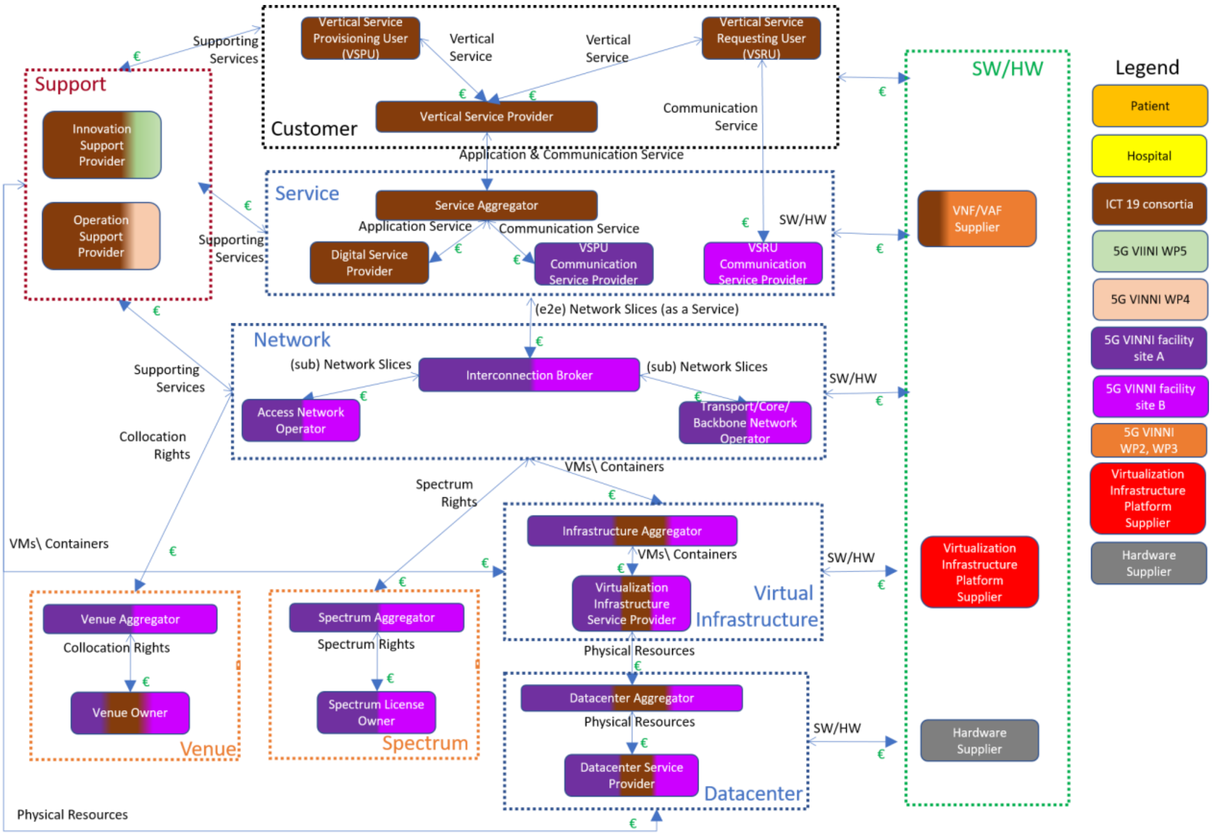

Figure 18: A candidate value network and involved business models for 5G testbeds (such as 5G-VINNI

Thus, the 5G actor role model (and related value network) can be used for describing a wide range of future scenarios for the 5G ecosystem.

3.3.2 A taxonomy of candidate business relationships in the 5G ecosystem

Summing up section 3.2 0we introduced three families of business relationships and illustrated examples of such relationships using the generic 5G value network in section 3.3.1. The two first families concern the dynamics in what we call the external ecosystem. The third is a more internal approach in the sense that the operator controls its resources through pre-established sourcing and agreements. In this section we mainly discuss the external views, elaborating on MNOs as the provider of a platform in a 5G ecosystem.

3.3.2.1 Candidate business relationships: MNO as 5G platform

Here we provide a model depicting the spatial representation of combinations of business relationships - see Figure 19. Next, we provide a few examples where some combinations are elaborated upon in order to substantiate the model.

In Figure 19, the main context is a primary MNO and its relationship with a vertical enterprise customer and the complementors involved. The simplest case will be one-one-one between the dimensions. In reality, there will be more complex combinations present in the market.

In the figure we use the notation Enterprise customer for one dimension, signalling one NSaaS contract. However, we want to emphasise that one Enterprise Customer can hold multiple NSaaS contracts. Furthermore, in principle, one NSaaS contract can be provided by one operator alone, or many different operators.

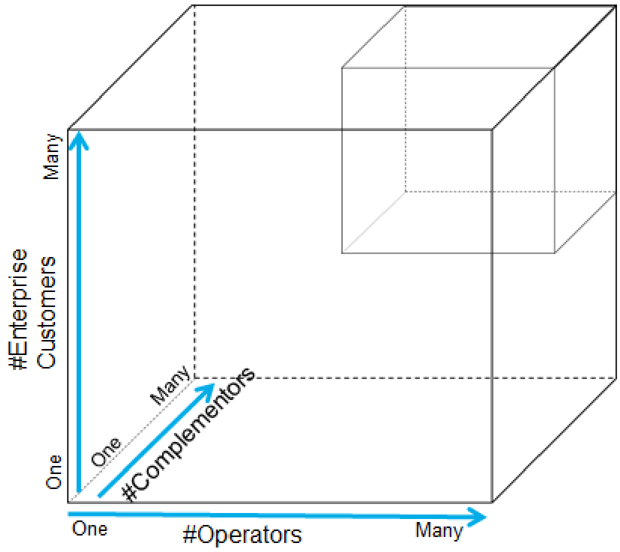

Figure 19: Spatial representation: combining business relationships in 5G platform ecosystems

The first example of combinations of dimensions in Table 5 is a simple base case. In the second example we elaborate on the presence of many complementors in the innovation and operation phase; in the remaining examples our focus is on the presence of many operators and vertical enterprise customers.

Table 5: Combinations of actor roles with scenario examples

	Combination	Scenario examples
1	One operator One enterprise customer One complementor	One operator sells and provides one NSaaS contract to one enterprise customer. It is only users and things within the operator domains that are connected to the NSaaS contract. This can be a manufacturing site that owns all the devices and chooses a single operator. All interaction with the field, the suppliers, distributors, and collaborators are controlled by the enterprise customer. Probably, this is a manufacturing site with limited activities beyond the site. One complementor, for instance an application provider, is having a role together with the operator to provide the complete service.
2	One operator One enterprise customer Many complementors	This is similar to combination 1, however, there are many complementors involved both in the innovation and operation phase. A consultant company is hired by the enterprise customer to map the end-users' (e.g. patients or field workers) interaction with the enterprise and reveal pain points and jobs to be done. Based on this, a system integrator is hired to elaborate on how to digitize processes and which applications that better can address the needs. Furthermore, many providers of health equipment are invited to take part. In the process, several solutions and applications are prototyped and tested. Existing sensors, connectivity solutions and devices are included in the prototyping, requiring APIs to access resources and data and test user interfaces.

	Combination	Scenario examples
		Also the NSaaS is included in the ongoing prototyping through the operators' business layer and APIs. Requests for proposals are introduced by the system integrator and enterprise customer jointly, and NSaaS providers, providers of SW, cloud services, devices and sensors are invited into the bid. A solution is chosen, which includes components from several complementors and the integration is managed by a system integrator. When in operation, the applications, devices, slices and hosting have to work together, providing the level of digitalization, efficiency and interoperability expected from current solutions.
3	Many operators One enterprise customer One complementor	One operator sells and provides one NSaaS contract to one enterprise customer. Users and things residing with other operators will also access this single NSaaS contract based on a roaming (most probably nationally) agreement amongst the operators. This can be a utility site which has contracted entrepreneurs doing field work, and many distributors. Devices from entrepreneurs and distributors need to be added to the slice on demand. This can be the defence holding rehearsals where civilians' devices must be given access to NSaaS contracts . This can be a hospital providing remote care for patients where their devices must be given access to the hospital NSaaS contract.
4	Many operators Many enterprise customers (for a vertical domain, i.e. health) Many complementors	Many operators sell and provide NSaaS contracts to several enterprise customers. Users and things residing with other operators will also access the different NSaaS contracts. We can assume that the health sector consists of many actors and cluster of actors with independent responsibilities. For instance, different regions or hospitals may independently source ICT solutions and their own NSaaS contracts. Furthermore, local health care can be controlled by independent municipalities. These constitute different enterprise customers, sourcing different NSaaS contracts. We should expect a requirement from enterprise customers that there is interoperability across these NSaaS contracts and users and things with residing with different operators. Likewise, there may be different regions and actors managing road infrastructure, transportation sectors (cars, trains, heavy transport), and brands (BMW, Volvo, Iveco). Different ports choose different NSaaS contract providers, and not the least, the different ship owners choose different solutions across the globe. Again, interoperability between slices and operators will be a demand.
5	Many operators Many enterprise customers One complementor	Like in scenario 3, the enterprise customer in question provisioned an NSaaS contract from a single operator but users/things from competing operators need to have access. In contrast to scenario 3, roaming is not allowed and in order to allow interoperability each operator has set up separate NSaaS contract for its members to reach the enterprise customer's resources. From an end-to-end point of view, these separate NSaaS contract are sub-contracts.
6	One operator Many enterprise customers One complementor	Like in scenario 1, the enterprise customer operates in a highly controlled environment where devices and applications are provisioned from a single complementor (e.g., a system integrator) and the connectivity needs are addressed by a single operator. In contrast to scenario 1, several NSaaS contracts are required for meeting the requirements (e.g., eMBB and mIoT).
7	Many operators	Like in scenario 2, the enterprise customer uses (sub)-systems from multiple

	Combination	Scenario examples
	One enterprise customer Many complementors	complementors and their requirements are met with a single slice type (e.g., eMBB). However, there are many different operators involved; either because different devices are registered to different operators, or (sub)-systems are reachable through several operators. Nevertheless, a single NSaaS contract is used as in the former case the operators allow roaming, while in the latter case the end-to-end slice is composed of multiple sub-contracts and operators have agreed on the revenue sharing details (e.g., initiating customer network pays).
8	One operator Many enterprise customers Many complementors	Like in scenario 4, the enterprise customer operates in an environment where (sub)-systems from several complementors need to interoperate and this happens using several NSaaS contract (e.g., according to template such as eMBB, mIoT etc. or domain). However, devices accessing the system(s) need to be associated with a single operator, which means that some users are screened.

Both Figure 19 and Table 5 illustrate how the combination with only few operators and slices is a subset of the many possible combinations. The normal situation will probably be the more complex combinations.

3.3.2.2 Implications from business relationships for 5G business models

In sum, the above understanding of what a 5G platform ecosystem may be, suggests that one specific operator must interact with other actor roles in the ecosystem along three dimensions:

- The complementors
- The other operators providing NSaaS
- The Enterprise Customers holding NSaaS contracts

This implies that value is created together with/among these other actor roles. Also the value captured, i.e. the revenue streams, are shared between the actor roles. Hence, business models and cases may build on this structure. Clearly, we see that one revenue stream that falls into the hands of operators is from connecting users/UEs/things to an NSaaS contract. Also, the operator offering NSaaS has a new revenue opportunity in the management and administration of all resources, interactions and connections included in the provisioning of a specific NSaaS contract. Finally, there are revenues streams from serving the interaction between NSaaS contracts.

Thus, there are three types of revenue streams for an operator serving enterprise customers directly:

- Connecting UE/users/things to a NSaaS contract
- Management of NSaaS contracts (e.g., allowing complementors and enterprise customers to monitor and dynamically configure custom such NSaaS contracts in terms of delay, throughput, etc. and non-functional properties like access control)
- Connecting NSaaS contracts

The operator must recognize that things and users (UEs) that are connecting to an NSaaS contract from another operator are subject to some sort of revenue sharing agreements.

Nevertheless, there are activities such as consulting, system integration, and hosting where other actor roles (complementors) are capturing the revenues and which are important for delivering complete solutions to an enterprise customer. These revenues come in addition to the MNO-related revenue streams mentioned above. To acquire such revenues are often referred to as "climbing in the value chain" for MNOs. In an existing market this implies to take on adjacent actor roles that currently are filled by complementors; in market with ecosystem characteristics such moves are potentially damaging for a fine balance between interdependent actor roles.

3.3.3 Business relationships capabilities in 5G ecosystem context

Business relationships between actors concern those aspects that are non-technical. However, it is not possible to fully separate technical and business relationships. In the following we may say that business relationships have functional and social capabilities. Both the functional and social capabilities can be grouped into technical and business-related capabilities. To succeed with new business models and growing markets, it is generally recognized that it is necessary to cater to all aspects of relationships.

Business relationships can be understood in a functional way, where the price set between parties incorporates all aspects of transactions. Relationships can also be extended to social aspects where factors such as culture and trust play a role for the realization of a transaction.

Technical relationships can be limited to pure technical interoperability; however, can also include social processes that ensure sharing of necessary knowledge between experts.

In the case of evolution of complex technological systems and platform ecosystems, a broader understanding of business relationships has been suggested. 5G is suggested to evolve to a new type of market dynamics, the ecosystem, with increased technological openness and innovation by many different partners; this suggests that the new relationships evolving are many-faceted.

Broadly speaking, in order to describe and understand new 5G business models we have to include both approaches. In Table 6 we provide a first attempt to systematically describe business aspects of relationships between 5G actor roles.

In line with this, it has been suggested to consider technical, semantic, organizational and legal interoperability to capture implementation challenges between parties that go beyond technology (European Commission, 2017b, p. 28), defining organisational interoperability as: documenting and integrating or aligning business processes and relevant information exchanged. This is different from technical interoperability which includes e.g. interface specifications, and semantic interoperability which is about shared format and meaning of data.

In Table 6 we do not include technical and semantic interoperability, but discuss aspects of interoperability that have organisational characteristics. It indicates capabilities of business relationships that are relatively important in an ecosystem context. For instance, because of the mutual dependency for actor roles in an ecosystem, it becomes important both to have shared revenue expectations and build trust in order to spur willingness to explore and invest. Still, some aspects of relationships have to be accompanied by more formal arrangements such as service level agreements (SLA). The described relationships are simplifications of contractual agreements which can vary a lot, and with regards to properties, dynamics, bilateral vs. multi-lateral.

Table 6: Different actor roles, business relationships, and relationships' characteristic

Primary role	**"Secondary" roles**		
	Network Operators	**Enterprise customer** **NSaaS contracts**	**Complementors**
Network operators	*Organisational interoperability* Pre-established expectations and agreements on: • business processes • federation, handover interconnection and roaming	*Selling/delivering NSaaS contracts to customer enterprises* Contracts SLAs Revenues: • from customer	*Organisational interoperability* Enabling complementors through business layer/processes to innovate and experiment with NSaaS together with verticals, so that they can deliver their

	Automated administration of interface Revenue sharing or pre-established paying regimes from other operators to NSaaS contracts “owner” Mutual trust	enterprise • from other operators to NSaaS contract “owner” Trust/brand	solutions to the same verticals • Sharing and building of knowledge • Mutual trust • Revenue sharing Pre-established expectations and agreements on: • prices • conditions
Enterprise customer **NSaaS contracts**	*Receiving NSaaS service from operator* Requirements on NSaaS interfaces, for making the best out of the NSaaS contracts (access to data, metadata, advanced services, customer support etc. (via APIs)) Requirement towards operators on interoperability between operators and NSaaS contracts	*Organisational interoperability* Predefined alignment of business processes between NSaaS contracts Pre-established agreements between “owners” of NSaaS contracts on exchanges of “users” and data	*Receiving and paying for services* from many different complementors, constituting the full vertical system Requirement towards complementors on interoperability
Complementor	*Requirement towards operators on access to NAaaS business layer* Pre-established processes/expectations • how to innovate together • how to support complementors Expectations to revenue sharing Requirement towards operators on interoperability between operators and complementor	*Selling/delivering application, consulting etc. to customer enterprises,* intertwined with NSaaS from operators, constituting a NSaaS contract	Knowledge sharing Mutual alignment of business processes Mutual trust Revenue sharing Requirements on interoperability

3.3.4 Evolution of 5G business relationships

The ecosystem approach to how markets evolve implies the understanding that ecosystems go through phases, from birth to decline (Moore, 1993; Hekkert, Negro, Heimeriks, & Harmsen, 2011). Subsequently, number of actors, relationships, challenges and strategies are different in these phases. We expect the 5G ecosystem to go through such phases. It is essential to distinguish between the current status and a future mature design, identify the gap, and enable a discussion on strategies that builds the sustainable 5G ecosystem in the long term.

In order to reach a stable state of an ecosystem, we can turn to insight from technological innovation systems and platform ecosystems. In order enable the growth of complex and systemic technologies (Gawer & Cusumano, 2014; Bergek et al., 2008), the following factors are often presented as prerequisites, in addition to technological interoperability achieved in particular by APIs.

- Trust and legitimation
- Knowledge building and sharing

- Expectations to profit
- Ability to experiment

These factors are catered to in the business relationships between actor roles. In order to achieve a level where these factors act as enablers, several aspects of a relationship must be addressed. Documentation and predictable and transparent prices build knowledge and trust, and lead to more predictability in business cases for other actor roles. Ability to try out and experiment with technology support explorative activity in innovation processes. Social events and experimental gatherings build and spread tacit knowledge and increase the community of actor roles which can and want to use 5G.

In sum, how the relationship between actor roles in 5G are managed in both the short and long term, affect the evolution of the 5G ecosystem and its potential success. This is illustrated in Figure 20.

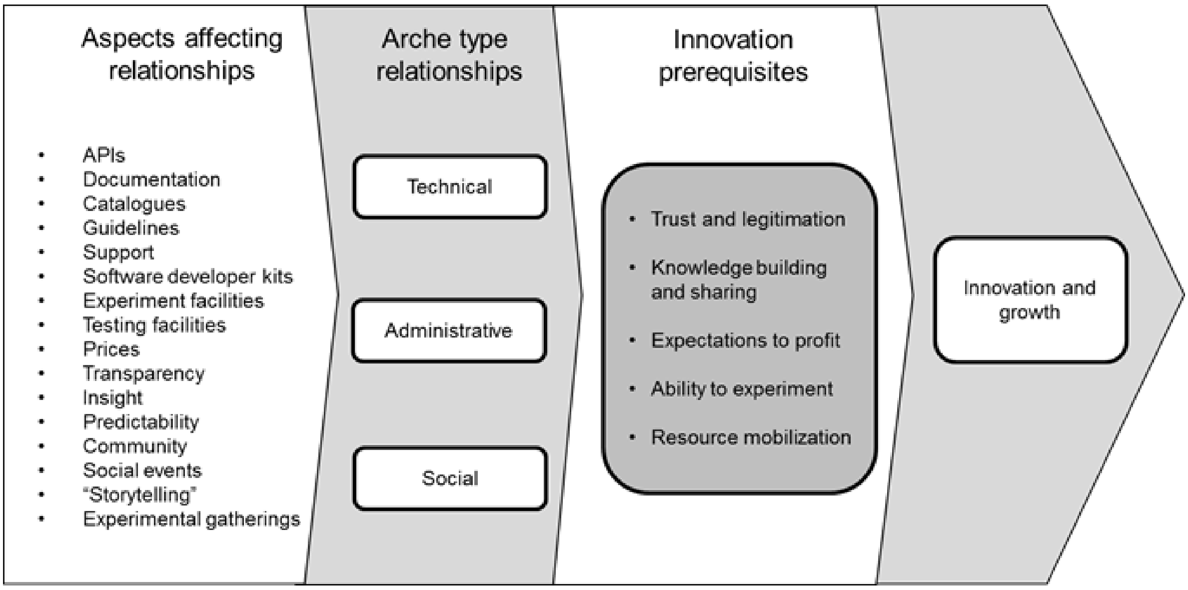

Figure 20 Concrete factors affecting business relationships, their status, and innovation and growth

In order to illustrate how business models (and consequently business relationships) can evolve over time using the value network for the 5G ecosystem, we below give an example of the role of the *Service Aggregator*. We conjecture that during the early stages of the 5G ecosystem (on the top of Figure 21) most Customers will have separate contracts for communication services (connectivity) and applications and thus few *Service* Aggregators will be active. As the 5G ecosystem matures, however, we expect that more actors will attempt to expand into the *Service Aggregator* market.

The actors well-suited to obtain a share of those revenues are *Vertical Service Providers* as these will be able to buy slices from Network Operators and act as Communication Service Providers (both VSPU and VSRU) as well. The driver of this business model evolution is more freedom to offer carefully selected "bundles" of services to the *Customers*. Doing so they differentiate their offering in value rather than prices and thus avoid competing on prices with other *Vertical Service Providers,* which is not a viable strategy. While Vertical Service Providers can become Communication Service Providers quite easily, the opposite is not necessarily true. In fact, unless Vertical Service Providers follow the SW-as-a-Service paradigm and expose APIs that allow third parties to manage the service, then the only option for Network Operators would be to develop their own online service.

This is why we anticipate two candidate scenarios for the mature 5G ecosystem. In the first scenario (shown in the middle of the figure), MNOs decide not to compete with Digital Service Providers. This could be attributed to their focus on the platform ecosystem enabler business model, where Digital Service Providers are seen as complementors that generate value.

In the second mature scenario (bottom of figure) a particular MNO (e.g., A) decides to take on the role of Digital Service Provider as well. There are several reasons for doing so; a) existing Digital Service Providers are reluctant to adopt 5G solutions for communication purposes, b) they anticipate higher revenues in the long term by combining following a more aggressive strategy.

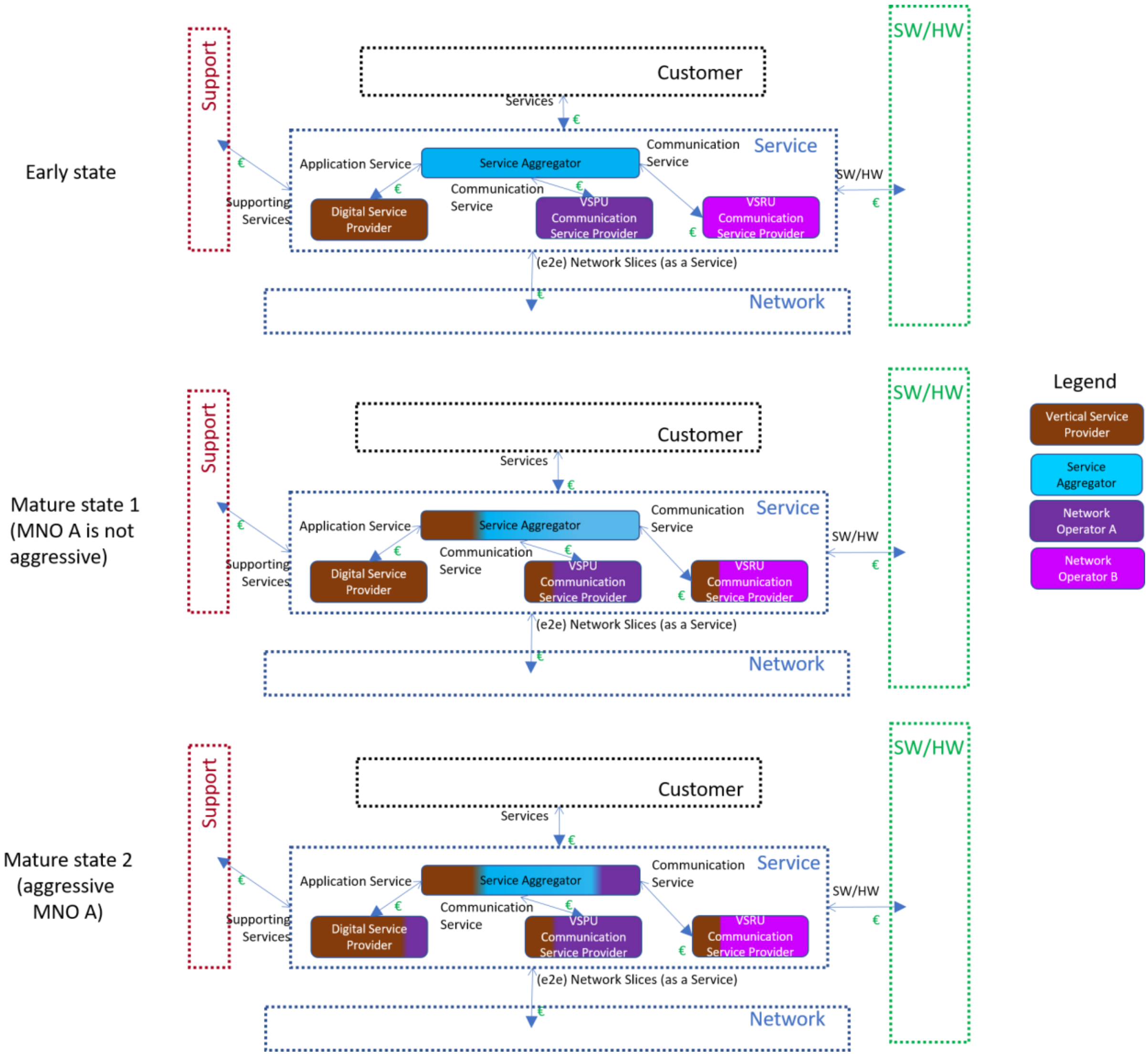

Figure 21 Potential evolution of the aggregator role through three maturity states

3.4 Summary 5G value network and ecosystem

The future 5G market has been associated with the concept of ecosystems. We start section 3 by describing the concept and origins of ecosystem as a business concept. More specifically, we have described the platform ecosystem concept, and complemented this with a description of the value network approach. Both approaches aim to capture the same market mechanisms which arise from seeing technologies as complex and interdependent systems. We also suggest a set of business concepts for better describing the different actor roles in such settings.

With these approaches as a starting point, we have carried out a detailed analysis of the complex 5G ecosystem. We have identified important business relationships in this context, how they might be handled, and implications for revenue streams.

We suggest a high-level actor role model for the 5G-VINNI facility. This is complemented with a more general 5G ecosystem model, which at the same time captures more of the ecosystem complexity with regards to the number of actor roles and their many-faceted relationships. Using the platform ecosystem approach, we elaborate on the actor roles in the 5G ecosystem which are non-telco, for instance application providers and system integrators. This approach enable us to illustrate and detail the complex business relationships in the 5G ecosystem: we suggest that there are three families of business relationships that need to be catered to: 1) between operators and other IT-firms; 2) between operators, and 3) between the NSaaS Contracts (logical networks) which are held between enterprise customers.

The analyses reveal that interoperability, both technologically and business wise is an issue in the future 5G ecosystem.

The analyses further reveal that there are three revenue streams that the MNOs can expect to emerge:

- Connecting UE/users/things to a NSaaS contract
- Management of NSaaS contracts
- Connecting NSaaS contracts

4 Value proposition and innovation potential

In this section we will first introduce the four maturity levels we foresee for the facility operations that are part of 5G-VINNI. This is used to perform an extensive SWOT analysis for the early maturity levels, and only indicatively assess the more mature levels. The section also includes an elaboration of the innovation potential of different verticals.

4.1 5G-VINNI maturity levels

We have identified multiple maturity levels of the 5G-VINNI facility operations, capturing its evolution over the years. We foresee that the operation of the facility during the project life time will significantly differ from the one after the 5G-VINNI project's completion, considering also the long-term vision of 5G-VINNI facility experimentation as a service. Note that these maturity levels have a different scope than the 5G-VINNI facility Releases as defined in (5G-VINNI Deliverable 1.1, 2019d). In fact, a maturity level may include one or more Releases, while two maturity levels go beyond project's lifetime. Figure 22 provides a graphical representation of the four 5G-VINNI maturity levels (vertical axis), their evolution in time (horizontal axis) and the associated releases.

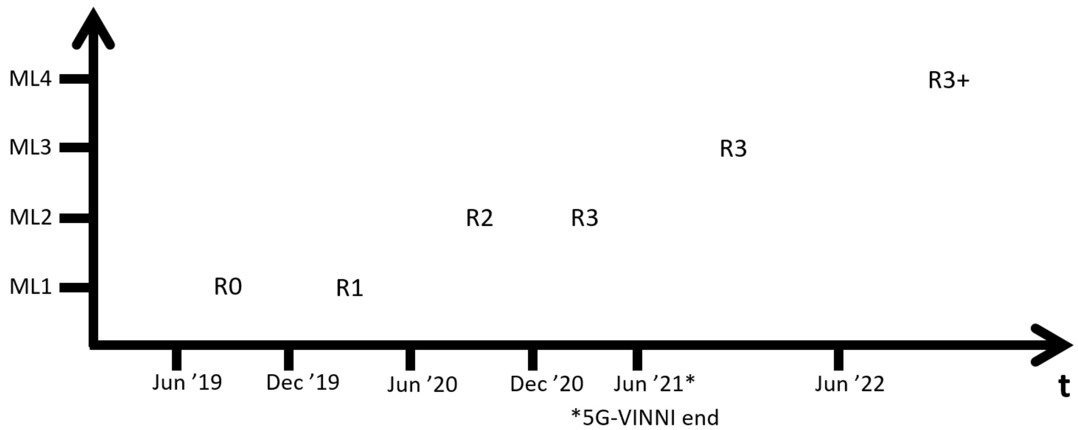

Figure 22: Mapping 5G-VINNI releases to maturity levels

The identified operation-maturity levels are:

1. **ML1: 5G-VINNI facility for internal testing.** This level refers to the operation of the facility during the early stage of the project, which is focused on running certain experiments for ensuring that 5G-VINNI Release 0 and 1 validate the 5GPP defined KPIs (e.g., maximum throughput).
2. **ML2: 5G-VINNI facility for experimentation by verticals during the project duration.** This level includes the second and third release (Release 2 and 3) of the 5G-VINNI facility for serving vertical "customers" during the project duration. These customers are mainly the *ICT-19 funded projects* (possibly ICT-18-22 also) and independent verticals from the *5G-VINNI External Stakeholders Board (ESB)*. We expect that these customers will be mostly interested in on-boarding their applications (i.e., Virtual Application Functions) into 5G-VINNI facility in order to identify integration challenges and explore what is technically feasible under varying network conditions and experiment configurations. Note that the cost for facility site resources consumed by these experiments will be mostly subsidised by 5G-VINNI, except for extreme cases where additional infrastructure needs to be deployed, or detailed guidance on running experiments is asked.
3. **ML3: 5G-VINNI facility for experimentation by verticals beyond the project lifetime (1-year).** This level refers to the operation of the facility for 1 year after project completion. In

fact, Release 3 of the 5G-VINNI facility is committed to serve ICT-19 funded projects during this time. The difference compared to ML2 is that certain incurred costs should be covered by ICT-19 projects, which will guarantee the sustainability of 5G-VINNI facility site. Furthermore, the facility could be opened for serving individual vertical stakeholders and SW suppliers that are willing to compensate 5G-VINNI for potential additional expenses incurred. Some of those enterprise customers may be ready to engage pilot users in their experiments before commercially launching their offerings, but we expect that this will not be the norm.

4. **ML4: Long term vision for 5G-VINNI experimentation as a service.** This level is the longest in terms of duration and refers to the long-term vision of 5G-VINNI facility operation, under the concept of experimentation as a service. We foresee that certain business and governance models could guarantee the sustainability of the 5G-VINNI facility toward the commercialization and promote the facility growth attracting new facility site operators to join. This maturity level captures the service toward vertical customers by an individual 5G-VINNI facility site, multiple 5G-VINNI facility sites or even multiple interworking facilities considering also others that may emerge as a result of other ICT-17 projects. We anticipate that 5G capabilities will have been demonstrated by then and enterprise customers will be buying NSaaS for running innovative business experiments with real users in order to understand their market potential. At the same time SW suppliers will be releasing new functionalities that need to be tested in pre-commercial 5G environments. Thus we expect that 5G-VINNI Release 3 (or new ones) will be used during all phases of product/service lifecycle and by a wide range of complementors and customers (including end-users).

The business requirements for each for these operation levels will be identified in the context of Task 5.2 in the 5G-VINNI project, while the mechanisms that need to be established for ensuring the sustainability of the platform in each operation level will be developed and evaluated within Task 5.3.

4.2 Value proposition of 5G-VINNI facility

In this subsection, we perform a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis focusing on the 5G-VINNI facility as a whole, under the concept of experimentation as a service. By means of this SWOT analysis, we aim to assess the value proposition of 5G-VINNI facility for all the involved stakeholders (internal and external), identifying both potential benefits and shortcomings. The objective is to highlight potential strategies for the involved stakeholders aiming to exploit strengths/opportunities and mitigate weaknesses/threats by combining information from two quadrants of the SWOT table. This approach is known as TOWS and involves the following pairs:

- **Strengths–Opportunities.** Use internal strengths to take advantage of opportunities;
- **Strengths-Threats.** Use strengths to reduce the probability of a threat being materialized or its consequences;
- **Weaknesses-Opportunities.** Improve weaknesses by taking advantage of opportunities.
- **Weaknesses-Threats.** Work to eliminate weaknesses to avoid threats.

Table 7 provides a graphical illustration of TOWS approach.

Table 7: An illustration of TOWS approach[12]

	Opportunities (external, positive)	**Threats** (external, negative)
Strengths (internal, positive)	**Strength-Opportunity strategies** Which of the company's strengths can be used to maximize the opportunities you identified?	**Strength-Threats strategies** How can you use the company's strengths to minimize the threats you identified?
Weaknesses (internal, negative)	**Weakness-Opportunity strategies** What action(s) can you take to minimize the company's weaknesses using the opportunities you identified?	**Weakness-Threats strategies** How can you minimize the company's weaknesses to avoid the threats you identified?

We perform this analysis for the 5G-VINNI operation-maturity levels identified above, since some conditions may be valid only under certain operation levels and thus different strategies/actions may be required. We assume that for operation levels ML1-ML3 the capabilities of the 5G-VINNI facility are known, assuming the development and evolution of the facility will follow the specified plan with respect to releases (Release 0 - Release 3 as defined in 5G-VINNI Deliverable 1.2 (2019b)). In addition, the customer groups that will be served under each operation level are also known and a-priori specified. On the other hand, ML4 is the long-term "TO-BE" situation where the operation of the facility is not restricted, e.g. on serving specific groups of customers. Hence, in this case, certain assumptions have to be made for performing the analysis and different scenarios (optimistic vs pessimistic) could be studied.

Note that the different operation levels affect the internal characteristic of 5G-VINNI facility, thus each level may exhibit different strengths and weaknesses. On the other hand, the external characteristics are not directly affected by the evolution of the 5G-VINNI facility, thus we assume that they remain the same for all operation levels. Furthermore, different roles are likely to have different strengths and weaknesses, so the analysis will drill down to specific stakeholders wherever it is deemed necessary.

4.2.1 SWOT analysis template

In the following SWOT analysis template (see Table 8), we classify a set of qualitative criteria as Strengths, Weaknesses, Opportunities and Threats in order to describe the value proposition of 5G-VINNI facility. These criteria appear as pairs so that each of them may be valid either as a strength or weakness/threat or opportunity, but not both. The value of a criterion should identify the overall positive or negative effect taking into account the impact on all actor roles in the ecosystem. It is quite possible the overall effect to be close to neutral because a certain criterion could be considered as strength (or opportunity) for a subset of the ecosystem and as weakness (or threat) for another subset. Additionally, a criterion that has been marked as strength may have an overall greater positive impact than others that have also been marked as a strength. This also applies for weaknesses, opportunities and threats. Hence, in order to have a greater granularity in our analysis, we determine a real value between -5 and 5 for each pair of strengths/weakness or opportunities/threats. This means that a positive value for a pair of criteria identifies a strength (or

[12] Source: https://articles.bplans.com/swot-analysis-challenge-day-5-turning-swot-analysis-actionable-strategies/

opportunity), a negative value identifies a weakness (or threat) and zero value identifies a neutral impact. This approach can provide qualitative insight without being too restrictive.

The benefits and shortcomings of each 5G-VINNI facility under a certain operation-maturity level can be evaluated by checking the determined value for each (paired) criterion of the following table. If a certain criterion is not directly applicable for a certain level then both the value is set to zero. The justification and analysis of the selected values is provided as structured text under the respective table for each of the studied scenarios and can be detailed at the level of individual role.

Table 8: The SWOT analysis template

Template	
Strengths	**Weaknesses**
I1. High-quality performance ○ Highly automated management ○ Performance guarantees with respect to customer's QoS ○ 5G PPP KPIs are met I2. Cost-efficient deployment ○ Low CAPEX I3. Cost-efficient operation ○ Low OPEX for performing testing I4. Innovation hub (local/global) ○ High ability to attract and engage verticals ○ Promotes innovation internally to facility stakeholders ○ Many points of presence of high-interest I5. Strong brand name ○ as a whole system ○ due to high reputation of certain/all individuals I6. High stakeholders collaboration ○ Collaboration stability ○ Sustainable business model ○ High levels of trust ○ Revenue predictability ○ Price and service stability ○ Efficient sharing of coded and tacit knowledge I7. Virtual technology allows expansion into geographic areas outside own spectrum/infrastructure footprint I8. Experience and professionality in managing large scale business/society critical networks I9. Ability to exploit new technologies	I1. Low-quality performance ○ Low automation ○ Customers experience unexpected delays and failures ○ Some 5G PPP KPIs cannot be met or cannot be measured I2. High deployment cost ○ High CAPEX I3. High operation cost ○ High OPEX for performing testing I4. Low innovation potential (local/global) ○ Low ability to attract and engage verticals ○ Low ability to internally facility stakeholders to innovate ○ Insufficient number of points of presence or of limited interest I5. No brand name I6. No abilities to escape/handle opportunistic behaviour-uncertain collaboration ○ Unstable Collaboration ○ Unsustainable business model ○ Distrust ○ Unclear revenue streams ○ Price wars/service unavailability ○ Dysfunctional processes and attitudes for knowledge sharing I7. Limited facility growth and geographical expansion I8. Network management limited to mobile operations – scarce experience with IT networks I9. Slow in taking advantage of new technologies/way of work

Opportunities	Threats
E1. Verticals' digitalization creates new requirements for network quality and flexibility	E1. Existing communications solutions are technologically sufficient (or perceived sufficient) for vertical's digitalization needs
E2. Private networks (defense, emergency, health) have become too expensive/challenging for non-ICT actors to handle	E2. Performance, security and privacy requirements create the need for a dedicated private network
E3. Globalization – firms and firms' activities become increasingly in a cross-national border base.	E3. Regulations on digitalization issues hinder geographical expansion
E4. Smaller firms have started to digitalize – a growing need for small scale "network as a service"	E4. Regulations hinder the emergence of new roles and the adoption of innovative business models by verticals
E5. Sufficient access and control over existing or new infrastructure and data	E5. There are stumbling blocks in terms of infrastructure(s) and access to data that hinder innovation by non-incumbents
E6. 5G research and industry visions drive and legitimize the market demand for 5G	E6. Current technology, architecture, operational and business models lock-in for telecom operators opposing 5G research and industry solutions
E7. Standardization lays the ground for dynamic solutions, collaborations, and business relationships	E7. Standardization processes are slow
E8. High culture for trust and collaboration across ecosystem actors	E8. No or limited culture for trust and collaboration across ecosystem actors
E9. Verticals experiment in-depth with the service/product portfolio before launched	E9. Limited organization experience or value (in terms of cost reduction, revenue increase etc.) in experimentation within the product/service lifecycle
E10. Strategic and operational concerns will be reduced due to increased performance control by customers, and isolation will be outweighed by new business opportunities	E10. Strategic and operational business concerns discourage the adoption of 5G technologies and services by verticals

4.2.2 Analysis for operation level ML2

In this section we perform the SWOT analysis for the ML2 operation level of the 5G-VINNI facility. We first mark the Internal and External points that apply to this level. More specifically, the internal points are evaluated and justified based on the interplay between vertical "customers" and the 5G-VINNI facility experienced so far during the project[13]. On the other hand, the External points are evaluated based on the findings of an online survey[14] (an overview of the survey analysis can be found in the Annex B.5) conducted between 1-31 of April 2019 so as to better understand the pain points that key industries face today, their propensity to experiment during product/service life-cycle and how the 5G ecosystem could help them innovate in a mutually beneficial way. The values

[13] Even though the values of the internal points are subjective and may be updated in the future based on new findings, special care was taken to reflect the authors' views. Obviously, higher values have a positive interpretation.

[14]The survey is available in the following url: https://www.5g-vinni.eu/5g-vinni-questionnaire-on-the-pain-points-that-european-industries-face-today_allin1/

assigned to both Internal and External points as well as a partition of these values to the corresponding qualitative criteria (i.e., opportunities, strengths, threats, and weaknesses) are depicted in Figure 23. With respect to this evaluation of Internal and External points we present and discuss a number of potential strategies and actions.

4.2.2.1 Internal points: justification of assigned values

I1. Performance (Value=4). 5G-VINNI virtualized environment is characterized by high-quality automation with respect to E2E service instantiation (network slice instantiation) and testing, online adaptation to the vertical customers' needs and recovery from potential failures. 5G-VINNI architecture and implementation promises the efficient, with respect to the customers' QoS requirements, operation of the facility by satisfying the customer SLAs and the targeted values on certain performance KPIs defined by 5G PPP, with respect to capacity, ubiquity, latency, reliability, service creation time, etc.

I2. Deployment Cost (value=1). CAPEX for deploying 5G-VINNI system is low compared to greenfield 4G setups (and in some cases incremental ones), since the network functions are running on general-purpose commodity servers. However, at this early stage of 5G deployments the cost of RAN equipment is not considered as low cost.

I3. Operational Cost (value=2). One of the main 5G-VINNI architecture design principle is the E2E virtualization of resource taking advantage of NFV technology. This allows for a low-cost automated network management, thus a low OPEX for on-boarding services and testing. However, at the early stage of the project the development of E2E MANO framework that allows the interworking of facility sites implementing different MANO framework will impose a start-up cost.

I4. Innovation potential (value=-1). In operation level ML2, 5G-VINNI is assumed to serve only verticals applications coming from ICT-19 funded projects and ESB-members. While openness and accessibility are two of the key design principles for 5G-VINNI, this limitation imposed on serving other customers will also limit the innovation potential of the platform. However, assuming that 5G-VINNI consortium members (Network Operators, vendors, etc.), ICT-19 funded projects and ESB can take advantage of the facility to innovate, the innovation cannot be considered as strongly unsustainable.

I5. Brand Name (value=1). 5G-VINNI consortium includes well-known vendors and operators, which helps in establishing a brand name. On the other hand, due to the limitation on the customers groups during ML2, it is unlikely for 5G-VINNI to be able to establish a strong brand name at this stage. Nevertheless, other 5G facility sites (e.g., other ICT17 projects) face similar issues and thus the outlook is positive.

I6. Stakeholders' collaboration (value=4). The collaboration among the 5G-VINNI members is guaranteed during the project lifetime and ML2 due to the consortium agreement and the management plan for mitigating relevant risks. Also, the sustainability of the platform for support ICT-19 funded projects is guaranteed by the ICT-17 fund. Under ML2 operation level 5G-VINNI does not seek for revenues, neither conduct pricing toward this direction. To this end, we assume that collaboration among the stakeholders of the 5G-VINNI facility, ESB members and ICT-19 funded projects is guaranteed.

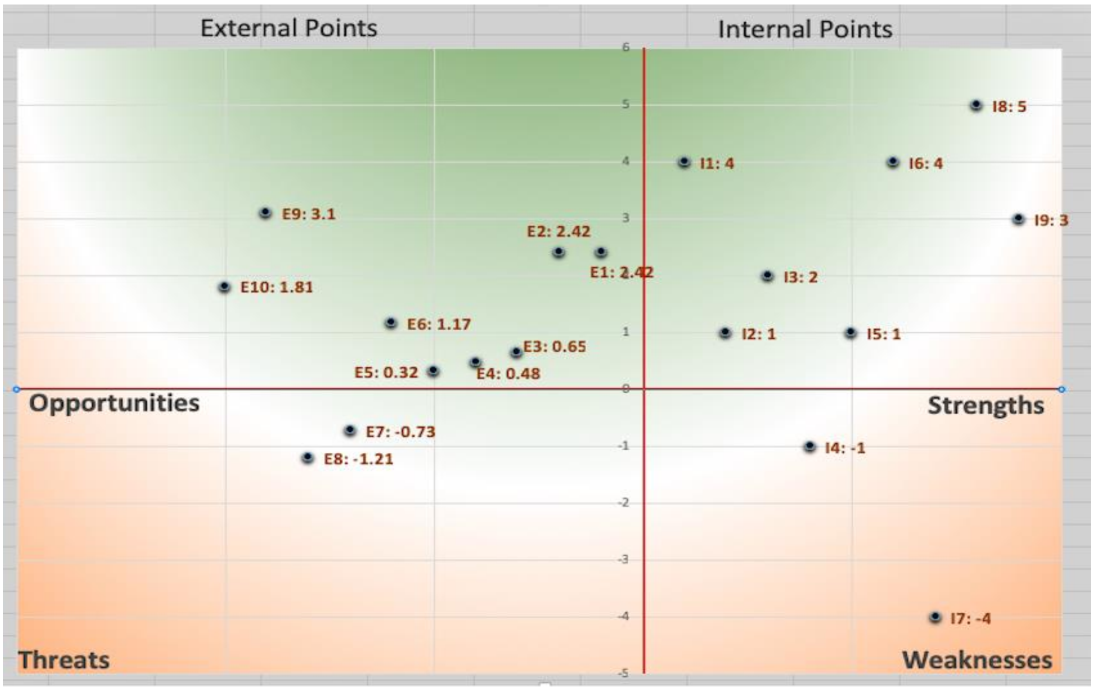

Figure 23: A partition of the values assigned to Internal and External points to qualitative criteria

I7. Facility growth-geographical expansion (value=-4). In operation level ML2, the 5G-VINNI facility is not expected to grow, since none of the individual sites is expected to interconnect with external sites. It is quite possible that an ICT-19 funded project may ask to interconnect an external facility site to 5G-VINNI but again this growth will be limited.

I8. Ability of managing large scale networks. (value=5) The Network Operators present in the consortium have great experience in managing large scale networks and critical applications. Furthermore, they are familiar with deploying new infrastructure and interacting with several market entities. Thus, we expect that this is a strong point for 5G-VINNI.

I9. Ability to exploit new technologies (value=3). One of key design principles for 5G-VINNI facility is the ability for each site to evolve both during and beyond the project's lifetime. Focusing on ML2, three of the planned releases (Release 1-3) of 5G-VINNI facility will happened during ML2. According to the plan, these releases will be backward compatible each of them introducing also additional functionalities and new technologies.

4.2.2.2 External points: an evaluation based on survey findings

As mentioned above a survey/questionnaire is conducted on the pain points that EU industries face today. Next, based on the answers of Questions 5-21 (denoted as Q5-Q21) of this survey, we provide an evaluation of the external points that applies on the ML2 operation level of the 5G-VINNI facility.

E1. Capacity of existing solutions to meet verticals' needs (value=2.42). Current communication solutions do not suffice to support the emerging requirements and trends towards digitalization. As we noticed (see Figure 24) the majority of survey participants (77%; it is the result of adding the positive answers, i.e., strongly and partly disagree) believe that the existing technologies cannot meet the mid-term requirements or that the advanced network quality, coverage and flexibility promised by 5G will have a significant effect on their industry. Most of them (61%) belong to small and medium-sized enterprises mainly from Smart cities and transportation, Utilities and Smart agriculture industries. Even though the number of customer groups that can be served during ML2 is limited, we anticipate that the funded ICT-19 projects will have developed interesting use-cases. Thus, this is an opportunity for 5G-VINNI.

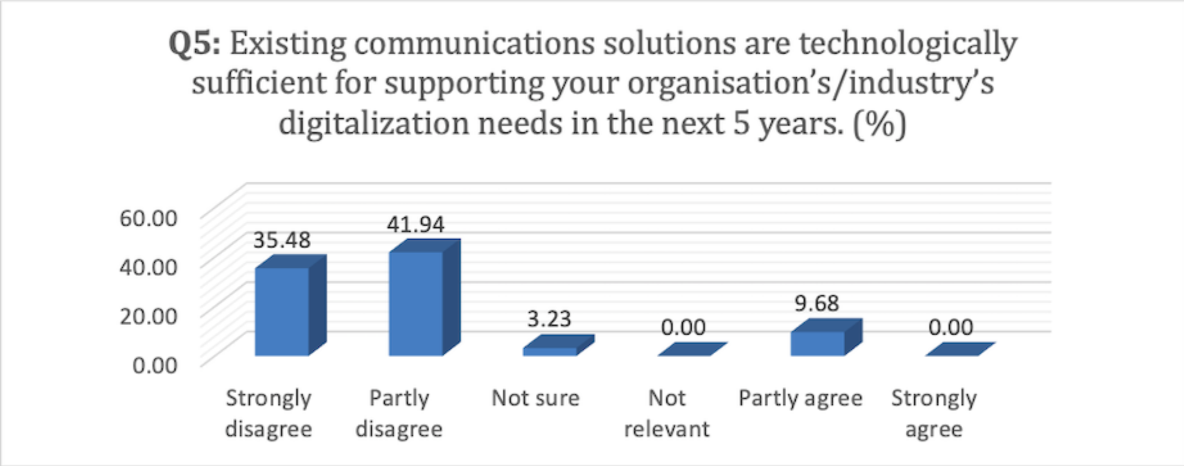

Figure 24: Survey answers regarding threats/opportunities from existing communications solutions

E2. Private networks (value=2.42). Private networks have become too expensive/ challenging for non-ICT actors to handle. The majority of participants (74%; it is the average value of the positive answers i.e., strongly and partly disagree in Figure 25 among questions/graphs Q8 and Q9), mainly from Smart cities and transportation and Smart agriculture industries, agree that 5G technologies will meet their performance requirements after some further validation or they are already confident that technical and isolation capabilities of 5G technologies together with increased control on network configuration, can meet their performance and security requirements. In particular, about half of participants to our small-scale online survey believe that the promises of network slicing technologies need to be validated, while most of them are optimistic. This is a great opportunity for 5G-VINNI facility, but the limitation with respect to customer groups during ML2 does not make this opportunity exploitable.

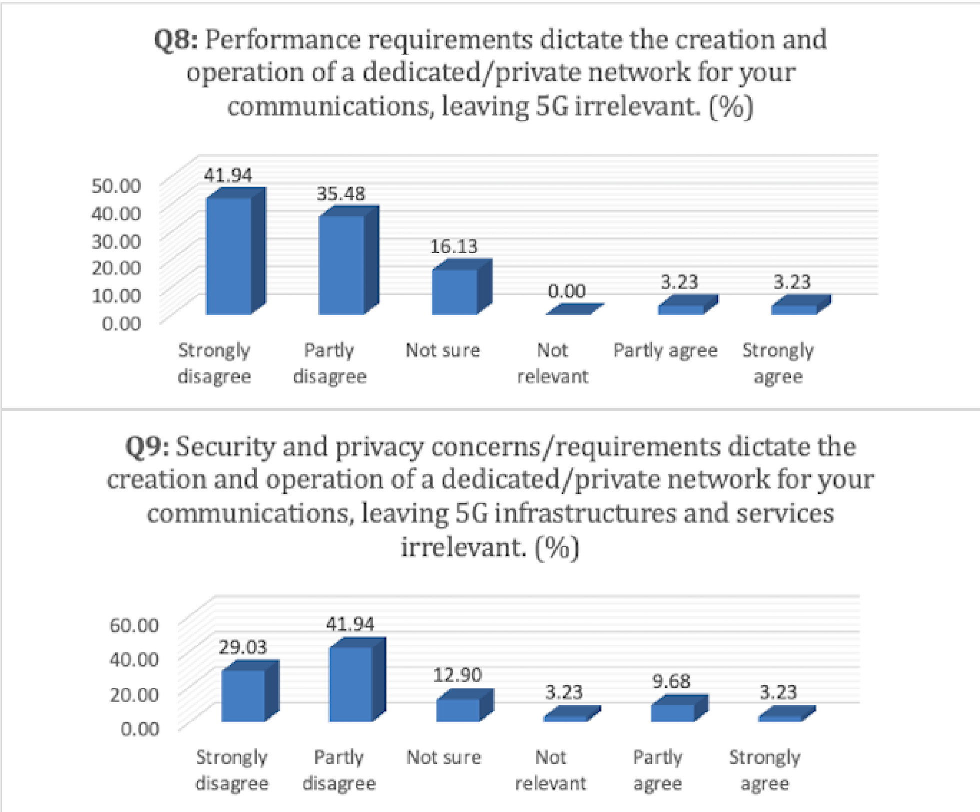

Figure 25: Survey answers regarding the threats/opportunities from Private networks

E3. Demand for advanced international networking services (value=0.65). A large number of the participants (42%; see Figure 26) agree that the future candidate geographical markets will require only moderate or minimal adaptation to their service/product portfolio in order to comply with regulation (such as on data management). However, there are quite a few participants that are not sure (16%) or they believe that regulations (on digitalization issues) hinder geographical expansion (29%). 5G-VINNI can take advantage of this during the ML2 operation level since interworking among different facility sites will be possible. However, during ML2 independent firms that not belong to ICT-19 consortia or ESB will not be possible to be served.

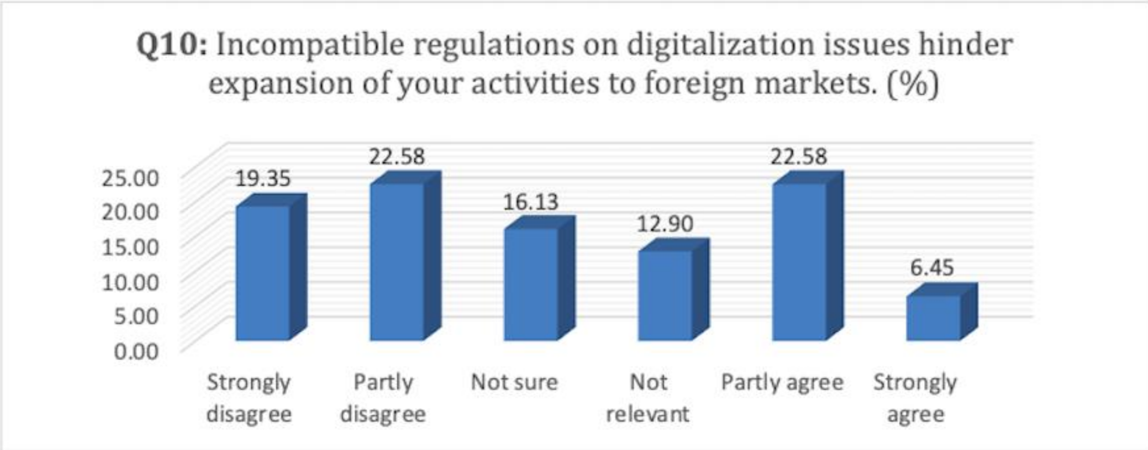

Figure 26: Survey answers regarding threats/opportunities from international networking services

E4. Innovation and Regulation (value=0.48). Like in case of E3, responses are quite balanced. There are many participants (42%, see Figure 27), most from small medium-sized industries (62%), which agree that there are no or only some regulatory constraints on the roles and business models they can adopt. On the other hand, some of the participants are not sure (16%) or they believe that some of the new roles and innovative business models they explore are blocked/delayed by regulation or competition authorities (35%); the latter mainly belong to Manufacturing and Utilities industries. It seems that smaller firms are usually more agile in terms of redesigning their business processes and adopting new technologies, but struggle in funding breakthrough technologies. This is seen as an opportunity for the firms that participate in ICT-19 consortia.

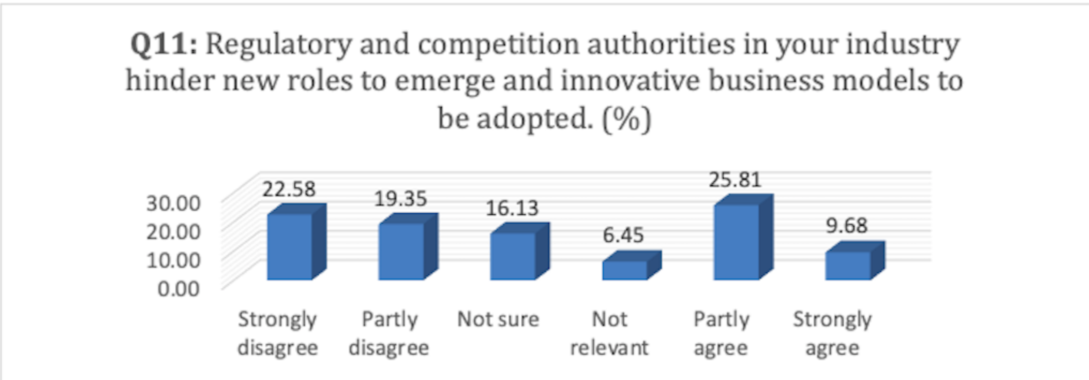

Figure 27: Survey answers regarding the threats/opportunities from Regulation

E5. Innovation and collaboration (value = 0.32). This external aspect was very controversial as 33% of participants (see Figure 28; it is the average value of the positive answers i.e., strongly and partly disagree among the 3 questions/graphs Q12, Q13 and Q14), mostly from Smart cities and transportation and Smart agriculture industries (50%), agree that they will have access and sufficient control to all new or existing infrastructure(s) or that the critical mass of required technologies will be reached. On the other hand, 34%of participants believe that access and control to existing or new infrastructures is a bottleneck, e.g., the rents asked will render their new business activities unviable, or they will have to subsidize/deploy the required technologies for reaching the critical mass, while 27% of the participants are not sure. So, this is unclear whether it is an opportunity or threat in general, although some industries are more likely to become early adopters. Nevertheless, almost half of respondents in Question 12 believe that their innovation potential is limited today due to lack of 5G testbeds and thus 5G-VINNI experimentation-as-a-service can fill this gap.

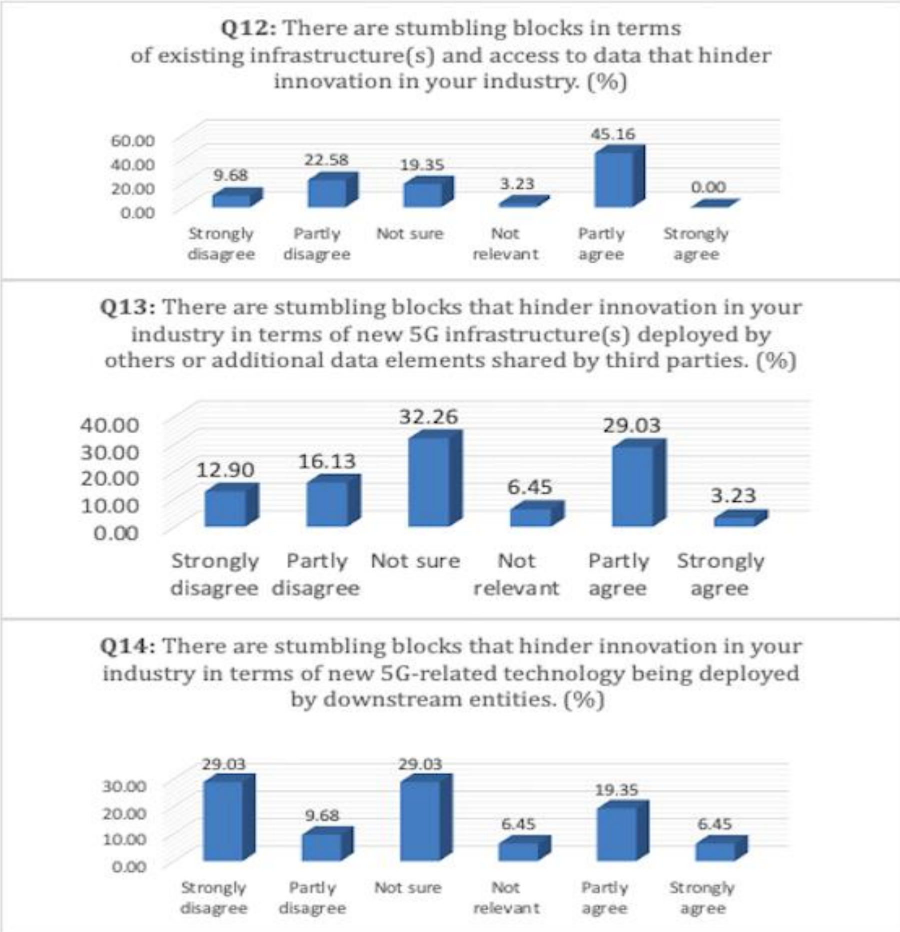

Figure 28: Survey answers regarding the threats/opportunities from collaboration

E6. Shared Vision (value=1.17). It is interesting to note (in Figure 29) that most of the participants (68%; it corresponds to the positive answers, i.e., strongly and partly disagree of the upper question/graph Q16), mainly from Smart cities and transportation, Media/Entertainment and Smart Agriculture industries as also by other industries, e.g. Telecommunications, Advisory services, Events, are either very confident or simply believe that industry forums and associations enable consensus building between industry members while setting future directions (including pre-standardisation, best practices). However, many participants are either not sure (29%; this value corresponds to the lower graph/question Q17 of Figure 29) or they believe that most market reports provide long-term business models (35%; it is the total percentage of negative answers, i.e., partly and strongly agree in the lower question/graph Q17 of Figure 29). Thus, a fair share of respondents seems to put more trust on industry members' views rather than external consultants.

The above can be better observed in the contingency Table 9 which presents the % percentage of each possible pair of answers in questions Q16 and Q17 (mapped with E6) where quite a few respondents that have positive opinion (strongly disagree or strongly agree) in Q16 have a negative opinion (mainly partly agree) in Q17.

Table 9: A contingency table for questions Q16, Q17 that capture E6

Q16 \ Q17	Strongly disagree	Partly disagree	Not sure	Not relevant	Parlty agree	Strongly agree
Strongly disagree	12,90	9,68	3,23	3,23	9,68	0,00
Partly disagree	0,00	3,23	6,45	0,00	16,13	3,23
Not sure	0,00	0,00	16,13	3,23	0,00	0,00
Not relevant	0,00	0,00	0,00	0,00	0,00	0,00
Partly agree	0,00	3,23	0,00	0,00	6,45	0,00
Strongly agree	0,00	0,00	3,23	0,00	0,00	0,00

The above logic can be translated to 48% of participants (by averaging the positive answers of the two questions/graphs of Figure 29 which agree that 5G research and industry visions drive and legitimize the market demand for 5G, while 24% have an opposite view. So we see this as an opportunity and expect that also the 5G-VINNI, ESB and ICT-19 funded projects' participants are open to new business models.

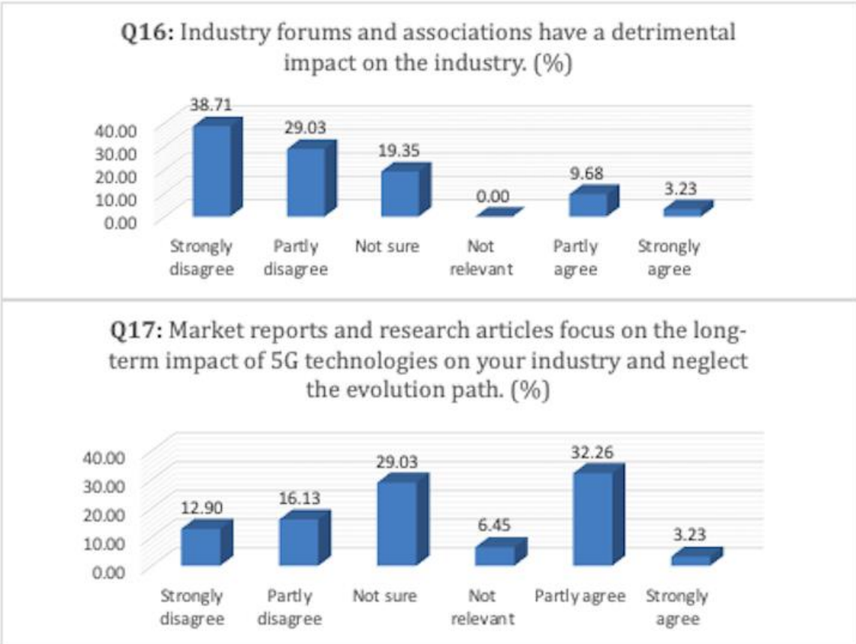

Figure 29: Survey answers regarding the threats/opportunities from Shared Vision

E7. Standardization process (value=-0.73). According to the survey findings, the narrow majority of the participants (52%, see Figure 30), from varying industries and organization size, agree that standardisation organizations are either good in identifying emerging needs but slow in addressing them or slow in both identifying and addressing emerging needs, while 29% believes the opposite. Although clear progress has been made during the last years, standardization processes are still slow and this is considered to be a threat.

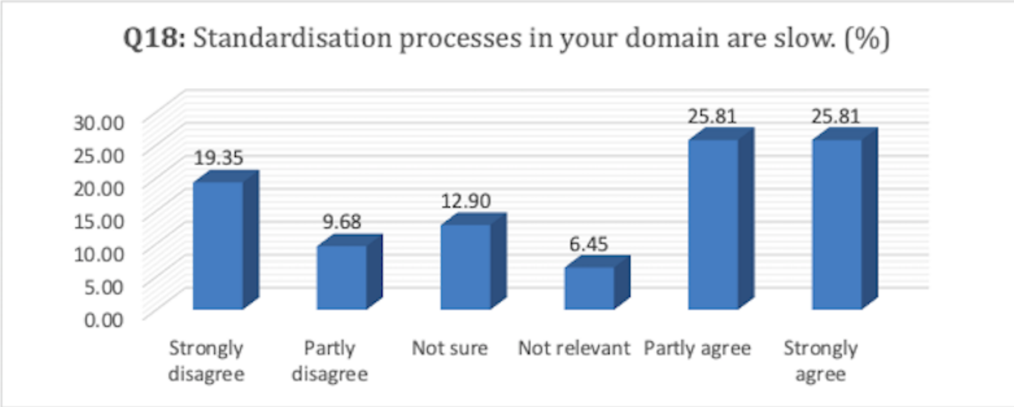

Figure 30: Survey answers regarding the threats/opportunities from Standardisation

E8. Culture for trust and collaboration across 5G actors (value=-1.21). Most of the survey participants (61%, see Figure 31), from a broad range of industries, believe that some additional mechanisms or new Service Level Agreements (SLAs) are needed for building trust between ecosystem actors (e.g., some commonly agreed operational policies and mechanisms should be in place for aligning the incentives of the rest of the entities), while only 29% have a different opinion. The 5G value network involves multiple actors that implement traditional Telco roles but also new ones that have emerged due to the digitalization of vertical sector, virtualization Network Infrastructure and softwarization of Network Operations. As described in Section 3, there are many cases where the 5G performance and business requirements will require the collaboration of actors belonging to different categories, thus absence of trust-enabling mechanisms is considered a threat.

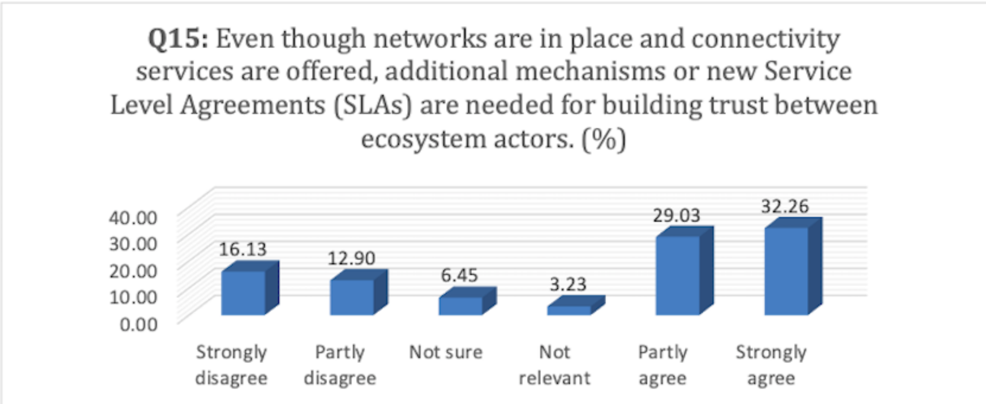

Figure 31: Survey answers regarding the threats/opportunities from culture for trust

E9. Vertical experimentation with the service/product portfolio (value = 3.1). Based on the survey findings, the majority of the participants (82%; it is the average value over the positive answers, i.e, strongly and partly agree of the three graphs/questions Q19, Q20 and Q21 of Figure 32) agree that their organization (mainly from Utilities, Media/Entertainment and Smart Agriculture industries) is comfortable and interested in running technical trials and business experiments throughout service/product lifecycle, as well as that these experiments are valuable e.g., in terms of reduced costs, increased revenues or new revenue sources.

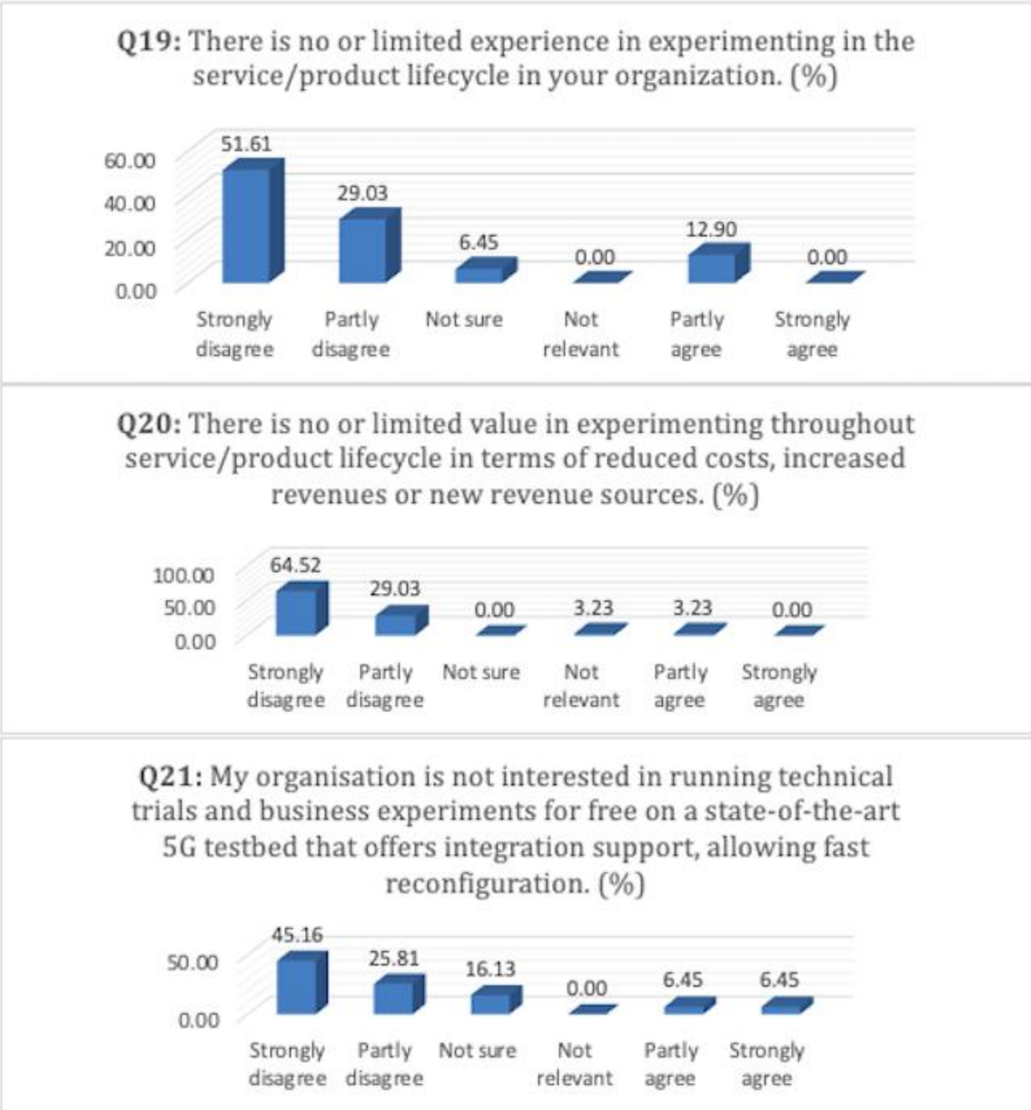

Figure 32: Survey answers regarding the threats/opportunities from Vertical experimentation

Table 10: Contingency tables for questions Q19, Q20 and Q20, Q21 that capture E9.

Q19 \ Q20	Strongly disagree	Partly disagree	Not sure	Not relevant	Parlty agree	Strongly agree
Strongly disagree	41,94	9,68	0,00	0,00	0,00	0,00
Partly disagree	12,90	16,13	0,00	0,00	0,00	0,00
Not sure	3,23	3,23	0,00	0,00	0,00	0,00
Not relevant	0,00	0,00	0,00	0,00	0,00	0,00
Partly agree	6,45	0,00	0,00	3,23	3,23	0,00
Strongly agree	0,00	0,00	0,00	0,00	0,00	0,00

Q20 \ Q21	Strongly disagree	Partly disagree	Not sure	Not relevant	Parlty agree	Strongly agree
Strongly disagree	35,48	16,13	6,45	0,00	3,23	3,23
Partly disagree	9,68	9,68	9,68	0,00	0,00	0,00
Not sure	0,00	0,00	0,00	0,00	0,00	0,00
Not relevant	0,00	0,00	0,00	0,00	0,00	3,23
Partly agree	0,00	0,00	0,00	0,00	3,23	0,00
Strongly agree	0,00	0,00	0,00	0,00	0,00	0,00

The above discussion can be further confirmed by the contingency Table 10. As we can observe in both tables the respondents have very similar positive opinions (most of them strongly or partly disagree) in all three questions which capture the vertical experimentation with the service/product portfolio external point; in fact, most of them disagree in all questions and the majority that disagree in Q20, disagree also in Q19 (41,94%) and in Q21 (35,48%). Thus, this is considered to be an opportunity for 5G-VINNI.

E10. Strategic and operational concerns (value = 1.81). As most of the survey participants agree (60; it is the average value over the positive answers, i.e., strongly and partly disagree of the 2 questions/graphs Q6 and Q7 of Figure 33) of the 2 questions/graphs) strategic concerns will be reduced due to increased performance obtained, control exercised by customers, as well as, isolation , while their organizations (whose industry categories and sizes vary) will be ready to adopt 5G technologies and services when these are offered, even though facing some minor operational challenges. Only a few participants (19%) have an opposite opinion, while even fewer (16%) are not sure. This is considered as an opportunity for 5G-VINNI.

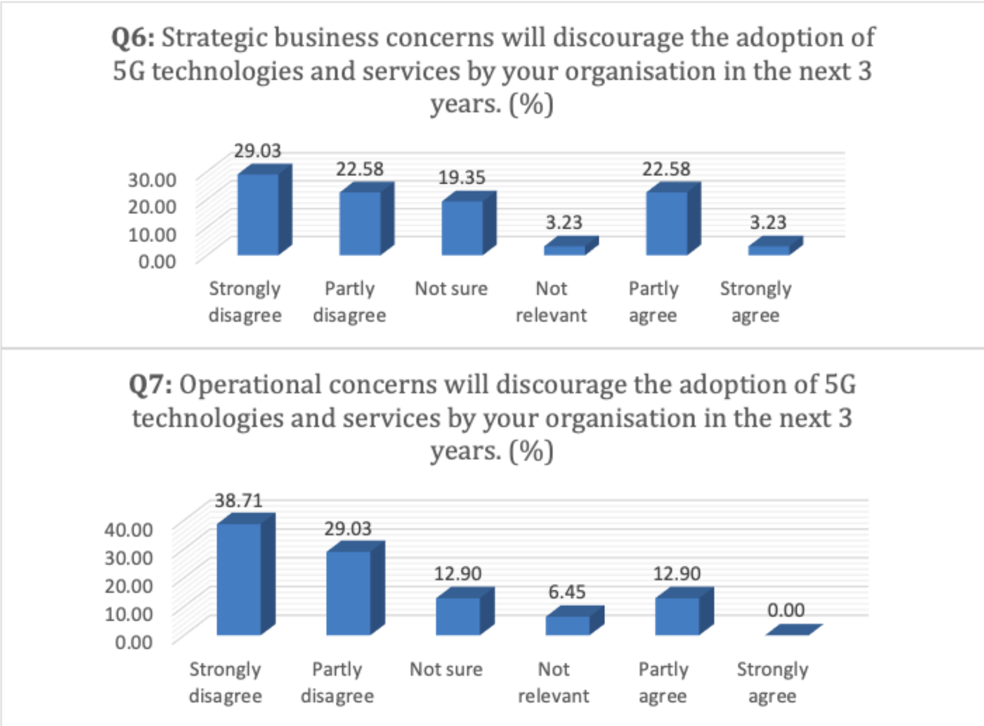

Figure 33: Survey answers regarding threats/opportunities from Strategic and operational concerns

4.2.2.3 Potential Strategies and Actions

Next we provide a brief overview of potential strategies (see Figure 34 for a graphical representation) based on the above evaluation of the Internal and External aspects.

4.2.2.3.1 Attack Strategies (Strengths & Opportunities)

(**S1:I1+E1+E4+E2**): The technical performance superiority of 5G-VINNI facility, gives 5G-VINNI the potential to exploit the high interest of some vertical industry sectors for offering value-added/assured quality services to their customers. In fact, 5G-VINNI should collaborate with verticals in order to design technical solutions that are able to meet vertical-driven KPIs. In addition, 5G-VINNI can take advantage of the opportunity that small firms are adopting the “network as a service” model in order to design tailored end-to-end slice solutions for certain verticals.

(S2:I1+I8+I9+E2): The fact that private networks (defence, emergency, health) have become too expensive/challenging for non-ICT actors to handle, revitalize the traditional strength of high performance and professionality, and ability to exploit new technologies are called for.

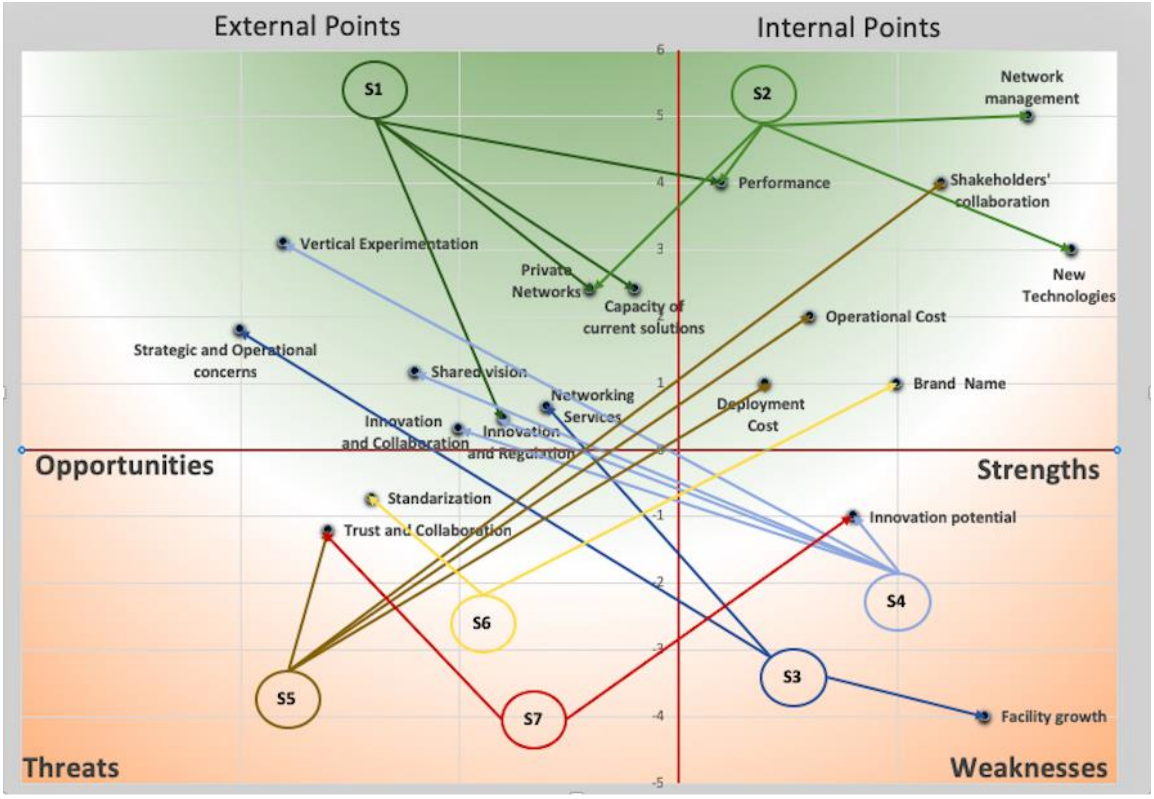

Figure 34: Potential strategies from every category

4.2.2.3.2 Reinforce Strategies (Weaknesses & Opportunities)

(S3: I7+E10+E3): The ability to geographically expand the facility is low, hindered by incompatible regulations. On the other hand, strategic concerns will be reduced due to increased performance control by customers and isolation will be outweighed by new business opportunities. Thus, expanding the scope of 5G-VINNI to additional customer segments in subsequent maturity levels is important.

(S4:I4+E9+ E6+ E4+ E5): Verticals have experience and see value in running trials and they seem to have reached a consensus on future directions. At the same time neither regulation nor lack of collaboration are roadblocks for some industries. Even though 5G-VINNI facility site is not open to all interested parties during ML2, the innovation potential will be reinforced in ML4.

4.2.2.3.3 Develop Strategies (Strengths & Threats)

(S5:I2+I3+ I6+E8): Taking advantage of the commitment from both private and public actors to invest in 5G-VINNI, experiments performed by vertical industries in ML2 will be subsidized. This means that 5G-VINNI facility promotes the stakeholders' collaboration, the openness of 5G stakeholders to novel business models and the emerging culture of trust across them. Nevertheless, 5G-VINNI has to devise and validate novel collaborative business models and "all-win" mechanisms that increase the market stability and accelerate the innovation in later stages.

(S6: I5+E7): Given that 5G-VINNI consortium includes vendors and operators with a strong brand name that are also highly involved in standardization bodies, 5G-VINNI can push the standardization process in Europe.

4.2.2.3.4 Avoid Strategies (Weaknesses & Threats)

(S7:I4+E8): The fact that during operation level ML2 the number of customer groups is restricted, limits the innovation potential negatively. This is unfortunate, since the opportunities are driven by verticals' and partners' eagerness to digitalize. In this respect, it is no longer enough to deliver high performance and acceptable cost levels (I1-3). The innovation capacity must be reinforced, which is expected to take place in later 5G-VINNI maturity levels. The positive effects of innovative products and business processes on revenues and costs (together with attractive business models building upon the 5G platform ecosystem and "all-win" market mechanisms) will build and improve the culture for collaboration and trust between 5G actors (E8).

4.2.3 Analysis for operation level ML3 and ML4

Figure 35 presents the SWOT analysis for the ML3 operation level of the 5G-VINNI facility. Note that we assume that the external aspects remain the same as in ML2. Thus, we justify the selected values for the internal aspects only.

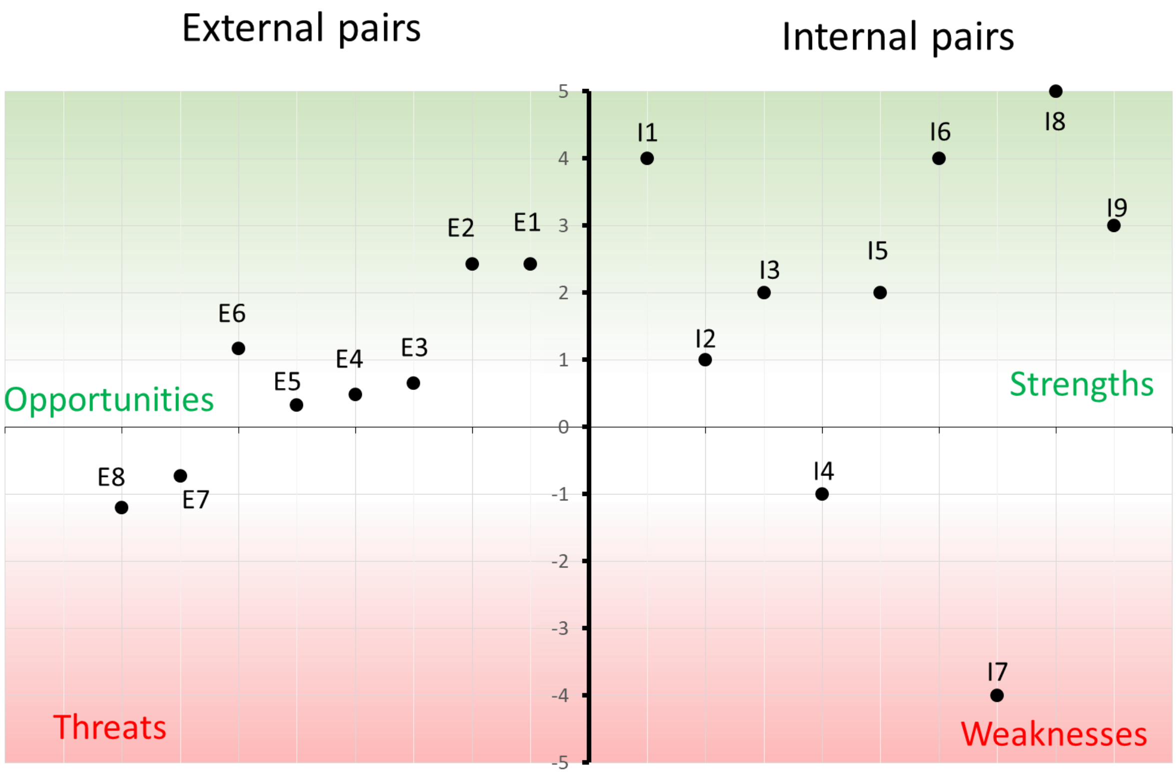

Figure 35: SWOT analysis for the ML3 operation level of the 5G-VINNI facility

Justification of assigned values

1. **Performance (Value=4).** As in ML2.
2. **Deployment Cost (value=1).** As in ML2.
3. **Operational Cost (value=2).** As in ML2.
4. **Innovation potential (value=-1).** As in ML2.
5. **Brand Name (value=2 instead of 1)**. We expect that 5G-VINNI will have established a stronger brand name during ML3 compared to ML2, stemming from the anticipated success in running and supporting a wide range of experiments during the lifetime of 5G-VINNI.
6. **Stakeholders' collaboration (value=4).** As in ML2.
7. **Facility growth-geographical expansion (value=-4).** As in ML2.
8. **Ability of managing large scale networks. (value=5)** As in ML2.
9. **Ability to exploit new technologies (value=3).** As in ML2.

Figure 36 presents the SWOT analysis for the ML4 operation level of the 5G-VINNI facility. As for ML3, the external aspects remain the same and thus we only focus on the internal aspects only.

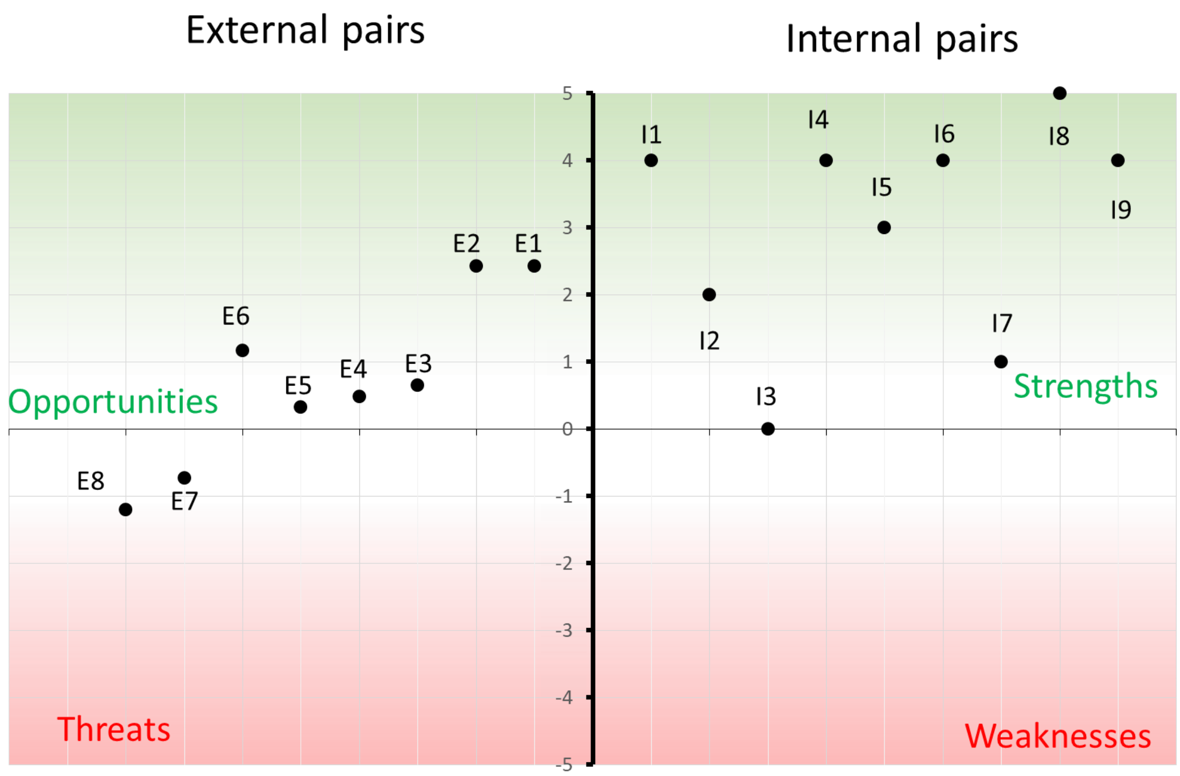

Figure 36: presents the SWOT analysis for the ML4 operation level of the 5G-VINNI facility

Justification of assigned values

1. **Performance (Value=4).** As in ML2, 3.
2. **Deployment Cost (value=2 instead of 1).** CAPEX for extending 5G-VINNI facility sites is not expected to be lower compared to ML2, ML3, however we anticipate that the proposed business models (e.g., network sharing arrangements) together with increased demand will mitigate this issue and allow further expansion.
3. **Operational Cost (value=0 instead of 2).** As the number of experimenters increase, we expect that the costs for customer support will increase.
4. **Innovation potential (value=4 instead of -1).** The innovation potential of 5G-VINNI is expected to be significantly improved during the last phase as any interested party will be able to setup and run experiments.
5. **Brand Name (value=3 instead of 2)**. We expect that 5G-VINNI will keep improving its brand name during this phase as soon as performance levels remain at high levels and costs are attractive.
6. **Stakeholders' collaboration (value= 4).**We expect that the proposed business models together with federation mechanisms defined will result in "all-win" scenarios and thus contribute to smooth collaboration amongst the involved actors in 5G-VINNI. Nevertheless, we cannot exclude the possibility of a partner leaving the consortium for other strategic or operational reasons. Even in this pessimistic scenario, we expect that other actors will be willing to join and thus no negative effects are expected.
7. **Facility growth-geographical expansion (value=1 instead of -4).** We anticipate that facility sites will be extended significantly given that network operators will have already rolled out

commercial 5G networks and offering experiments-as-a-service will require few additional resources (see “operational costs” item above).

8. **Ability of managing large scale networks. (value=5)** As in ML2, 3.
9. **Ability to exploit new technologies (value=4 instead of 3).** We expect that 5G-VINNI members will have increased ability in adopting new technologies as a result of the knowledge gained during the first phases.

4.3 Innovation potential

According to Oslo Manual 2018 (OECD/Eurostat, 2018), there are two types of business[15] innovations; **product innovations** (new or improved good or service) and **business process innovations** related to business functions. In both cases, these innovations a) need to differ significantly from the existing ones and b) must be introduced on the market/brought into use by the firm. Given the second requirement we can say that 5G-VINNI is important for validating the potential of innovative solutions and identifying any adjustments that should take place as early as possible.

Product innovations must provide significant improvements to one or more product characteristics or performance specifications. Relevant functional characteristics include: quality, technical specifications, reliability, durability, economic efficiency during use, affordability, convenience, usability, and user friendliness.

Business Process Innovations cover the following aspects:

- Production of goods or services: Activities that provide increased observability and control when transforming inputs into goods or services, including engineering and related technical testing, analysis and certification activities to support production.
- Distribution and logistics: transportation and service delivery, warehousing and order processing.
- Marketing and sales: marketing methods (including advertising and market research), pricing strategies, sales and after-sales activities.
- Infrastructure provision and maintenance (incl. Information and communication systems).
- Administration and management, such as strategic decision-making, human resources management (training and education, staff recruitment, workplace), procurement of necessary inputs, as well as, managing external relationships with suppliers and partners.
- Product and business process development, which includes activities to scope, identify, develop, or adapt products or a firm's business processes.

Both types of innovation are triggered by one or more business objectives that can be categorised as follows:

- Markets for the firm’s products: upgrade goods or services, expand the range of goods or services, create new markets, enter new markets or adapt existing products to new markets, increase or maintain market share, increase the reputation, brand awareness, or visibility of goods or services, comply with market regulations, adopt standards and accreditation;
- Production and delivery: upgrade outdated process technology or methods, improve quality of goods or services, improve flexibility for producing goods or services, increase speed of producing goods or delivering services, reduce labour costs per unit of output, reduce material, energy costs or operating costs per unit of output, reduce time to market;

[15] Innovation by non-profit organisations, households and individuals is considered out of scope.

- Business organisation: improve capabilities for absorbing, processing and analysing knowledge, improve sharing or transfer of knowledge with other organisations, improve the efficiency or function of the firm's value chain, improve communication within the firm, improve or develop new relationships with external entities (other firms, universities, etc.), increase business resilience and adaptability to change, improve working conditions, health or safety of the firm's personnel, implement a new business model, contribute to the development of standards;
- Economy, society or environment: reduce negative environmental impacts/deliver environmental benefits, improve public health, safety or security, improve social inclusion, improve gender equality, improve quality of life or well-being, comply with mandatory regulations, comply with voluntary standards.

In the rest of this section we will perform a qualitative analysis on the expected potential of 5G-VINNI, and 5G in general, to industries and consequently users and society. The approach followed appears in Figure 37 (based on European Commission (2014)). 5G-VINNI capabilities allow and support vertical industries in evaluating and launching innovative business processes and products. These innovations were identified together with vertical industries' representatives that expressed interest in using 5G-VINNI E2E facility.

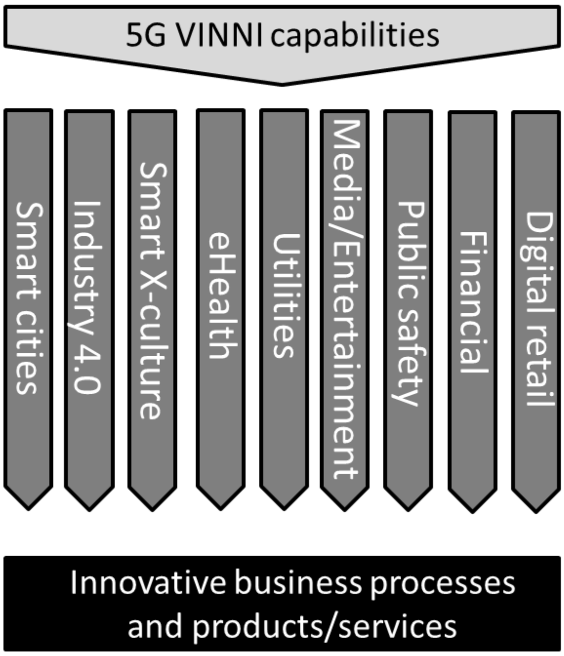

Figure 37: Framework: expected potential of 5G to industries and consequently users and society

4.3.1 Innovation potential of Primary industry verticals (Agriculture/Aquaculture)

The innovation potential in the Agriculture/Aquaculture domain is mostly related to business processes. The Table 11 gives an overview of innovative business processes that are enabled by 5G.

Table 11: Innovation potential of Primary industry verticals

Innovation example	Innovation type	Business function/ Functional characteristics	Expected benefits
IoT soil sensing deployments	Increased observability	Production of goods or services	Provides faster reaction time
Early crop disease identification	Increased observability	Production of goods or services	Provides faster reaction time

Water quality monitoring	Increased observability	Production of goods or services	Provides faster reaction time
Livestock health	Increased observability	Production of goods or services	Provides faster reaction time
Precision farming	Increased control	Production of goods or services	Higher productivity of the fields and a more controlled production and rationalized and sustainable use of resources such as water, fertilizers or herbicides.
Automated irrigation systems	Increased control	Production of goods or services	Improve operational efficiency, maximize yield, and minimize wastage
Advanced feeding/breeding approaches	Increased control	Production of goods or services	OPEX reductions related to feed cost, and improved fish health
Remote maintenance	Increased control	Infrastructure provision and maintenance	Reducing failure of machines on the field increase farmers' revenue due to less disruptions
Remote assistance in treatment	Increased control	Production of goods or services	Early problem detection and instant suppressive reactions are the cornerstones for eliminating pests, controlling diseases, and confining quarantine pathogens before further expansion.
Augmented Reality (AR) tools that visualise underground infrastructures	Avoidance of damages	Infrastructure provision and maintenance	Avoid damages that can result in high costs for restoring infrastructure and foregone revenues from lost crops/livestock

4.3.2 Innovation potential of Public Safety vertical industry

Even though the main entities involved in public safety are not profit-seeking, we could argue that the innovation potential is related to business processes. The following table gives an overview of these innovative business processes that are enabled by 5G.

Table 12: Innovation potential of Public Safety vertical industry

Innovation example	Innovation type	Business function/ Functional characteristics	Expected benefits
Proactive and context-aware anomaly detection in urban environment	Increased observability	Production of goods or services	Improved threat detection and real-time alerting, faster reaction time, better decision making using more descriptive analytics
Proactive and context-aware anomaly detection in urban environment	Increased control	Production of goods or services	Improved threat detection and real-time alerting, faster reaction time, better decision

			making using more descriptive analytics
Reactive and context-aware anomaly analysis and reaction	Increased observability	Production of goods or services	Better decision making using more descriptive analytics
Incident reconstruction	Increased observability	Production of goods or services	Efficient and complete forensic analysis

4.3.3 Innovation potential of Smart cities and transportation

Table 13: Innovation potential of Smart cities and transportation

Innovation example	Innovation type	Business function/ Functional characteristics	Expected benefits
Smart traffic management based on real-time information	Improved service	Quality and convenience	Reduced congestion, less pollution, increased productivity
Preferential treatment to emergency units	New service	Reliability	Reduced response time
Dynamic bus routing	New service	Convenience, user friendliness and usability (for riders), economic efficiency during use (for both riders and public transportation company)	Reduced rider wait times, personalised hop-on/off, efficient bus inventory, more attractive public transport services
Smart parking	Improved service	Quality, convenience, user friendliness and usability	Reduced congestion, less pollution, increased productivity
Emergency warning systems	Improved service	Reliability	Reduced alert creation time (e.g., using 5G flood sensors for identifying flooding and avoiding flooded areas)
Fully autonomous cars (level 5) based on V2X paradigm (e.g., vehicle-to - vehicle communications)	Improved service	Reliability, Quality, convenience, economic efficiency during use, user friendliness and usability	Less accidents, Reduced congestion, increased productivity

4.3.4 Innovation potential of Industry 4.0

Table 14: Innovation potential of Industry 4.0

Innovation example	Innovation type	Business function/ Functional characteristics	Expected benefits
Smart digital engineering	Activities to improve design cycles	Product and business process development	Direct feedback from the manufacturing environment to design of tools
Smart production planning and management	Warehousing and order processing	Distribution and logistics	Increase quality by increased productivity
Autonomous manufacturing	Increased control	Production of goods or services	Reduction in cost and time-to-market
Collaborative robotics	Increased control	Production of goods or services	Improved product quality and personalization

Integrated planning and monitoring	Marketing and sales	Marketing and sales	Adaptation to demand in *real-time*
Smart maintenance and service	Procurement of necessary inputs	Administration and management	Reduced maintenance costs
Smart maintenance and service	Spate part logistics	Distribution and logistics	Reduced downtime periods
Smart maintenance and service	Fault diagnosis and predictive maintenance	Infrastructure provision and maintenance	Prescriptive design and operations

4.3.5 Innovation potential of eHealth industry

Table 15: Innovation potential of eHealth industry

Innovation example eHealth	Innovation type	Business function	Expected benefits
Access to patient records on mobile device – on/off hospital site	New service	Service quality, Reliability, Usability, Affordability	Service quality
Hospital asset tracking and management	Resources management	Administration and management	Keep track of all "things" in hospital
Hospital inventory management	Resources management	Infrastructure provision and maintenance	Process: efficiency in logistics
Management organ donation	Transportation and service delivery	Distribution and logistics	Expand the range of service
Robotics - Remote surgery	Remotely assisted surgery	Quality, reliability, economic efficiency during use, affordability, convenience	Upgrade service Expand the range of service
Access to digital twins (video/3D) of patients	New service	Reliability, user friendliness	Upgrade service
Monitoring patients on mobile devices, off hospital site	New service	Quality, reliability, economic efficiency during use, affordability, convenience	Expand the range of service
Life style prevention	New service	Quality, reliability, economic efficiency during use, affordability, convenience	Upgrade service
Assisted living in chronic scenarios	Improved service	Quality, reliability, economic efficiency during use, affordability, convenience	Expand the range of service
Smart pharmaceuticals	Improved service	Quality, reliability, economic efficiency during use, affordability, convenience	Upgrade service
Remote interventional support	Improved service	Quality, reliability, economic efficiency during use, affordability, convenience	Upgrade service

4.3.6 Innovation potential of Utilities

The innovation potential in utilities, especially in energy utilities domain, is mostly related to business processes but it can also impact on the capacity of providing new services to the end customers. The following table gives an overview in particular of the innovative services enabled by 5G empowered by the adoption of innovative technologies solutions (NVF, SDN, cloud native application etc.), taking into account that the innovation potential about processes is related to the possibility to pass from a centralised to an decentralised way to work for providing services to end customers.

Table 16: Innovation potential of Utilities

Innovation example	Innovation type	Business function/ Functional characteristics	Expected benefits
Predictive Maintenance for utility infrastructures using drone	Proactive maintenance	Infrastructure provision and maintenance	Improve the efficiency of the utility infrastructure maintenance. Reduce maintenance cost.
Real time Demand Response for frequency regulation	Improved services	Reliability, Quality and usability	Improve communication making it in real time
5G enabled Smart Meters	Improved services	Production of goods or services	Improve communication making it in real time
New energy services based on 5G enabled Smart Meters	New service	Quality, affordability, convenience, usability and user friendliness	Improved real time communication.

4.3.7 Innovation potential of Media/Entertainment industry

The innovation potential in media/entertainment industry domain is mostly related to the provision of new or improved services, but we can envisage also improvements in terms of business processes. The following table is an overview in particular of the innovative services enabled by 5G empowered by the adoption of innovative technologies solutions (NVF, SDN, cloud native application etc.). The whole 5G ecosystem and 5G technologies may have a deep impact on the modality to provide services to end customers and consequently on the current business processes.

Table 17: Innovation potential of Media/Entertainment industry

Innovation example	Innovation type	Business function/ Functional characteristics	Expected benefits
High quality video streaming	Improved services	Quality, reliability, economic efficiency during use, affordability, convenience	Delivering new capabilities to media service providers by distributing UHD content (4K and 8K) with an optimal consumption of resources
Smart and Remote media production	Flexibility	Production of goods or services	To provide broadcasters with ad-hoc, scalable, flexible and time-saving production mechanisms leveraging professional and user-generated remote media content.
Immersive games	Improved services	Quality, reliability,	Ensuring Quality of

		economic efficiency during use, affordability, convenience	Experience for real-time multi-party applications.

4.3.8 Innovation potential of financial industry

Table 18: Innovation potential of financial industry

Innovation example	Innovation type	Business function/ Functional characteristics	Expected benefits
Mobile Trading and payments	Improved Service	Convenience, usability, user friendliness, reliability	Increased volume of transactions on-the-go, backup solution in case of landline communications failure
Remote teller	Improved Service	Users: convenience, usability, user friendliness	Personalized remote customer service on-the-go
Multi-layered authentication	Improved Service	Reliability, convenience, usability, user friendliness	Reduced false negatives in customer authentication by aggregating biometric data from different user's devices
Open banking	Improved Service	Reliability, economic efficiency during use	Ultra-Low latency and virtualization of 5G will support third-party applications in using APIs to access banks' databases

4.3.9 Innovation potential of Digital retail industry

Table 19: Innovation potential of Digital retail industry

Innovation example	Innovation type	Business function/ Functional characteristics	Expected benefits
Channel digitisation	Improved service	Customers: convenience, usability, reliability	Moves the experience of dealing with customers to digital channel(s). More timely to market, extra customisation, faster interactions, improved market insight.
Omnichannel	Improved service	Customers: convenience, reliability, seamless experience	Provides linked processes and data for multi-channel (web, social media, phone, text, etc.) interactions between retailers and their customers.
Digital supply chain	Improved service	Retailers: improved time to market, supply reliability	Provides strong links between retailers and their supply chains. Reduces

			supply timelines, enables just-in-time delivery.
Digital premises	Improved service	Customers: convenience, seamless experience	Integrates the convenience of the digital channel to the touch/feel benefit of the in-person experience.
Automated check-out	Improved service	Customers: convenience	Uses monitoring, remote scanning, sensor technology and AI to eliminate the need for item scanning and queuing.
Real-time pricing	Improved service	Customers: cost reduction	Allows real-time price comparison and spot price reduction based on 360-view of the market
Interactive store fronts/premises	Improved service	Customers: convenience, personalisation	Use of personalisation that allows customers to interact with store fronts and in-premise displays which customises their shopping experience
Virtual product usage	Improved service	Customers: try-before-you-buy	Use of Augmented Reality (AR) / Virtual Reality (VR) to present customer with a virtual experience of usage the purchased product (e.g., clothes, vehicles, etc.)

4.3.10 Conclusions on the innovation potential offered by 5G

We identified 58 families of use-cases in total for these vertical industries. Figure 38 presents a high-level overview of these results. More than half of candidate innovations were classified as product innovations that meet candidate customers' requirements while serving the vertical enterprises' needs for improved goods or services, new offers for establishing new markets or entering to existing ones. The rest innovations were associated to improved business processes for upgrading outdated processes, technology or methods, reducing operational costs and waste per unit of output, reducing time to market by improving capabilities for absorbing, processing and analysing knowledge, as well as integrating processes with other organisations.

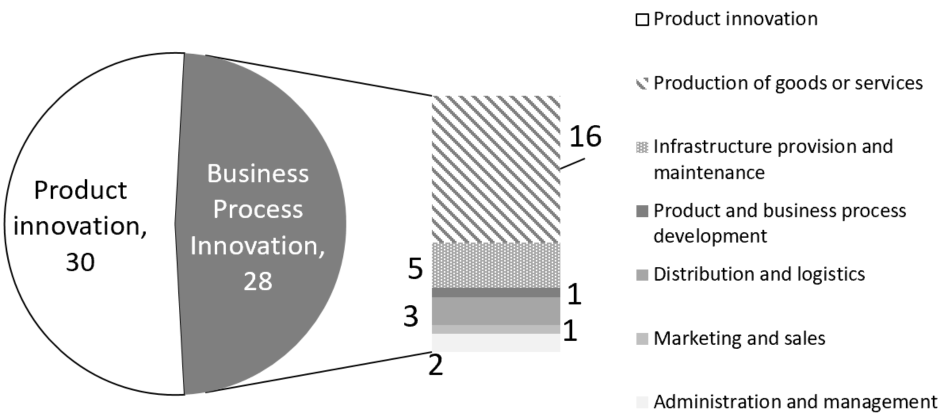

Figure 38: Candidate innovative outputs per innovation type

These innovative outputs are not limited to few vertical domains only, but as shown in Figure 39, at least 3 interesting families of use-cases can be identified for each vertical industry. This is important as it demonstrates that business experiments could be performed by a wide range of actors

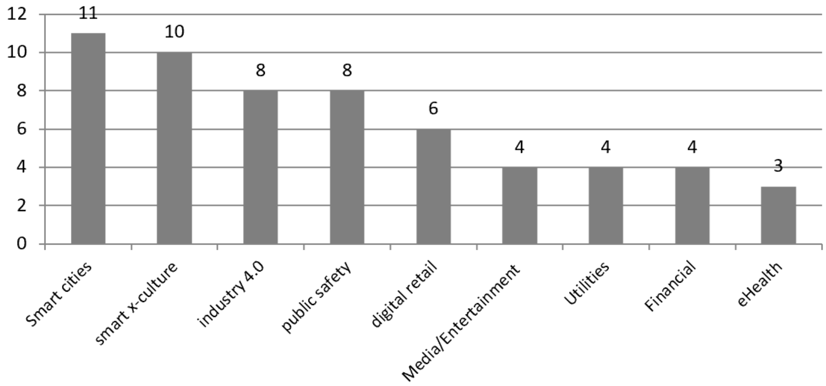

Figure 39: Candidate innovative outputs per vertical industry

5 Business and economic KPIs

The purpose of this section is to validate a) the business potential of the 5G-VINNI facility and b) its impact on the vertical industries by means of specifying business and economic Key Performance Indicators (B&E KPIs) and evaluating these based on measurements and knowledge gained from the experiments hosted. These KPIs complement the selected 5G PPP technical KPIs like delay, throughput, coverage, etc.

The KPIs need to be clearly defined by using a mathematical formula. This makes it easier for understanding what exactly is evaluated and what measurements are needed for computing the values. Furthermore, this allows results obtained from 5G-VINNI experiments to be compared with threshold values coming from Business-as-Usual (BaU) scenarios, set by 5G-VINNI partners (e.g., based on expectations and state-of-the-art advances), or even across different maturity levels of 5G-VINNI.

Even though KPIs are very useful for tracking progress and understanding the potential impact on the stakeholders, there are several challenges. One important challenge is that some necessary inputs/measurements depend on external entities' actions or conditions. In some cases, KPIs may be computed only after 5G-VINNI has completed. Thus, we rely on entities such as vertical customers to provide us the required inputs and inform us on the conditions of the business experiments executed (e.g. starting and ending date). This risk may be mitigated by identifying technical KPIs that could serve as proxies for 5G-VINNI impact on verticals. Even though most technical KPIs will have an effect on user experience, some of them could also be used for assessing 5G-VINNI's impact on verticals' ability to innovate. We call these proxy KPIs for Business KPIs. Figure 40 illustrates the relationship between technical, economic and business KPIs using a Venn diagram.

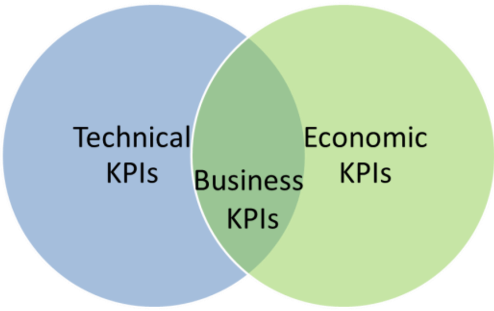

Figure 40: Venn diagram of relationships between technical, economic and business KPIs

Another challenge is that KPIs can be computed for several system/service/ecosystem configurations. A configuration can refer to the inclusion of new components, different component settings (e.g., higher video resolution in case of a use-case involving online video processing), modified set of users (e.g., a broader one for testing system's scalability) and so on. Furthermore, the same KPIs could be computed even for the same configuration, but across different maturity levels and locations (5G-VINNI facility sites).

In the following we present a preliminary set of business and economic KPIs that were identified at this stage. Note that some KPIs may eventually be excluded when performing the actual economic assessment and new ones may be added.

The technical KPIs are not presented below as these are documented in D4.1 (5G-VINNI Deliverable 4.1, 2019e). However, we should note that they are related to the business KPIs, in the sense that the technical aspects they describe affect the facility site's costs or decisions made in the business layer of 5G-VINNI. For example, the order duration (see 5.2.8) for a 5G-VINNI facility site to execute an experiment depends on the throughput of the underlying network. On the other hand, satisfying a certain threshold value for throughput may imply deploying a more dense network of base stations that increases the total capital expenditures (see 5.1.1.2 for example) Thus, technical KPIs such as Minimum Expected Upstream Throughput, Minimum Expected Downstream Throughput, Maximum Expected Latency, Network Reliability, UL Peak Throughput, DL Peak Throughput may also need to be analysed in order to have a complete view, or interpret the values of other business KPIs.

5.1 Economic KPIs

5.1.1 Cost efficiency

5.1.1.1 Total CAPEX for 5G-VINNI facility member

This KPI calculates the total cost of the infrastructure deployed by a certain member $i = 1, \dots, I$ of the 5G-VINNI facility. In particular, it covers the CAPEX for a certain setup j of the facility site where this member belongs to and is sensitive to the dimensioning needed, the business models adopted, etc. It is calculated as the present value (PV) of all these cost items $c = 1, \dots, C$ over a period of e.g., 10 years with a certain interest rate (e.g. WACC). The formula to be used is the following:

$$5GVINNI\ MemberCAPEX_{i,j} = \sum_{c=1,\dots,C} PV(CapEx_{i,j}^{c}, WACC)$$

where:

1) $CapEx_{i,j}^{c}$ is the capital cost item c (e.g., for masts) of site member i under setup/value network j

2) WACC is the Weighted Average Cost of Capital for telecoms industry in site's country.

5.1.1.2 Total CAPEX for 5G-VINNI facility site

This KPI calculates total cost of the infrastructure deployed by the members $1, \dots, I$ of a 5G-VINNI facility site. In particular, it covers the CAPEX for a certain setup j of the facility site in terms of dimensioning, business models adopted, etc. It is calculated as present value of these costs over a period of e.g., 10 years with a certain interest rate (e.g. WACC). The following formula is to be used:

$$5GVINNI\ SiteCAPEX_{j} = \sum_{i=1,\dots,N} 5GVINNI\ MemberCAPEX_{i,j}$$

where $5GVINNI\ MemberCAPEX_{i,j}$is defined in Section 5.1.1.1

5.1.1.3 Total OPEX for 5G-VINNI facility member

This KPI calculates the total variable costs for the services offered by a certain member $i = 1, \dots, I$ of the 5G-VINNI facility. In particular, it covers the Operational Expenditures (OPEX) for a certain setup j of the facility site and is calculated as the present value (PV) of these costs over a period of e.g., 10 years with a certain interest rate (e.g. WACC). The formula to be used is the following:

$$5GVINNI\ MemberOPEX_{i,j} = \sum_{o=1,\dots,O} PV(OpEx_{i,j}^{o}, WACC)$$

where:

1) $OpEx_{i,j}^{o}$ is the operational cost item o of site member i under setup/value network j

2) WACC is the Weighted Average Cost of Capital for telecommunications industry in site's country.

5.1.1.4 Total OPEX for 5G-VINNI facility site

This KPI calculates the total variable costs for the services offered by the members $1, \dots, I$ of a 5G-VINNI facility site. In particular, it covers the Operational Expenditures (OPEX) for a certain setup j of the facility site in terms of dimensioning, business models adopted, etc. It is calculated as the present value of these costs over a period of e.g., 10 years with a certain interest rate (e.g. WACC). The formula to be used is the following:

$$5GVINNI\ SiteOPEX_j = \sum_{i=1,\dots,N} 5GVINNI\ MemberOPEX_{i,j}$$

where $5GVINNI\ MemberOPEX_{i,j}$ is explained in Section 5.1.1.3.

5.1.1.5 Total Cost of Ownership for a 5G-VINNI facility site

This KPI calculates the total cost of ownership (TCO) for all members of a 5G-VINNI facility site. It is calculated as the sum of the respective KPIs for the CAPEX and OPEX for a particular site configuration j. The formula to be used is the following:

$5GVINNI\ SiteTCO_j$ = $5GVINNI\ SiteCAPEX_j$ + $5GVINNI\ SiteOPEX_j$

where $5GVINNI\ SiteCAPEX_j$ is described in Section 5.1.1.2, while $5GVINNI\ SiteOPEX_j$ in 5.1.1.4.

5.1.1.6 Percentage reduction on Total Cost of Ownership for a 5G-VINNI facility site

This KPI calculates the % reduction on total cost of ownership for all members of a 5G-VINNI facility site. It is calculated by comparing the total cost of ownership of setup j for a 5G-VINNI facility site with that of the Business-as-Usual (setup 0). The formula to be used is the following:

$5GVINNI\ SiteTCO\ reduction\%$ = ($5GVINNI\ SiteTCO_0$ - $5GVINNI\ SiteTCO_j$)/ $5GVINNI\ SiteTCO_0$

where $5GVINNI\ SiteTCO_0$ and $5GVINNI\ SiteTCO_j$ refer to the "atomic" KPI of Section 5.1.1.5, as computed for the Business-as-Usual and a certain 5G-VINNI-enabled setup $j > 0$.

5.1.2 Value creation

5G-VINNI creates value for the vertical industries and the other involved stakeholders since it facilitates the innovation. Value is created for every stakeholder that either Joins 5G-VINNI as facility provider or uses 5G-VINNI for testing.

5.1.2.1 Total Revenues for 5G-VINNI facility member

This KPI calculates the total revenues for the services offered by member $i = 1, \dots, I$ of the 5G-VINNI facility. It includes the incomes for a certain setup j of the facility site (e.g., business models adopted, etc) from the services offered to its customers, like those in the targeted vertical industries. It is calculated as the present value (PV) of these costs over a period of e.g., 10 years with a certain interest rate (e.g. WACC). The formula to be used is the following:

$$5GVINNI\ MemberRevenues_{i,j} = \sum_{r=1,\dots,R} PV(Revenues_{i,j}^{r}, WACC)$$

where:

1) $Revenues_{i,j}^{r}$ is the revenue stream r of site member i under setup/value network j

2) WACC is the Weighted Average Cost of Capital for telecommunications industry in site's country.

5.1.2.2 Total Revenues for 5G-VINNI facility site

This KPI calculates the total revenues for the services offered by the members $1,2, \dots, I$ of a 5G-VINNI facility site. It includes the incomes for a certain setup j of the facility site (e.g., business models adopted, etc) from the services offered to its customers, like those in the targeted vertical industries.

Similarly to 5.1.1.2, it is calculated as the present value (PV) of these revenues over a period of e.g., 10 years with a certain interest rate (e.g. WACC). The formula to be used is the following:

$$5GVINNI\ SiteTotalRevenues_j = \sum_{i=1,\dots,N} 5GVINNI\ MemberRevenues_{i,j}$$

where $5GVINNI\ MemberRevenues_{i,j}$ are documented in Section 5.1.2.1.

5.1.3 Total Earnings/Losses

This KPI calculates the total net benefit of all members participating on a 5G-VINNI facility site for a certain setup j. It is calculated by subtracting the total cost of ownership for that particular facility site from the revenues. The formula to be used is the following:

$5GVINNI\ SiteTotalEarnings_j$ = $5GVINNI\ SiteTCO_j$ - $5GVINNI\ SiteTotalRevenues_j$

where $5GVINNI\ SiteTCO_j$ is described in 5.1.1.5, and $5GVINNI\ SiteTotalRevenues_j$ in 5.1.2.2.

5.1.4 Entry Barriers - Cost of testing products in realistic settings

This KPI compares the cost of vertical organisations for deploying and testing an application over the 5G-VINNI platform between period K>=1 and period L>K. For example, period K could be the last 6 months of 5G-VINNI lifetime, while period L could be 6 months after the 5G-VINNI is over. The formula to be used is the following:

$$AverageVerticalCosts\ \%Reduction = Average(1 - \frac{\sum_{o=1,\dots,O} 5GVINNIsite\ charges_L^o}{\sum_{o=1,\dots,O} 5GVINNIsite\ charges_K^o})$$

Where $\sum_{o=1,\dots,O} 5GVINNIsite\ charges_K^o$ and $\sum_{o=1,\dots,O} 5GVINNIsite\ charges_L^o$ refer to the costs during periods K and L, respectively.

5.2 Business KPIs

Figure 41 provides an overview of key business KPIs identified so far for tracking progress and understanding the potential impact of 5G-VINNI on vertical organisations and other complementors. More details on the definition of each Business KPI appear on the subsections below.

5.2.1 CustomerAccounts_%Change

This KPI measures percentage change on the number of accounts registered to the Product Catalog of a 5G-VINNI facility site between period K>=1 and period L>K. The following formula is to be used:

$$\text{CustomerAccounts\_\%Change} = 1 - \frac{CustomerAccounts_L}{CustomerAccounts_K}$$

Consider for example that there are 500 customers registered to the Product Catalog of a 5G-VINNI facility site by the end of month 1 and have been increased to 850 by the end of month 2. This implies a CustomerAccounts_%Change of 350/500=70%.

Therefore, negative values indicate that some customers deleted their accounts, which could be attributed to reduced interest in 5G-VINNI.

5.2.1 CustomerBrowses_%Change

This KPI measures percentage change on the number of browses performed on the Product Catalog of a 5G-VINNI facility site between period K>=1 and period L>K. The following formula is to be used:

$$\text{CustomerBrowses\_\%Change} = 1 - \frac{CustomerBrowses_L}{CustomerBrowses_K}$$

Consider for example that 3000 browses on the Product Catalog of a 5G-VINNI facility site had taken place by the end of month 2 and have been increased to 8000 by the end of month 4. This implies a CustomerBrowses_%Change of 5000/3000=166.7% during months 3 and 4.

Negative values do not necessarily indicate reduced interest in using 5G-VINNI as this could be attributed to usage patterns (e.g., customers have become familiar with 5G-VINNI offerings or they perform trials).

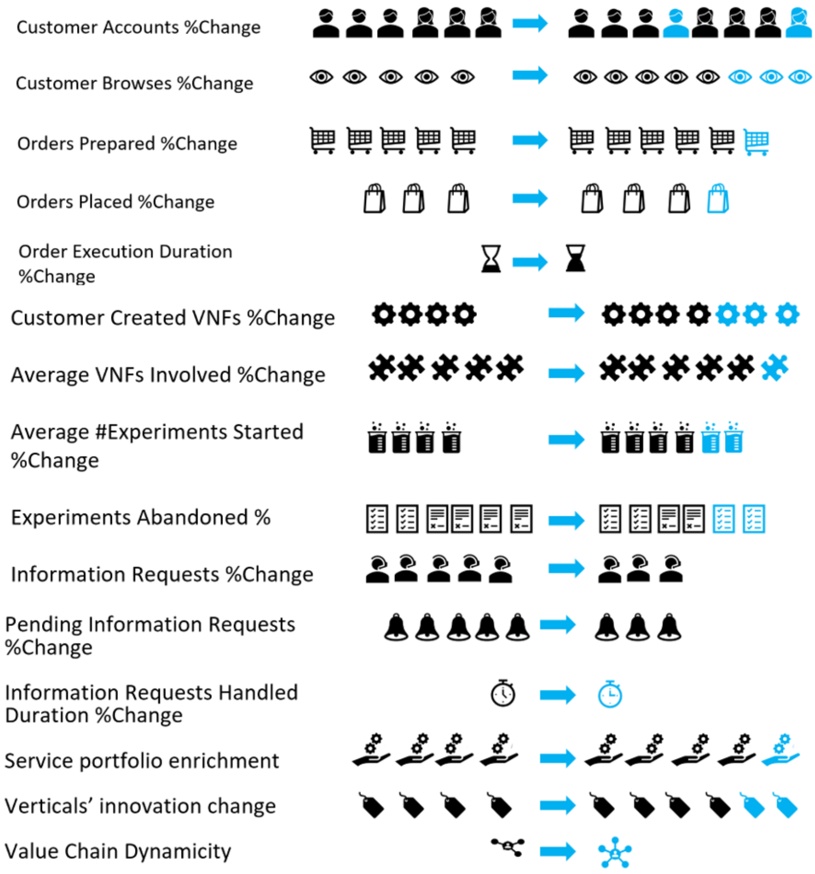

Figure 41: An overview of key business KPIs

5.2.2 OrdersPrepared_%Change

This KPI measures the percentage change on the number of orders prepared on the Product Catalog of a 5G-VINNI facility site between period K>=1 and period L>K. The following formula is to be used:

$$\text{OrdersPrepared\_\%Change} = 1 - \frac{\text{OrdersPrepared}_L}{\text{OrdersPrepared}_K}$$

Assume for example that 130 orders were prepared on the Product Catalog of a 5G-VINNI facility site by the end of month 2 and have been increased to 230 by the end of month 3. This implies an OrdersPrepared_%Change of 100/130=76.9% between months 2 and 3.

As in the previous case, negative values could be attributed to usage patterns and not associated with reduced interest in using 5G-VINNI.

5.2.3 OrdersPlaced_%Change

This KPI measures the percentage change on the number of orders placed on the Product Catalog of a 5G-VINNI facility site between period K>=1 and period L>K. The formula to be used is the following:

$$\text{OrdersPlaced\_\%Change} = 1 - \frac{\text{OrdersPlaced}_L}{\text{OrdersPlaced}_K}$$

If, for example, 90 orders were placed on the Product Catalog of a 5G-VINNI facility site by the end of month 2 and have been increased to 130 by the end of month 3, there would be an OrdersPlaced_%Change of 40/90=44.4% between months 2 and 3.

As in the previous case, negative values could be attributed to usage patterns and not associated with reduced interest in using 5G-VINNI.

5.2.4 OrderExecutionDuration_%Change

This KPI measures the percentage change on the (average) time for a 5G-VINNI facility site to process the orders placed between period K>=1 and period L>K. We should note that this KPI is primarily affected by constraints on the resources of different 5G-VINNI facility sites. The formula to be used is the following:

$$\text{OrdersExecutionDuration\_\%Change} = 1 - \frac{\text{OrdersExecutionDuration}_L}{\text{OrdersExecutionDuration}_K}$$

Assume for example that the (average) time for a 5G-VINNI facility site to process the orders placed is 60 minutes during the first two months and becomes 63 minutes by the end of month 3. This implies an OrdersExecutionDuration_%Change of 3/60=5% between months 2 and 3.

Negative values could be justified if OrdersPlaced%Change is positive. Even if OrdersPlaced%Change is negative it could be attributed to higher complexity of orders placed; if for example AverageVNFsInvolved_%change (see below) is positive.

5.2.5 CustomerCreatedVNFs_%Change

This KPI measures the percentage change on the number of custom VNFs (i.e., those created by customers themselves) being activated on a 5G-VINNI facility site between period K>=1 and period L>K. The formula to be used is the following:

$$\text{CustomerCreatedVNFs\_\%Change} = 1 - \frac{\text{CustomerCreatedVNFs}_L}{\text{CustomerCreatedVNFs}_K}$$

For example, if there were 20 custom VNFs activated on a 5G-VINNI facility site by the end of month 1 and have been increased to 32 by the end of month 2, this would imply a CustomerCreatedVNFs_%Change of 12/20=60%.

5.2.6 GenericVNFs_%Change

This KPI measures the percentage change on the number of VNFs and VAFs activated on a 5G-VINNI facility site between period K>=1 and period L>K. The formula to be used is the following:

$$\text{GenericVNFs\_\%Change} = 1 - \frac{Generic\text{VNFs}_L}{\text{GenericVNFs}_K}$$

Assume for example that there were 4000 custom VNFs and VAFs activated by the end of month 1 and have been increased to 5800 by the end of month 2. This would imply a GenericVNFs_%Change of 1800/4000=45%.

5.2.7 AverageVNFsInvolved_%Change

This KPI measures the percentage change on the total number of VNFs (both custom and generic) activated on a 5G-VINNI facility site between period K>=1 and period L>K. The formula to be used is the following:

$$\text{AverageVNFsInvolved\_\%Change} = 1 - \frac{\text{AverageVNFsInvolved}_L}{\text{AverageVNFsInvolved}_K}$$

where:

$\text{AverageVNFsInvolved}_K = \text{CustomerCreatedVNFs}_K + \text{GenericVNFs}_K$

(the last two terms are described in Sections 5.2.5 and 5.2.6 respectively).

For the examples of the two previous sections we have AverageVNFsInvolved=60 by the end of month 1 and AverageVNFsInvolved=90 by the end of month 2. Therefore there is an increase of 30/60=50% in the AverageVNFsInvolved.

5.2.8 OrderDuration_%Change

This KPI measures the percentage change on the (average) duration of the experiments activated on a 5G-VINNI facility site between period K>=1 and period L>K. Note that a period may include more than one orders, but we assume that each order involves a single experiment. Thus, if a vertical customer needs to test the feasibility, effectiveness, efficiency, etc. of a certain system/service configuration, then several orders should be placed. The formula to be used is the following:

$$\text{OrderDuration\_\%Change} = 1 - \frac{\text{OrderDuration}_L}{\text{OrderDuration}_K}$$

Assume for example that the (average) duration of the experiments activated on a 5G-VINNI facility site is 2 days during the first two months and becomes 4 days by the end of month 3. This implies an OrderDuration_%Change of 2/4=50% between months 2 and 3.

5.2.9 Average#ExperimentsStarted_%Change

This KPI measures the percentage change on the average number of experiments/orders started on a 5G-VINNI facility site between period K>=1 and period L>K. The formula to be used is the following:

$$\text{Average\#ExperimentsStarted\_\%Change} = 1 - \frac{\text{Average\#ExperimentsStarted}_L}{\text{Average\#ExperimentsStarted}_K}$$

5.2.10 ExperimentAbandonded_%

This KPI measures the percentage of the experiments abandoned on a 5G-VINNI facility site between period K>=1 and period L>K. The formula to be used is the following:

$$\text{Average\#ExperimentsAbandoned\_\%Change} = 1 - \frac{\text{Average\#ExperimentsAbandoned}_L}{\text{Average\#ExperimentsAbandoned}_K}$$

5.2.11 InformationRequests_%Change

This KPI measures the percentage change on the number of requests for technical support, financial information etc. on a 5G-VINNI facility site between period K>=1 and period L>K. The formula to be used is the following:

$$\text{InformationRequests\_\%Change} = 1 - \frac{\text{InformationRequests}_L}{\text{InformationRequests}_K}$$

5.2.12 PendingInformationRequests_%Change

This KPI measures the percentage change on the number of requests that are pending X hours upon receipt on a 5G-VINNI facility site between period K>=1 and period L>K. We should note that this KPI is primarily affected by constraints on the resources of different 5G-VINNI facility sites. The formula to be used is the following:

$$\text{PendingInformationRequests\_\%Change} = 1 - \frac{\text{PendingInformationRequests}_L}{\text{PendingInformationRequests}_K}$$

5.2.13 InformationRequestsHandledDuration_%Change

This KPI measures the percentage change on the (average) handling duration of information requests on a 5G-VINNI facility site between period K>=1 and period L>K. We should note that this KPI is primarily affected by constraints on the resources of different 5G-VINNI facility sites. The formula to be used is the following:

$$\text{InformationRequestsHandledDuration\_\%Change} = 1 - \frac{\text{InformationRequestsHandledDuration}_L}{\text{InformationRequestsHandledDuration}_K}$$

5.2.14 Service portfolio enrichment

This KPI calculates percent change of the number of new services developed, deployed and tested using the 5G-VINNI facilities between period K>=1 and period L>K. We define as *new*, those services that stop using testing slices and start using production slices. The following formula is to be used:

$$\text{Service\_Portfolio\_Enrichment\_\%Change} = 1 - \frac{\text{Number\_of\_Services\_created}_L}{\text{Number\_of\_Services\_created}_K}$$

5.2.15 Innovation

This KPI calculates the % change of the number of new products introduced by a vertical in 5G-VINNI between periods K>=1 and L>K. These numbers can be derived from the questionnaire, and we may consider as period 1 the current situation. The formula to be used is the following:

$$\text{5GVINNI\_Innovation\_\%Change} = 1 - \frac{\text{New\_products\_introduced}_L}{\text{New\_products\_introduced}_K}$$

5.2.16 Dynamic value chains

This KPI calculates the average number of components interacting with a specific VNF in the value chain. This number is defined as the degree of the VNF in the forwarding graph of VNFs and the interactions among them, and can be derived from an appropriate question to be included in future online surveys. The formula to be used is the following:

$$\text{ValueChainDynamicity} = \frac{\text{Avg(VNF\_degree)}_L}{\text{Avg(VNF\_i\_degree)}_K}$$

where Avg(VNF_degree)_L is the average degree of VNF (i.e., the number of VNFs that it is connected to) during period L.

5.2.17 Entry Barriers - Difficulty of testing products in realistic settings

This KPI calculates the minimum sum of the number of VNFs and VAFs required in order to test a product in a large-scale, end-to-end setup in 5G-VINNI, over all such products of vertical organisations $v = 1, \dots, V$. The formula to be used is the following:

$$\text{ResourceDifficulty\_Entry\_Barrier} = \frac{\min_v \sum(VNF_{v,L} + VAF_{v,L})}{\min_v \sum(VNF_{v,K} + VAF_{v,K})}$$

where $VNF_{v,L}$ and $VAF_{v,L}$denote the number of Virtual Network Functions and Virtual Application Functions required for vertical enterprise v, during period L (respectively for period K).

6 _Total_OPEX_Total_CAPEConclusions and recommendations

5G, in contrast to previous mobile network generations, has been conceived with vertical industries in mind. This means that in order to understand the business relationships and business models to be shaped in the Digital Single Market era, one should not focus on the telecommunications industry and the ICT sector as separate business domains. A broader approach is necessary instead, for better grasping the 5G value creation dynamics; one where these two worlds are combined.

By using the value network methodology, we identified 23 key actor roles resulting in a full-blown, but complex, 5G ecosystem actor role model. We demonstrated that this actor role model can be used for describing a wide range of important business scenarios, such as network slice federation, handover and roaming. Furthermore, we showcased that we can use it for describing composite business models (those that suggest a single actor to take on multiple roles) and their likely evolution (especially when it comes to who could perform the role of the service aggregator). In order to reduce this inherent complexity, we followed several complementary strategies.

The first one was to restrict the scope to 5G test-beds only, which are deployed and managed by a limited set of stakeholders for pre-commercial validation of 5G technologies. Considering that (during its early stages) 5G-VINNI is such a test-bed, this case is very important when discussing technical interfaces with other 5G-VINNI partners or members of broader communities (e.g., like the 5G PPP Architecture working group).

The second approach was to rely on the platform ecosystem theory in order to follow a more extrovert and abstract view. Three families of roles where recognized; enterprise customers that request composite services, complementors that offer atomic or composite services, and network operators running the platform that facilitates business interactions amongst the demand and supply side. We highlighted that even though the role of complementors is supportive, their existence is crucial not only for delivering value-added services, but also during the innovation phase. Indeed, successful platform ecosystems are characterized by a large and diverse set of players that result in substantial value creation, innovation and new growth. Furthermore, we motivated the importance of inter-operator agreements regarding federation and roaming in order to allow for positive network externalities to emerge. For that reason, we introduced a "cube model" for capturing the fact that 5G ecosystems can range from very simple ones (i.e., those where each family of roles is represented by a single entity) to very complex ones, where the cardinality is higher.

Furthermore, we performed a SWOT analysis for several maturity levels of 5G-VINNI in order to understand the Strengths, Weaknesses, Opportunities and Threats of a "5G experimentation-as-a-service". This offered and identified candidate strategies for exploiting strengths and opportunities and mitigating weaknesses and threats. We found that 5G-VINNI is expected to be well-suited for helping vertical industries deal with the pain points that these face today. Nevertheless, a key finding was that the need for attractive business models and incentive-compatible governance models is expected to be key for building and improving the culture for collaboration and trust between 5G actors. For that reason we will propose and evaluate different schemes for cooperation and revenue sharing agreements that covers a wide range of scenarios, including inter-facility (or inter-operator and inter-platform) as well as intra-platform (between complementors and operators) cases. A very promising finding from an associated survey to enterprise customers, was that the majority of the participants claimed that their organisation (especially those in Utilities, Media/Entertainment and Smart Agriculture industries) is comfortable and interested in running technical trials and business experiments throughout service/product life-cycle, as well as, that these experiments are valuable e.g., in terms of reduced costs, increased revenues or new revenue sources.

By performing desk research we qualitatively analysed the expected potential of 5G to industries and consequently users and society. More than half of the candidate innovations were classified as product innovations that meet candidate customers’ requirements, while serving the vertical enterprises’ needs for improved goods or services, new offers for establishing new markets or entering to existing ones. The rest of the innovations were associated to improved business processes for upgrading outdated processes, technology or methods, reducing operational costs and waste per unit of output, reducing time to market by improving capabilities for absorbing, processing and analysing knowledge, as well as, integrating processes with other organisations. These innovative outputs are not limited to few vertical domains only, but it was found that at least 3 interesting families of use-cases can be identified for each vertical industry. This is important as it demonstrates that business experiments could be performed by a wide range of actors.

Furthermore, we identified several business and economic KPIs for validating the business potential of the 5G-VINNI facility and its impact on the vertical industries based on measurements collected at run-time or via online surveys. Economic KPIs can be decomposed into two categories (cost efficiency and value creation), while Business KPIs are mostly used for understanding how vertical industries innovate.

References

3GPP TR 28.801. Telecommunications management; Study on management and orchestration of network slicing for next generation networks. Retrieved 28th June 2019 from: https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3091

5GPPP Arch. WP. (2017). 5G PPP 5G Architecture White Paper Revision 2.0 – (White Paper version 2.0 Dec 2017). Retrieved 28th June 2019 from: https://5g-ppp.eu/wp-content/uploads/2018/01/5G-PPP-5G-Architecture-White-Paper-Jan-2018-v2.0.pdf

5GEx Deliverable 2.1. (2016). Initial System Requirements and Architecture. Available online at: https://bscw.5g-ppp.eu/pub/bscw.cgi/d139873/5GEx_D2.1v1.1_public_version.pdf

5GPPP. (2017). 5G - Innovations for new business opportunities. Retrieved May 23, 2017, from 5g-ppp.eu: https://5g-ppp.eu/wp-content/uploads/2017/03/5GPPP-brochure-final-web1-with-Author-credits.pdf

5G-VINNI Deliverable 3.1. (2019a). Specification of services delivered by each of the 5G-VINNI facilities.

5G-VINNI Deliverable 3.2. (2019b). Publication of first version of service catalogues to vertical consumers.

5G-VINNI Deliverable 1.2. (2019c). Design of network slicing and supporting system v1.

5G-VINNI Deliverable 1.1. (2019d). Design of infrastructure architecture and subsystems v1.

5G-VINNI Deliverable 4.1. (2019e). Initial report on test-plan creation and methodology, and development of test orchestration framework.

Allee, V. (1999). The art and practice of being a revolutionary. *Journal of knowledge management*, 3(2), 121-131.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme for analysis. *Research Policy*, 37, 407-429.

Brown, G.W. (2009). Value chains, value streams, value nets, and value delivery chains. *Business Process Trends*, April 2009, 1-12.

Christensen, C. M. (1997). The innovators dilemma: When new technologies cause great firms to fail. Boston: Harvard Business School Press.

ESOA. (n.d.). Satellite communications services: An integral path of the 5G Ecosystem. Retrieved June 19, 2019, from www.esoa.net: https://www.esoa.net/cms-data/positions/ESOA%205G%20White%20Paper%204.pdf

ETSI TS 122.261. (2018) 5G; Service requirements for next generation new services and markets. Retrieved 28th June 2019 from: https://www.etsi.org/deliver/etsi_ts/122200_122299/122261/15.05.00_60/ts_122261v150500p.pdf

Euro-5G. (2016). D2.4 Intermediate report on programme progress and KPIs. Available online at: https://5g-ppp.eu/wp-content/uploads/2017/07/Euro-5G-D2.4_Progress_on_KPIs.pdf

European Commission. (2017a). Factsheet, Digital Single Market - Making the most of the digital opportunities in Europe. Retrieved 28th June 2019 from: https://ec.europa.eu/digital-single-market/en/news/digital-single-market-making-most-digital-opportunities-europe

European Commission. (2017b). New European Interoperability Framework, Retrieved 21th June 2019 from: https://ec.europa.eu/isa2/sites/isa/files/eif_brochure_final.pdf

European Commission. (2016a). 5G for Europe: An Action Plan. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM (2016) 588 final, Brussels 14.9.2016

European Commission. (2016b). 5G Global Developments. Commission Staff Working Document, accompanying the document, "5G for Europe: Action Plan" Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM (2016) 306 final, Brussels 14.9.2016.

European Commission. (2015). A Digital Single Market Strategy for Europe - COM(2015) 192 final. Available at: https://ec.europa.eu/digital-single-market/en/news/digital-single-market-strategy-europe-com2015-192-final

European Commission. (2014). Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe. Available online at: https://connectcentre.ie/wp-content/uploads/2016/10/EC-Study_5G-in-Europe.pdf

Gawer, A., & Cusumano, M. A. (2014). Industry platforms and ecosystem innovation. *Journal of Product Innovation Management*, 31(3), 417-433.

GSMA. (2019a). Embracing payments as a platform for the future of mobile money. London: GSM Association

GSMA. (2019b). The mobile economy 2019. London: GSMA

GSMA. (2018) From vertical industry requirements to network slice characteristics. Available online at: https://www.gsma.com/futurenetworks/wp-content/uploads/2018/09/5G-Network-Slicing-Report-From-Vertical-Industry-Requirements-to-Network-Slice-Characteristics.pdf

Hanseth, O., & Lyytinen, K. (2010). Design theory for dynamic complexity in information infrastructures: the case of building the internet. *Journal of Information Technology*, 25(1), 1-19.

Hekkert, M., Suurs, R., Negro, S., Kuhlman, S., & Smits, R. (2007). Functions of innovation systems: a new approach for analysing technological change. *Technological Forecasting and Social Change*, 74(4), 413-432.

Hekkert, M., Negro, S., Heimeriks, G., & Harmsen, R. (2011). Technological innovation system analysis: A manual for analysts. Retrieved June 21, 2019, from https://pdfs.semanticscholar.org/68e1/abecbbe0da073c7e63d95dbb750f5d910024.pdf?_ga=2.144104053.175814242.1561126961-818632011.1561126961

Iansiti, M., & Levien, R. (2004). The keystone advantage. What the new dynamics of business ecosystems mean for strategy, innovation and sustainability. Cambridge, MA: Harvard Business School Press.

ITU. (2018). Setting the scene for 5G: Opportunities and challenges. Geneve: ITU. Available at: https://www.itu.int/en/ITU-D/Documents/ITU_5G_REPORT-2018.pdf.

Jacobides, M., Cennamo, C., & Gawer, A. (2018). Towards a theory of ecosystems. *Strategic Management Journal*, 1-22.

Johnston R. & Lawrence P. (1988), Beyond Vertical Integration -The Rise of the Value-Adding Partnership. *Harvard Business Review*, 66 (4), 94 – 101.

Mademann, F. (2017). System architecture milestone of 5G Phase 1 is achieved. Retrieved, June 21, 2019 from https://www.3gpp.org/news-events/1930-sys_architecture.

McKinsey. (2018). Network sharing and 5G: A turning point for lone riders. Available at: https://www.mckinsey.com/industries/telecommunications/our-insights/network-sharing-and-5g-a-turning-point-for-lone-riders.

Moore, J. (1993). Predators and prey: a new ecology of competition. *Harvard Business Review*, 71(3), 75-86.

NGMN. (2015). NGMN 5G white paper. NGMN Alliance. Retrieved 19th June, 2019, from: https://www.ngmn.org/fileadmin/ngmn/content/images/news/ngmn_news/NGMN_5G_White_Paper_V1_0.pdf.

OECD/Eurostat. (2018). Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition. Paris/Eurostat, OECD Publishing.

Pil, F.K. & Holweg, M. (2006). Evolving from value chain to value grid. *MIT Sloan management review*, 47(4), 72.

Porter, M. (1985). The Competitive Advantage: Creating and Sustaining Superior Performance. New York, Free Press.

Rafael L.A., Thanos G., Kanakakis M., & Fearnley G. (2019). Business models for decentralized energy. *Journal of transnational law & policy / Florida State University*. 20.

Reuver, M. d., Vershuur, E., Nikayin, F., Cerpa, N., & Bouwman, H. (2014). Collective action for mobile payment platforms: A case study on collaboration issue between banks and telecom operators. *Electronic Commerce Research and Applications*, 14, 331-344.

Stabell, C. B. & Fjeldstad, Ø. D. (1998). Configuring value for competitive advantage: on chains, shops and networks. *Strategic Management Journal*, 19, 413-437.

Thorelli, H. B. (1986). Networks: Between markets and hierarchies. *Strategic Management Journal,* 7(1), 37–51.

Annex A Existing actor role models

A.1 3GPP actor role model

3GPP TR28.801[16] defined a number of roles and their client/provider relationships as shown in Figure 42 below.

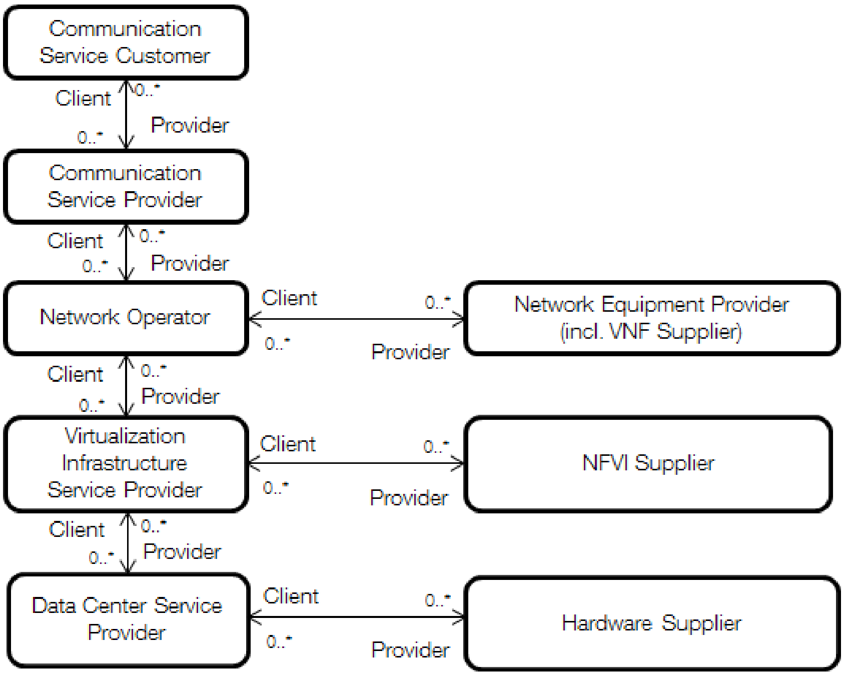

Figure 42: The 3GPP actor role model

In particular, the following roles were identified:

- Communication Service Customer (CSC), which represents the consumer of communication services. This role ranges from an end-user, to an SME doing business on a specific vertical or to a large service provider that offers online application services. This role is also commonly referred to as tenant[17].
- Communications Service Provider (CSP), which offers communications services through own/leased/brokered network to CSCs. Apart from CSCs, a CSP may also offer communication services to other CSPs. Hence, a communication service can be considered as either as B2C, B2B or even B2B2X. Network Operator, who provides Layer 2 or Layer 3 network services. Designs, builds and operates its networks to offer such services. The Network Operator can be further classified to Access and Core Network operators.
- Network Equipment Provider, who supplies network equipment. For sake of simplicity, VNF Supplier is considered here as a type of Network Equipment Provider. There are currently several, both small and large, companies in the market serving as VNF suppliers. Among them you can find leading vendor companies like Nokia, Ericsson, Huawei, HPE, Cisco, AT&T etc. Also, there is a variety of VNF products that are currently offered in the market either as

[16] 3GPP TR 28.801: Telecommunications management; Study on management and orchestration of network slicing for next generation networks.

[17] "5G PPP 5G Architecture - White Paper," July 2016

VNF Suites that include multiple VNFs or single purpose VNF products. Examples of such products are vCPE, vEPC, vRAN, VoLTE, vADC, vRouter, Video Traffic Manager, etc.

- Virtualization Infrastructure Service Provider, which provides virtualized infrastructure services. Designs, builds and operates its virtualization infrastructure(s). Virtualization Infrastructure Service Providers may also offer their virtualized infrastructure services to other types of customers including to Communication Service Providers directly, i.e. without going through the Network Operator. VISP offer virtualization infrastructure services ranging from multi-purpose VMs/Containers to complete virtualized infrastructure management solutions on compute, storage, network, IoT, etc.
- NFVI Supplier, who supplies network function virtualization infrastructure to its customers.
- Data centre Service Provider that provides data centre services and thus instances of this role design, build and operate the data centres.
- Hardware Supplier, who supply hardware, such as Common-of-the-shelf (COTS) servers, IoT sensors, etc.

A.2 5GEx actor role model

5GEx has also defined some additional roles that harmonically complement the actor role model defined by 3GPP. The complementary roles that were defined and are of high interest for 5G-VINNI, were identified as Support roles. These supporting roles include the following:

- NFVI Operations Support Provider: Offering operations support services for the readiness, operations, administration and maintenance of NFVI.
- VNF Deployment Support Provider: Offering VNF (SWaaS) support service for on-boarding, deployment and related readiness tasks.
- VNF Operations Support Provider: Offering VNF (SWaaS) in-use operations support services. This can depend on the specific function of the VNF and can cover a range of support tasks, e.g. data analytics.

A.3 The SLICENET Business Roles Model

SLICENET is particularly focused towards the exploration of realistic Use Cases from business verticals, and the project consortium includes a variety of stakeholders that can assume a variety of roles in the business relations involved in providing a service to a final SLICENET customer.

As such, the *a priori* identification and definition of the roles that can be assumed by the various stakeholders is important, as this helps to define the context and boundaries of the solution being addressed by SLICENET.

3GPP has already addressed this matter in TR 28.801 (see Figure 42) and issued a model identifying the main roles that are expected to be played in a slicing-based ecosystem, where Network Softwarization (SDN, NFV, Cloud) will enable new roles that will most likely result in new business entities and new business relationships:

- Virtualization Infrastructure and Data Centre Services may be provided by new specialized business actors
- VNFs are beginning to be marketed and expected to be an important market in the future[18].

[18] IDC study "IDC Forecasts Telecom Virtual Network Functions (VNF) Revenues to Reach $16.4 Billion in 2022", available online at https://www.idc.com/getdoc.jsp?containerId=prUS44275418

In this model, the Communication Service Customer (CSC) represents the vertical consumer of the services that are offered by a Communications Service Provider (CSP). This is the basic role for our verticals: verticals are today the customers for the communications services that are offered to them by CSPs, who are usually also Network Operators, but not necessarily:

- OTT CSPs offer their services either over a Network Operator or over the Internet Connection Service of another CSP;
- Virtual Network Operators are CSPs that use a Network Operator's network to provide their own services,

SLICENET is seeking a business roles model that clearly supports the business opportunities created by Network Slicing, namely those that arise from the possibility of a Network Operator offering to a customer:

- A network slice instance as a service, i.e., providing an environment that "is like" an isolated, purpose-built network that fits to the customer's requirements.
- The possibility to manage and control the purpose-built network that is offered.
- The possibility to host customer's virtualized applications and services on the slice infrastructure.

In this scenario, Communication Service Providers may fall short in what can be provided using the resources that a Network Operator may offer.

To address this, SLICENET extends the roles model proposed by 3GPP (3GPP TR 28.801), by defining a new pair of roles: the **Digital Services Provider (DSP)** and the **Digital Services Consumer (DSC)**, as depicted in Figure 43. The DSP represents the role of a service provider who can take advantage of the aforementioned possibilities, to offer new, wider scoping tailor-made services, and the DSC represents the end client that takes advantage of these new network services. The CSP's role is still part of the model, since both the DSP and the DSC can be clients to more the "traditional" communication services.

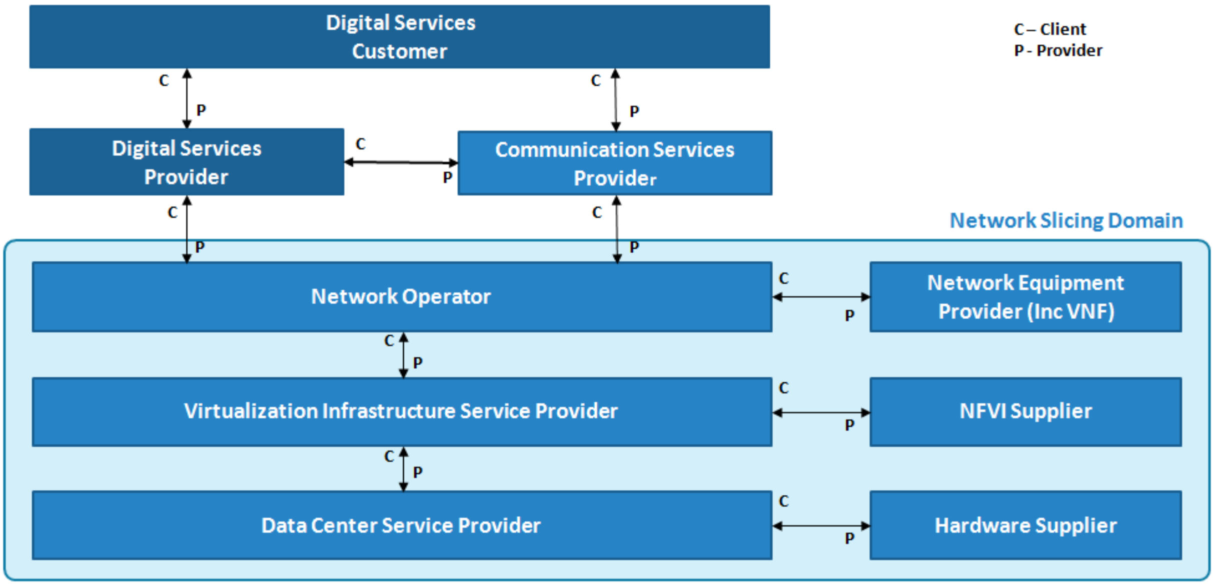

Figure 43: SLICENET high-level model of roles

It is important to note that this is not a hierarchical model. The relationships between the various roles have only a Client/Provider nature. It is also worth noting that these relationships are not only confined to the ones illustrated here. There may be others, e.g., a DSP may be a client to a Data Center Service Provider who will host his services. Represented here are relationships that are considered to be mainstream.

Digital Services: Extension to Communications Services, defined by 3GPP (3GPP TR 28.801). Digital Services encompass Communication services and other services that may be built using the resources offered by Network Operators and other sources. These services may be provided under several categories (B2B, B2C, B2B2x). SLICENET's focus is on B2B2x, namely services that a Network Operator may provide to a Digital Services Provider, who provides their services to a Digital Services Consumer (e.g. a business vertical).

Digital services have a communications component, but they may encompass other aspects into an offer that covers the needs of DSCs, e.g., a Smart Grid Protection Service may include fixed and mobile communications services for protection nodes interconnection, as well as specific protection mechanisms and protocols, adequate to an energy transport operator.

Digital Services Customer: The DSC is the consumer of the Digital Services provided by the Digital Services Provider. Business verticals typically assume this role, and the SLICENET Business Use Cases (i.e. an energy transport Operator, a Smart City grid, and a Medical Emergency Service) fulfil this role under a B2B or B2B2B relationship.

Digital Services Provider: The DSP builds and explores services that are adequate for the needs of Digital Services Customers.

The Digital Services Provider may be a client to a Communications Services Provider, in the sense that he subscribes to Communications Services, but also a client directly to the Network Operator, using Network Slices as a network support for services that may span across a wider scope than just communications, and offer highly customized services to Digital Services Consumers (typically business verticals).

Network Operator: *Provides network services. Designs, builds and operates its networks to offer such services* (3GPP TR 28.801).

In the particular context of SLICENET, these Network Services will be provided using Network Slice Instances that are exposed as Services (NSaaS – Network Slice-as-a-Service).

The capabilities that an NO exposes may have a wider scope than just Network Services, as the NO will be able to expose aspects of a slice's control layer or to host client's own VNFs.

NOs will be able to expose Network Slices to other NOs, allowing the construction of end-to-end slices that involve more than one administrative domain.

Network Equipment Provider: *Supplies network equipment. For sake of simplicity, VNF Supplier is considered here as a type of Network Equipment Provider* (3GPP TR 28.801).

VNFs will have to go through a specific validation process (not in the scope of SLICENET), but the outcome is essentially the same as for PNFs: VNFs are on boarded to the NO to be used like PNFs do. Nevertheless, the business dynamics for VNFs can be very different.

Virtualization Infrastructure Service Provider: *Provides virtualized infrastructure services. Designs, builds and operates its virtualization infrastructure(s). Virtualization Infrastructure Service Providers may also offer their virtualized infrastructure services to other types of customers including to Communication Service Providers directly, i.e. without going through the Network Operator* (3GPP TR 28.801).

NFVI Supplier: *Supplies network function virtualization infrastructure to its customers* (3GPP TR 28.801).

Data Centre Service Provider: *Provides data centre services. Designs, builds and operates its data centers* (3GPP TR 28.801).

Hardware Supplier: *Supplies hardware* (3GPP TR 28.801).

Stakeholders

Business roles are performed by real world entities that may aggregate more than one role. For instance, a "traditional" TelcoA will typically accumulate the roles of a Network Operator and a Communications Service Provider, providing to its customers (business or consumer) the communications services that it builds using the network it typically owns. In this case, TelcoA is a stakeholder assuming two business roles: Network Operator and Communications Service Provider.

For the SLICENET Use Cases, the various roles are assumed by the organizations involved, in stakeholder configurations that are variable. Various roles may be assumed by the same organization and roles may be omitted.

Business Roles vs. Slicing Management

Figure 43 highlights a number of business roles under the name "Network Slicing Domain". This is to make clear that, although SLICENET is mostly about Slice Management, some of the business roles identified in this scope are completely unaware of Network Slices. What a Communication/Digital Services Provider expects from a NO that is providing a Network Slice-as-a-Service, is an isolated network with a certain set of features that he can treat as his own network, obviously under the conditions that the NO defines as a Service Provider.

The Digital Services Customer is even further away from the Network Slice Concept, since he will be using the services exposed by the CSP/DSP. Hence, Network Slicing is a concept that is (as should be) completely opaque to verticals.

It is within the technical domain of the NO and its (direct and indirect) providers that network slicing is important and carries consequences:

Network Operator: It is the NO that explores the Network Slicing principle to provide isolated, custom built Networks to its customers. To be able to do that, the NO will have to require certain capabilities from its providers:

- **Network Equipment Provider:** All Network Equipment, either physical and/or virtual network functions, will have to guarantee the mechanisms for traffic isolation and multi-tenancy;
- **Virtualization Infrastructure Service Provider, NFVI Supplier:** Compute Nodes, Storage and Network will have to provide the isolation mechanisms for building slices
- **Data Centre Service Provider, Hardware Supplier:** data centres and Hardware must meet the requirements needed to implement slicing.

Obviously, to be able to build isolated network slices the network technology must support it. For instance, for mobile generations prior to 5G, the radio network protocols are not the most adequate for building slices at the RAN level.

Annex B 5G-VINNI Questionnaire

The SWOT analysis reported in this deliverable includes an online survey conducted between 1-31 of April 2019. The survey was directed at enterprise customers and, among other things, enabled an assessment of the status of external points of the SWOT analysis - i.e. opportunities and threats.

B.1 Research Approach

In terms of this study a basic quantitative descriptive approach[19] is chosen, i.e., a basic research method which enables a researcher to examine a situation at its time of existence and its current state, while involving the identification/determination of specific characteristics/particular phenomena based on observation as a means of collecting data. More precisely, the method of cross-sectional survey research[20] is applied to conduct this descriptive research, since it is appropriate to examine a single time-point or capture a one-time snapshot approach involving observations of a population's sample.

Concerning sample selections and data collection, the non-probability sampling procedure[21] is selected, which does not provide any basis for estimating the probability of each individual in a population to be included in the final sample. More precisely, in order to conduct the survey a core group of 125 participants was initially selected from different organizations (from various vertical industries) operating in the EU market. The participants were selected from all organization levels, while organizations where selected independently from their size and their economic business activity. They could invite other participants as they see fit, i.e., we used the snowball sampling technique. Eventually, the sample size reached 31 anonymous respondents.

B.2 Data collection and questionnaire structure

The collection of the primary data was made according to the standard online survey method (considered to be an essential tool for selecting information for a variety of research areas[22]) where a self-administered structured questionnaire with concrete and predetermined questions is designed and being used. The 5G-VINNI questionnaire was sent to the participants by email, in which the scope of the survey was clearly stated. The respondents were provided access to the questionnaire through a URL link[23] which directed them to the online UI form. The questionnaire consisted of a total of 25 carefully selected questions that were carefully selected and adjusted to serve the purpose of the specific survey, which was to better understand the pain points that key industries face today, their propensity to experiment during product/service life-cycle and how the 5G ecosystem could help them innovate in a mutually beneficial way. The survey was comprised by the seven parts: 1) respondent's role in the organization, organization type and size, 2) 5G as well as existing networks and communications solutions, 3) Regulation, 4) Industry wide collaboration, standardisation and visions, 5) Trials and experimentation, 6) Drivers and barriers, and 7) respondent's organization's innovation activity outcomes. It is important to note that the questions

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[19] Creswell, J. W. & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications.

[20] Glasow, P. A. (2005). *Fundamentals of survey research methodology.* Retrieved January, 18, 2013.

[21] Cochran, W. G. (2007). *Sampling techniques*. John Wiley & Sons.

[22] Manfreda, K. L., Bosnjak, M., Berzelak, J., Haas, I., & Vehovar, V. (2008). Web surveys versus other survey modes: A meta-analysis comparing response rates. *International journal of market research*, *50*(1), 79-104.

[23] https://www.5g-vinni.eu/5g-vinni-questionnaire-on-the-pain-points-that-european-industries-face-today_allin1/

of Parts 2-5 have been designed and adjusted so that they will be the key-tool to lead us in shaping and evaluating the External points (presented in the SWOT analysis Section 4.1) of the second 5G-VINNI maturity level (ML2). The question types are mainly closed-ended, including Likert-type scaled and multiple choice questions; however, for each question, an optional choice for lengthier (with more depth) responses is provided of dichotomous questions, multiple choices, branching questions, matrix questions and Likert-type scaled questions. The online survey took place between 15th of April 2019 and 2nd of May 2019.

B.3 Survey analysis and findings

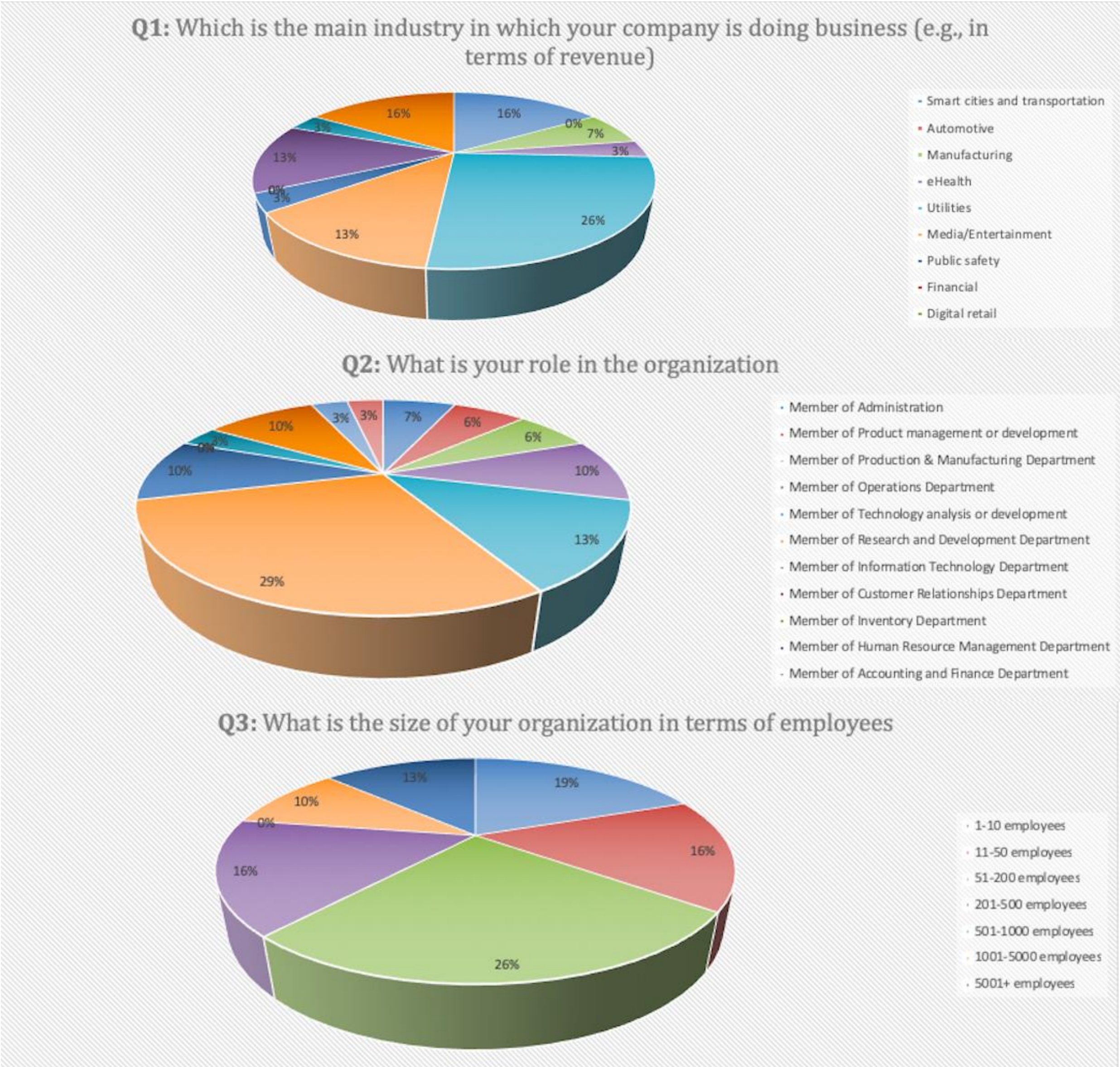


Figure 44: Pie charts for the answers of Q1-Q3 of Part 1, regarding the respondents' vertical type, role, and company size

The first part of the questionnaire consists of four questions (Q1-Q4) referring to the respondent's profile: the vertical type, their role and the size of their company, as well as their participation in initiatives closely-related to the 5G-VINNI concept, such as Public Private Partnerships, EU-funded projects (e.g., under Horizon 2020), National/regional research innovation projects.

As it is shown in Figure 44, the majority of survey's participants (71%) are from Utilities (26%), Media/Entertainment (16%), Smart cities and transportation, and Smart agriculture/aquaculture

(13%) industries. They are mainly members of the Research and Development department (29%), Technology analysis or development (13%), or Information Technology department (10%) of small and medium-sized organizations (61%, 1-200 employees). Moreover, in Figure 45, we can see that the majority of the respondents have participated in EU-funded projects (67,74%), while many of them have also worked in National/regional research projects (48,39%) and Public Private Partnerships (45,16%). This is not surprising as most of the participants (or dissemination channels, such as 5G PPP Verticals Engagement Task Force mailing lists) that were personally invited to fill-in the survey are affiliated to different European organisations that are active in 5G research, standardisation, commercialisation and exploitation. While these participants are expected to be the early adopters of 5G technologies and services, we highlight that the opinion of those who were not involved in any EU-driven initiative is of high value. As the survey was anonymous, we conjecture that about 13% of respondents, who answered "Other", represent the latter segment of the 5G ecosystem.

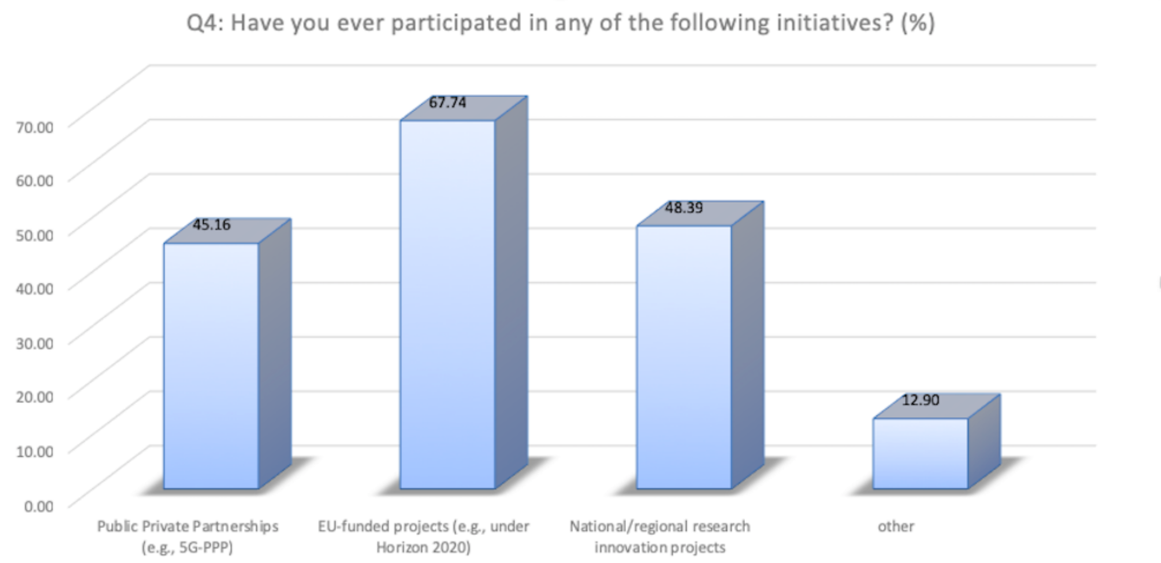
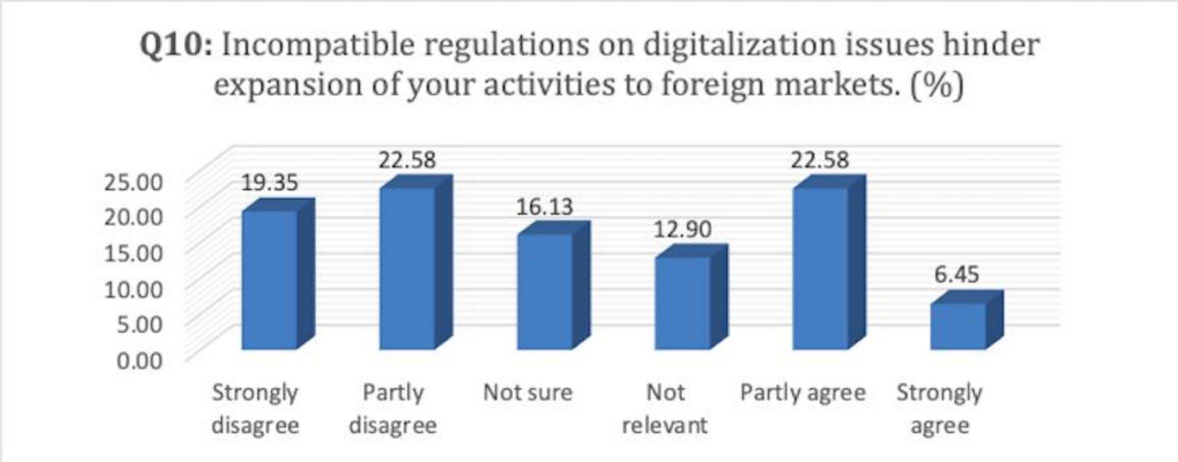


Figure 45: Answers of survey question Q4 in Part 1, regarding the respondents' participation in EU-driven initiatives

B.4 Parts 2-5: Evaluation of External points

In Parts 2-5 we have provided a set of 17 Likert-type scaled questions (Q5-Q21) which capture the main pain points that key industries face today and the propensity for experimentation during product/service life-cycle. Due to space limitations, we provide in Figure 46 a small sample of the answers to these questions, in the case of Part 3. As it can be shown, the majority of the respondent's (41.96% in both Q10 and Q11) disagree that regulations on digitalization issues hinder geographical expansion as well as the emergence of new roles and the adoption of innovative business models by verticals.



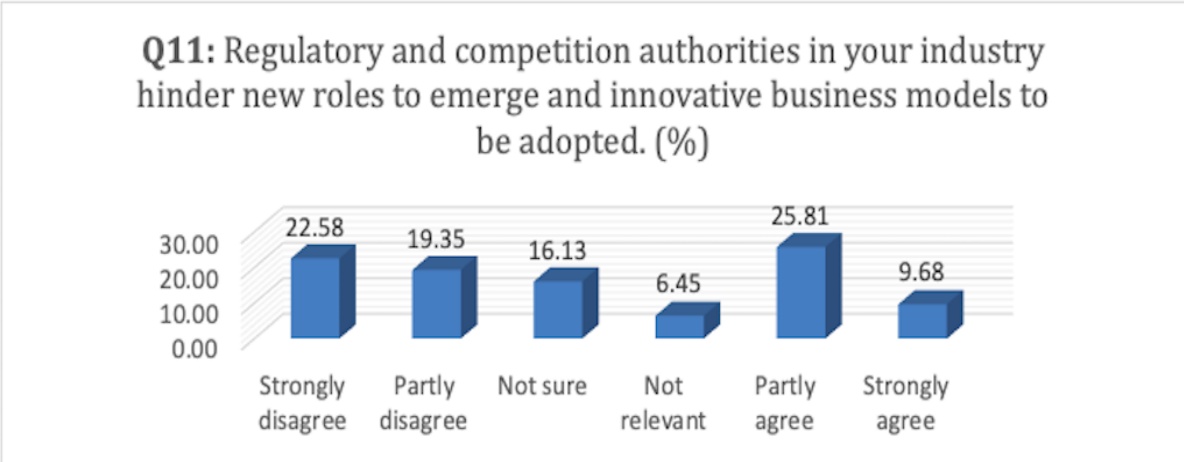


Figure 46: Answers of survey questions Q10, Q11 in Part 2, regarding threats/opportunities from regulations.

As already-mentioned the answers to questions Q5-Q21 have been used in order to evaluate the external points in Section 4.1. To this direction for each of the 6 possible answers we have used the following values.

- Strongly disagree: 5
- Partly disagree: 2.5
- Not sure: 0.0001
- Not relevant: -0.0001
- Partly agree: -2.5
- Strongly agree: -5

Note that the range of values [-5, 5] is selected with respect to the granularity level chosen for the evaluation of each pair of strengths/weakness or opportunities/threats, which is also from -5 to 5. Note also that the values of Not sure and Not relevant, due to their neutral nature, have received a pretty small value which is close to but different than zero in order to distinguish between the two different choices. Based on this valuation, each question has received a value equal to the weighted average of the above values multiplied by the number of the corresponding responses, e.g., in Q10 we have 7 responses in Strongly disagree, 6 Partly disagree, 5 Not sure, 2 Not relevant, 8 Partly agree, and 3 Strongly agree. Thus, the value of Q10 is equal to 7*5+6*2.5+5*0,0001 + 2*(-0,0001) = 0.65.

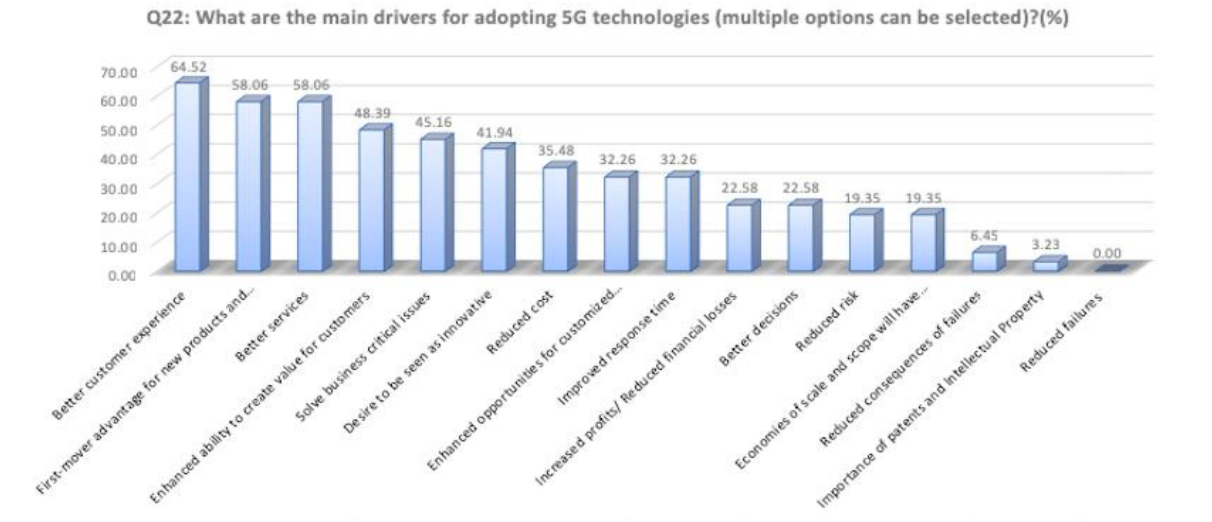
Then, we proceed with a mapping of external points to questions. More precisely, for the External points E1-E10, described in Section 4.1.1 (see Table 20) we consider the following mapping.

Table 20: Mapping of survey questions Q5-Q21 to External points

External Point	Survey Question
E1	Q5
E2	Q8
E2	Q9
E3	Q10
E4	Q11
E5	Q12
E5	Q13
E5	Q14
E6	Q16
E6	Q17
E7	Q18
E8	Q15
E9	Q19
E9	Q20
E9	Q21
E10	Q6
E10	Q7

Based on the above mapping, a straightforward valuation of each external point could consider a value equal to the weighted average of the values of its mapped questions. For the shake of convenience, in the current operation-maturity level of 5G-VINNI we consider the weight of each question to be equal to 1, and thus the value of each external point becomes equal to the average value over its mapped questions, e.g., for E5 we have that the mapped questions, Q12, Q13, Q14, have received values -0.08, 0.16, and 0.89 respectively, thus its value is equal to 0.32.

B.5 Part 6: Reasons for adopting or not adopting 5G



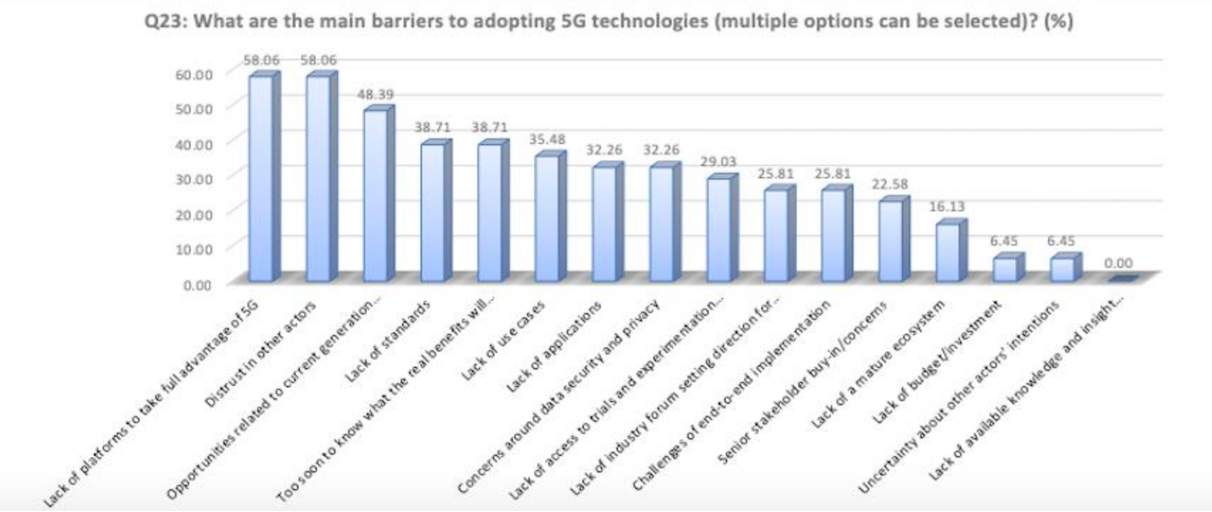


Figure 47: Answers of survey questions Q22, Q23 in Part 6, regarding drivers and barriers in the adoption of 5G technology

The results of this part show that the reasons for adopting 5G technologies seem to slightly outweigh those for not adopting, i.e., there are 158 answers on the main drivers and 147 on the main barriers, shown in graphs Q22 and Q23 of Figure 47 respectively. More precisely, almost 60% of the participants believe that the adoption of 5G will bring better customer experience, better services and first-mover advantage for new products and services, while more than 30% agree that 5G will enhance opportunities for customized solutions, reduce their costs, increase innovation potential, solve business critical issues, and enhance the ability to create value for their customers. On the other hand, the majority of the participants (58%) believe that the adoption of 5G will be mainly hindered by distrust in other actors and lack of platforms to take full advantage of 5G. Moreover, at least one of three participants agree that the adoption of 5G will be difficult due to the fact that the opportunities related to current generation of mobile networks are not yet fully exploited, while also due to concerns around data-security and privacy, lack of standards-use cases-applications, and due to the fact that is too soon to know what the real benefits will be.

B.6 Part 7: Innovation activity outcomes

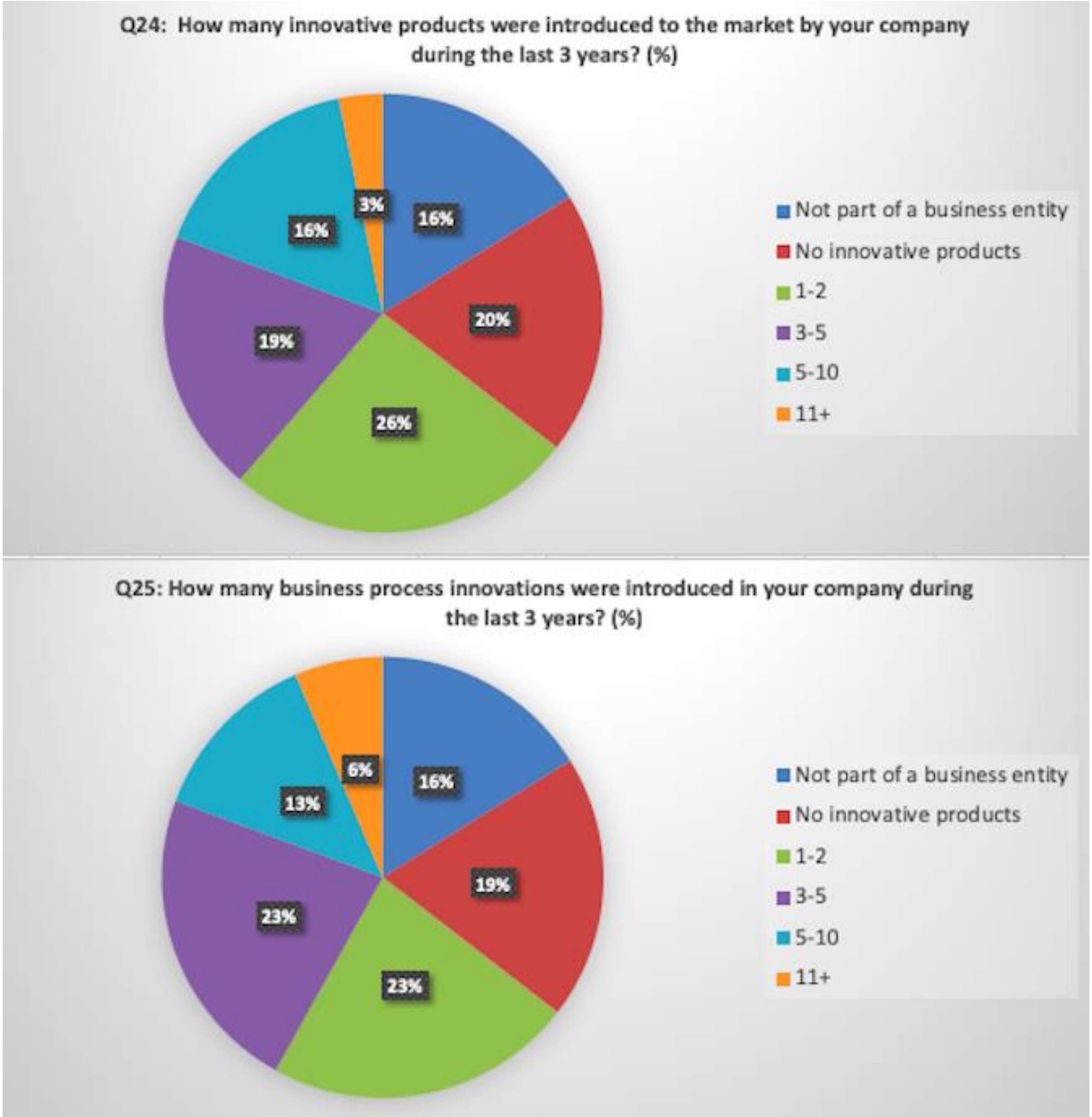


Figure 48: Answers of survey questions Q24, Q25 in Part 7, regarding innovative products and business processes introduced by their companies

As it is shown in graphs Q24 and Q25 in Figure 48, many of the participant's companies (~45%) have introduced 1-5 innovative products and business processes during the last 3 years, while there is a 19% with more than 5 innovation activity outcomes. Some 30% of these companies are from Smart cities and Utilities industries, another 30% are from Manufacturing, Media and Smart agriculture/aquaculture companies, while there is some 22% from other industries (e.g., construction, telecommunications, cultural events). It is worth noting that there are quite a few participant companies (~20%), mainly from the Utilities industry (60%), which have produced none innovative outcome over the last 3 years.

