*VertIcal demos over Common large scale field Trials fOr Rail, energy and media Industries*

# D5.4 Business Plans, Exploitation Strategies and Project Impact Assessment

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# Table of Contents

# Executive Summary

This deliverable documents the activities and outcomes of Task 5.3 "Business Plans, Impact Assessment and Exploitation strategies" within the 5G-VICTORI project. The task involves identifying and promoting the project's impact through various aspects. The deliverable focuses on three main elements: business plans and business modelling, exploitation strategies and outcomes and a sustainability impact assessment.

**Business plans** and sustainability-oriented business modelling drive economic impact and are crucial for commercial exploitation, ensuring that innovative ideas are supported by fitting and sustainable business models (SBMs). **Exploitation strategies** aim to maximize the impact of the project by leveraging its results in technological, commercial, and scientific ways. These strategies are essential for further development and adoption of project outcomes. The **impact assessment** examines the sustainability impact, specifically regarding environmental and social aspects both at a broader level and within the context of the project. It analyses how the different developments align with the Sustainable Development Goals (SDGs) and assesses potential contributions of the project.

The document is accordingly organized into three sections. The first section covers business models, discussing sustainable business modelling in the 5G ecosystem context and its application in 5G-VICTORI. It presents the approach, including tools that were created and the process of application, in workshops and other formats. It also gives a brief overview of the business modelling outcomes for those partners that participated in the facilitated workshops. It also discusses the next necessary steps.

The second section discusses exploitation, first briefly discussing definitions and categories for identifying exploitation activities and outcomes. It goes on to present the main assets created within 5G-VICTORI as well as other broad assets that can be utilized by other actors and provide value for the community as a whole. The section also documents exploitation activities and outcomes by partners. The section shows that the diversity of partners in 5G-VICTORI is mirrored by the variety in exploitation activities and outcomes.

The third section focuses on the impact assessment, explaining its approach, methodology, and results. The first step of the assessment itself is to create and select two different scenarios for further developments of 5G infrastructures and services, via the method of scenario analysis. These two scenarios are compared with regards to their impact on the Sustainable Development Goals (SDGs). In a further step the insights are brought into relation with the contributions of the 5G-VICTORI project, assessing what aspects contribute to which trajectory. In conclusion it emphasizes the potential of 5G-enabled services to provide net contributions to sustainability goals, but also underlines the necessity of proactive shaping of developments through various methods, including sustainability-oriented business modelling.

# Acronyms

## General

| Acronym | Description |
|---|---|
| 3GPP | Third Generation Partnership Project |
| 5G | Fifth Generation cellular system (3GPP related) |
| 5QI | 5G QoS Identifier |
| AI | Artificial Intelligence |
| API | Application Programming Interfaces |
| App | Application |
| AR | Augmented Reality |
| AWS | Amazon Web Services |
| BBU | Baseband Unit |
| BI | Business Idea |
| BIK | Business Information Kit |
| BMC | Business Model Canvas |
| BSCW | The document server used in the 5G-VICTORI project |
| CAD | Computer Aided Design |
| CAPEX | Capital Expenditure |
| CCTV | Closed Circuit TeleVision |
| CDN | Content Delivery Network |
| CIB | Cross Impact Balance |
| (T)CN | (Transport and) Core Network |
| CO2 | Carbon Dioxid |
| CPE | Customer Premises Equipment |
| CPRI | Common Public Radio Interface |
| CSRD | Corporate Sustainability Reporting Directive |
| eCPRI | evolved Common Public Radio Interface |
| eMBB | eMBB Enhanced Mobile Broadband - enhanced MBB |
| E2E | Edge-to-Edge |
| ETCS | European Train Control System |
| FRMCS | Future Railway Mobile Communication System |
| FS | Functional Split |
| GBR | Guaranteed Bit Rate |
| GIS | Geographic Information System |
| gNB | Next Generation Node B |
| GhZ | Gigahertz |
| GPU | Graphics Processing Unit |
| GHG | Greenhouse Gas |
| GWh | Gigawatt hours |
| HD | High Definition |
| HV | High Voltage |
| ICT | Information and Communications Technology |

| | |
|---|---|
| **IoT** | Internet of Things |
| **IIoT** | Industrial IoT |
| **iPerf** | Measurement tool, can be downloaded here. |
| **IPTV** | Internet Protocol TV |
| **KF** | Key Factor |
| **KPI** | Key Performance Indicator |
| **LCM** | Life Cycle Management |
| **LV** | Low Voltage |
| **MaaS** | Mobility as a Service |
| **MANO** | Management and Orchestration |
| **MBB** | Mobile BroadBand |
| **MEC** | Mobile Edge Computing/Multi-Access Edge Computing |
| **MHz** | Megahertz |
| **MIMO** | Massive Input Massive Output |
| **ML** | Machine Learning |
| **MLFO** | Machine Learning Function Orchestration |
| **mMTC** | Massive Machine Type Communications |
| **MOCN** | Multi-Operator Core Network |
| **MVP** | Minimal Viable Product |
| **NB-IoT** | Narrowband IoT |
| **NPN** | Non-Public Network |
| **NRF** | Network Repository Function |
| **NSaaS** | Network Slice as a Service |
| **NVF** | Network Function Virtualisation |
| **OAI** | Open Air Interface |
| **OPEX** | Operational Expenditure |
| **O-RAN** | Open RAN |
| **PDU** | Protocol Data Units |
| **POC** | Proof of Concept |
| **PR** | Public Relations |
| **QoS** | Quality of Service |
| **RAN** | Radio Access Network |
| **RAT** | Radio Access Technology |
| **RTC** | Real-time Communications |
| **RU** | Radio Unit |
| **SA** | Standalone |
| **SBM** | Sustainability-Oriented Business Model |
| **SDG** | Sustainable Development Goal |
| **SDN** | Software Defined Networking |
| **SME** | Small and Medium Enterprise |
| **TCN** | transport and) core network |
| **TCO** | Total Cost of Ownership |
| **ThZ** | Terahertz |

| | |
|---|---|
| **TOBA** | Telecom On-Board Architecture |
| **TOC** | Table of Content |
| **TRL** | Technology Readiness Level |
| **UC** | Use Case |
| **UE** | User Experience |
| **UN** | United Nations |
| **UPF** | User Plane Function |
| **URLLC** | Ultra-Reliable Low Latency Communications |
| **vBBU** | Virtualised Baseband Unit |
| **vCDN** | Virtual Content Delivery Network |
| **VoD** | Video on Demand |
| **VNF** | Virtualized Network Function |
| **VR** | Virtual Reality |
| **Wi-Fi** | Wireless local area network |
| **WLAN** | Wireless Local Area Network |

### 5G-VICTORI and related EU projects

| Acronym | Description |
|---|---|
| **5GENESIS** | The Berlin ICT-19 Cluster |
| **5G-EVE** | Alba Iulia ICT-19 Cluster (e) |
| **5G-PPP** | 5G infrastructure Public Private Partnership |
| **5G-VINNI** | The Patras ICT-19 Cluster (v) |
| **5G-VIOS** | 5G-VICTORI Infrastructure Operation System |
| **ADMIE** | IPTO – Independent Power Transmission Operator |
| **AIM** | Alba Iulia Municipality |
| **Alstom** | Bombardier Transportation |
| **COSM** | COSMOTE |
| **DCAT** | Digital Catapult |
| **D3.7** | Deliverable 3.7 (within WP3, T3.4) |
| **DBH** | Deutsche Bahn Holding |
| **DBN** | Deutsche Bahn Netze |
| **EUR** | Eurecom |
| **FhG** | Fraunhofer FOKUS |
| **GA** | Grant Agreement |
| **I2CAT** | i2CAT Foundation |
| **IASA** | Institute of Accelerating Systems & Applications |
| **ICT-17** | The 5G platform developed for the 5G-PICTURE EU project |
| **ICT-19** | The 5G platform developed for the 5G-VICTORI |
| **ICOM** | Intracom Telecom |

| | |
|---|---|
| **IHP** | Innovations for High Performance microelectronics |
| **IR** | Interim Review (done 2020-10-08) |
| **IZT** | Institute for Futures Studies and Technology Assessment |
| **KCC** | Kontron Transportation Austria AG |
| **MS10** | Milestone 10 (within WP5, T5.3) |
| **MATI** | Mativision |
| **Orange** | Orange France |
| **ORO** | Orange Romania |
| **PXI** | Paxlife Innovations |
| **RBB** | Rundfunk Berlin-Brandenburg |
| **T3.4** | Task 3.4 (within WP3) |
| **UHA** | Urban Hawk |
| **UNIVBRIS** | University of Bristol |
| **UoP** | University of Patras |
| **UTH** | University of Thessaly |
| **WP2** | Work Package 2: Description – Use cases/ Specifications |
| **WP3** | Work Package 3: Vertical Services to be demonstrated |
| **WP4** | Work Package 4: Trials of Coexisting Vertical Services, validation and KPI evaluation |
| **WP5** | Work Package 5: Standardisation, Dissemination, Commercial Exploitation and Impact Assessment |
| **ZN** | Zeetta Networks |

# 1 Introduction

This deliverable reports the work carried out in the context of Task 5.3 and documents the results of the activities undertaken during the 5G-VICTORI Project duration. Task 5.3, entitled “Business Plans, Impact Assessment and Exploitation strategies”, comprises different aspects of identifying and promoting the impact of the 5G-VICTORI project. Accordingly, what unites the three elements named in the task is that each one of them deals with the impact of the project. These three elements are:

**Exploitation strategies** promote activities aimed at exploiting the project results in technological, commercial and scientific ways, thus enlarging the direct impact of the project in these three realms. Exploitation is fundamental to any kind of impact of the project, as it describes the further use of all results, insights and collaborations, which is necessary for technologies being further developed and adopted at a larger scale and thus having further impact, e.g. on environmental sustainability. In this deliverable we present the main assets created through 5G-VICTORI as well as the exploitation activities and outcomes by partner.

**Business plans** and business modelling are closely related to commercial exploitation. A technological innovation and a related idea for commercial exploitation need a good and fitting business model in order to succeed. 5G technology does not only enable an immense range of new applications to be built and services to be offered, it also substantially reshapes the ecosystem in which actors operate, necessitating strong business models that also take this into account. As Henry Chesbrough puts it: “A mediocre technology pursued within a great business model may be more profitable than a great technology with a mediocre business model”. The section on business plans is about the impact regarding specific business models and commercial exploitation strategies, as well as about impact in regard to learnings for sustainability-oriented business modelling in a 5G ecosystem context in general. With the new EU Corporate Sustainability Reporting Directive (CSRD) more companies are required to engage in sustainability reporting, which also implies focusing increasingly on sustainability also in business modelling and business plans.

The third type of impact is only partly covered by exploitation: this is the impact with respect to sustainability goals, in particular regarding environmental and social sustainability. This is what we examine under the heading **impact assessment**. Since this type of impact emerges once technologies/apps/services are adopted at scale, assessing the impact of a project such as 5G-VICTORI necessarily deals with future potentials and possible developments. Moreover, the impact is highly dependent on the context in which and on how the technologies/apps/services are adopted. Accordingly, we broaden the focus and look at the impacts with respect to the Sustainable Development Goals (SDGs) to be expected from future developments in the 5G infrastructure and with respect to important service areas in which the 5G-VICTORI use cases (UCs) are situated. We then examine achievements in 5G-VICTORI, analysing how these contribute to different expected developments.

Assessing the expected impact with regards to all aspects of sustainability is highly important, given that 5G is a key enabler for digitalisation. Digitalisation and the transition to a sustainable society are challenges that need to be addressed simultaneously. 5G infrastructures and associated innovative applications and services are expected to impact all three dimensions of sustainability if a sustainability perspective is introduced in R&D projects. For this reason, sustainability considerations were included in 5G-VICTORI in the UC assessment, in the work on business modelling and business plans and the impact assessment.

**Organisation of the document:**

This deliverable consists of three parts, the first part is dealing with business models, the second part is dealing with exploitation and the third part is dealing with the impact assessment. These three parts are respectively structured as follows:

Section 2 concentrating on business models first describes the framework with regards to sustainable business modelling and business modelling in 5G ecosystem contexts and then describes the approach taken to business modelling and the formulation of business plans in 5G-VICTORI. It then describes the process and results from business modelling activities in the project. More detail on the results can also be found in Appendix.

Section 3 focusing on exploitation describes the definitions and categories used for identifying exploitation activities and outcomes. It then presents the main assets created in 5G-VICTORI and documents the exploitation activities and outcomes by partners.

Section 4 presents the impact assessment, first explaining the general approach and goals. It then describes the methodology employed, which is scenario methodology. In the third subsection the four steps of scenario analysis are documented. Subsequently, the scenario results are analyzed with respect to their contribution to the SDGs and the relation of the 5G-VICTORI work to the two scenarios is examined. Finally, general insights from the impact assessment are formulated.

Section 5 presents the conclusions of this document.

# 2 Business models

To turn ideas into innovation, these ideas must prove at least three abilities: feasibility, desirability and viability. Technological *feasibility* has been essential for most work streams in the 5G-VICTORI project. *Desirability* for future customers and *viability* of a suitable business model also need explicit attention and need to be considered as early as possible, since both can heavily affect the technological requirements. Business modelling and planning were therefore defined as Task 5.3 in the Description of Work (DoW), to be carried out by the consortium and facilitated by **UXBerlin** and **IZT**. It was carried out as an iterative development process feeding back into the technical workstreams early on. Regarding desirability, despite being at the early stage of development with little empirical data on customer acceptance and user experience (cf. deliverable **D3.7** User Dimension of the Use Case assessment) [1]), there is a positive outlook of services becoming highly desirable in the near future. Business viability was investigated on the basis of customer value propositions that were further elaborated through business modelling activities. This section reports these activities and sums up their results.

## 2.1 Sustainable Business Modelling: Framework and Approach

Modelling the 5G business is a challenging task for at least three reasons: this business will take place mostly in the future, it will be based on contributions from a whole new ecosystem of actors and stakeholders, and it needs to be a sustainable business.

Firstly, since technologies and UCs are at initial commercialisation phases, there is still a large (market and business) design space to explore. On the one hand, this means that the envisioned future deployments and scenarios rest to a relevant extent on assumptions. On the other hand, this also implies a real chance to shape deployments towards desirable outcomes.

Secondly, the enabling ecosystem is likewise under development. However, potential future formulations are already foreseen and anticipated [2] and their implications for new business in the enabling ecosystem and for selected vertical business ideas have been elaborated upon (section 2.2). Thirdly, new businesses resulting from 5G-VICTORI need to be sustainable to motivate contributions from diverse stakeholders, to ensure desirability in the long-term, while complying with European regulation.

To address these three challenges within 5G-VICTORI, conceptual and methodological advancements were needed, which then were used in workshops and business modelling perspectives. These are described in the following sections of section 2.1 (and their results in section 2.2). First, we created a tailored approach to co-create SBMs, or to enable the business partners in the consortium to do this themselves using a generic process model. Both the approach and the process model are described in section 2.1.3. To address the ecosystem perspective, an existing innovation management framework was advanced into a conceptual framework for sustainability-oriented ecosystem and business model development. This framework is described in section 2.1.2. To create the conceptual foundations for both the ecosystem perspective and the project approach, we start with disambiguation of values-based and SBMs in section 2.1.1.

### 2.1.1 Values-based and Sustainable Business Models

A business model "describes the design or architecture of the value creation, delivery, and capture mechanisms [an enterprise] employs" [9]. Until a decade ago, this value was understood in a rather narrow sense of providing customer benefits, profit to investors and wages to employees through company revenues, and (indirect) benefits to society through taxes and employment [2]. This understanding of value in terms of benefits of economic activity has been expanded to the creation of social (e.g. inclusion services, participation or access) and ecological advantages (e.g. reduction of emissions or positive contributions to the strengthening of ecosystems). This move from traditional to an extended value creation aiming at economic, social and ecological benefits is now becoming mandatory with the new EU CSRD and EU taxonomy. The new CSRD requires even mid-sized companies from 2023 to professionalize their sustainability reporting and, in many cases, to innovate their business model in a sustainability-oriented manner in order to comply with the EU taxonomy. This taxonomy requires business activities to contribute to at least one of the six EU environmental goals – climate protection, adaptation to climate change, water/marine protection, circular economy, environmental pollution and biodiversity / ecosystems – to do no significant harm with regards to the other goals, and to fulfil social minimal standards.

In sum, sustainable value creation, delivery, and capture should therefore contribute to solving sustainability challenges [3] and create likewise economic, social and ecological benefits [2].

⇨ *It is still an open issue for business development and economic research, which particular ecological, social and economic benefits sustainable new business can and should provide, not only with respect to 5G.*

There is no conclusive list of such benefits in the scientific literature, and normative frameworks like the Sustainable Development Goals (SDGs) and the EU taxonomy only provide high level guidance that business actors need to explore and specify through their individual, future value propositions. 5G-VICTORI contributes to this scientific discussion: The sustainable value propositions identified in 5G-VICTORI are presented in section 2.2.3.

Moreover, since “a sustainable organisation expresses its purpose, vision and/or mission in terms of social, environmental and economic outcomes" [4], multidimensional (economic, social, ecological) value creation, six environmental goals of the EU, seventeen SDGs (with 169 targets and even more indicators) of the UN normative framework, all need to be translated into unique normative guidelines (vision, mission, purpose) and underlying values for service providers. Sustainability-oriented business model development implies a reconsideration of organisational and stakeholder values and has therefore been referred to as values-based innovation [5]. What may appear as a detour (i.e. reflecting upon and specifying these values), helps innovators and business developers to direct their efforts, to specify their offerings, and to integrate diverse stakeholders (such as regulators or communities embedding new business) that can substantially contribute to the success or failure of a new business.

Accordingly, a values-based and sustainability-oriented business modelling approach was chosen to advance 5G-VICTORI business ideas and ecosystem implications.

A key challenge in integrating sustainability-oriented and ecosystem business modelling is to find ways to deal with the complexity of different business model components or activities, different types of (economic, social, and ecological) value creation and different stakeholders, including ecosystem partners, being involved. A business modelling methodology is needed, which integrates sustainability orientation consistently in each of the steps and ensures that sustainable value creation is considered from the outset, and not just as “end-of-the-pipe” assessment.

### 2.1.2 Ecosystem Modelling Approach

Market formulations for 5G and beyond 5G service provisioning are shifting from the “value chains” of earlier-generation telecom networks to exhibit more complex ecosystem characteristics [6]. How to model and create sustainable business ecosystems in this domain is an emerging topic of scientific debate. Our work on 5G-VICTORI contribute to developing a suitable approach to ensure that not just single firm business models, but the whole ecosystem of interdependent actors creates ecologically, socially and economically beneficial outcomes. First results have recently been published in a white paper [7].

In a first step, the joint elicitation, exploration, and elaboration of values and normative orientations can be utilized to re-frame and expand existing innovation methods and frameworks and build shared sustainability values that all ecosystem stakeholders commit to – aiding coordination within the ecosystem. Subsequently, stakeholders build their business model on top of this basic framing (see Figure 2-1). The re-framing of actors' business models and the ecosystem as a whole occurs through an iterative process. Once defined and stabilised, such shared values and normative orientations can guide stakeholders in seeking out attractive business models and business model components (e.g., a green freemium revenue modal to promote green usage of, for example, mobility services).

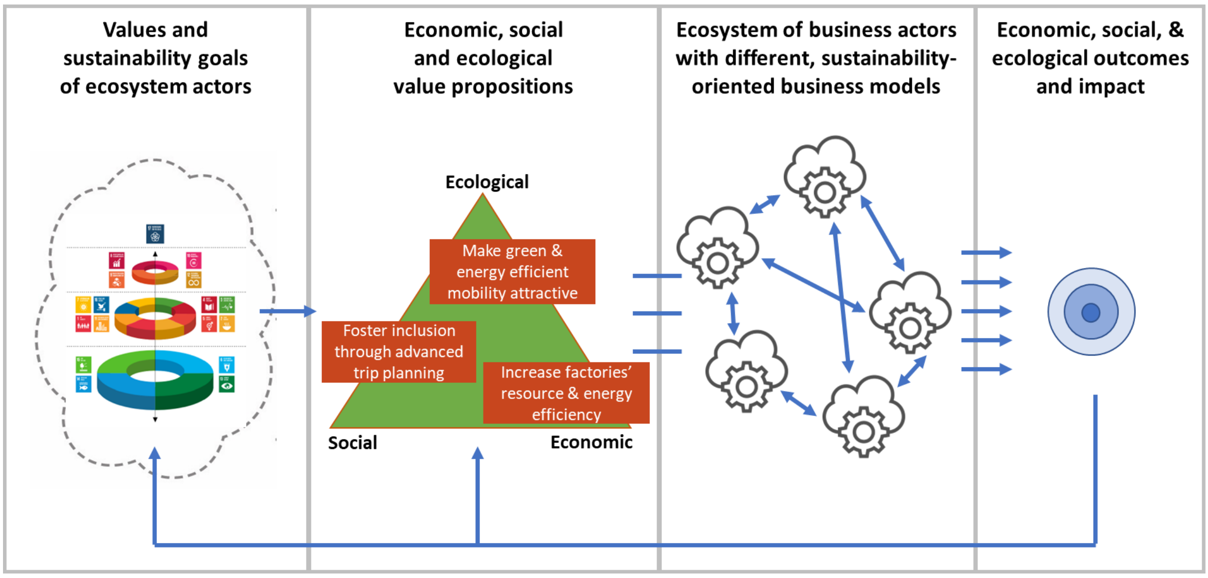


**Figure 2-1 From values to outcomes and impacts**

Shared values and a common vision can drive innovation in the distinct business models of the involved actors [13]. The second stage of this process is facilitated by various tools focused on sustainability and values-based business modelling [11]. In particular, the Business Innovation Kit (BIK) [12] was developed expressly for this purpose. It takes a small group of participants from understanding the fundamental values and normative orientations of a business or business idea to considering various value propositions, and on to ideation, selection, and combination of suitable business model components, including stakeholders, capabilities, revenue models, and cost structures. The success of the model is validated not just through economic performance indicators but also by the resultant social and ecological value creation and its influence on value-based and normative goals (such as sustainable development) that motivate and provide the basic framing for the ecosystem.

### 2.1.3 Creating Sustainable Business Models in 5G-VICTORI

The basic approach to create sustainable business in 5G-VICTORI consisted of five steps, from reviewing the initial business idea to facilitating a series of SBM workshops and creating a generic process model for others to replicate these workflows, to refining ecosystem implications and preparing validation. Figure 2-2 illustrates this basic approach.

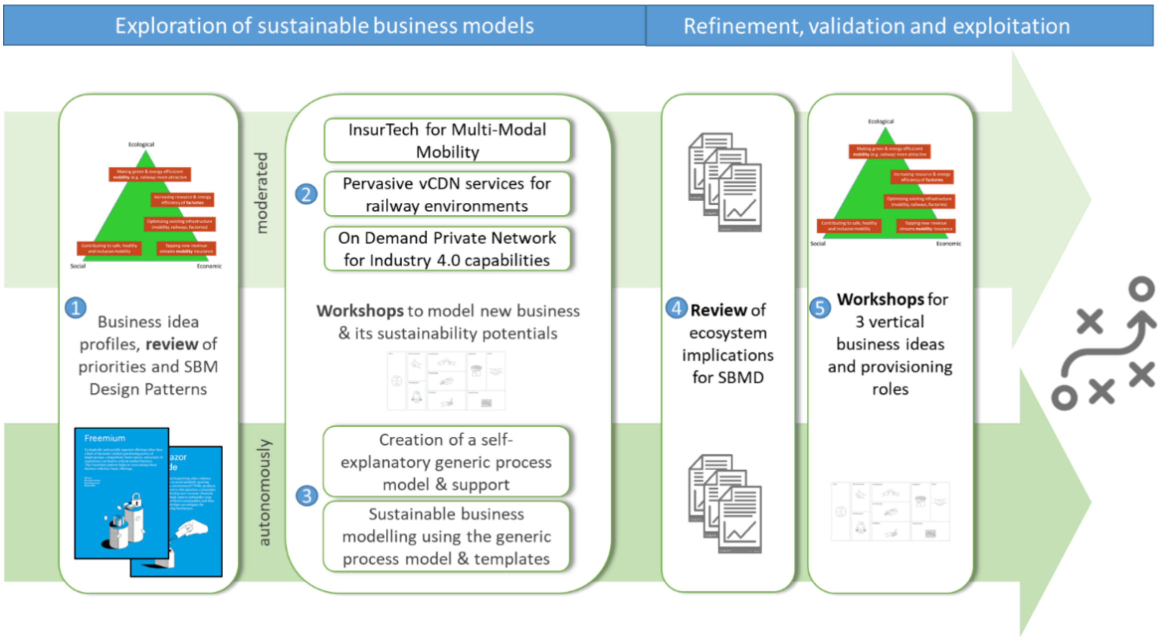


**Figure 2-2 5G-VICTORI Business Development Approach**

#### 2.1.3.1 Review of Business Ideas (1)

As a first step, we collected initial, business-related ideas from consortium partners and reviewed their business priorities respectively values. A survey with a profile template (see Appendix 7.1) was conducted to identify business ideas (BIs) either at UC or service type level. Each business profile consists of a name, a list of relevant 5G-VICTORI service types, a description of the team promoting the idea, the priorities of the BI, the unique market gap, and its potential economic, social and environmental impact. It also includes the Technology Readiness Level (TRL – see appendix) and business model related ideas (i.e. with respect to motivating values, value proposition, stakeholders, touchpoints, distribution, revenue model, capabilities, partners and cost structure).

Project partners selected whether they preferred to enter the moderated track to business modelling, or to do this autonomously using the generic process model. Three BI providers were chosen for the moderated track, covering the different regions and clusters / verticals (i.e. Rail Transportation Services; Media Services; Energy/Factories of the Future) and, therefore, representing good orientation points for others.

With each of the three idea providers, we prepared and conducted a semi-structured expert interview using an interview guide. Preparing for these interviews we identified SBM patterns [2] that could be used as a resource to enhance the BI and to advance towards a SBM. Two examples:

- One BI considered a freemium model to gather revenues for a multimodal mobility application. The “social freemium” pattern [2] provides free basic services to underprivileged customers. Translating the pattern to multimodal mobility business, one could provide underutilised capacities for free to those in need. However, one could also focus on environmental sustainability issues and introduce a “green freemium” revenue model subsidising CO2 neutral journeys by charging extra for high emission combinations of modalities.
- In the case of virtual Content Delivery Network (vCDN) services for railways, the Resource Efficiency and Productivity pattern [2] suggested to enhance the business model through system thinking and technological solutions that can reduce energy consumption. Based on these considerations, the following guiding questions were

derived and presented to the participants at the beginning of the workshop. For example: How can we make the most efficient use of technology? How can we increase resource productivity if we think about the whole vCDN system rather than isolated parts?

Through these interviews we explored the history of the BI, lessons learned and experience-based, contextual knowledge of the idea provider, e.g. with respect to the market situation and competition (e.g. why previous, similar initiatives might have failed), the idea providers (and stakeholder) priorities and values regarding their project, their understanding of sustainability-considerations (and their potential to advance their ideas), and discussed the relevance of the selected SBM patterns for the BI and their providers. Finally, we clarified open issues that could have emerged from the profiles and materials provided by the idea owners.

#### 2.1.3.2 Workshops to model new business and its sustainability potentials (2)

Secondly, we prepared and conducted business-modelling workshops with the three BI providers and some of their stakeholders and documented and refined the results (for an overview over the main workshop see Table 2-1). Within these workshops, sustainability-orientation was further differentiated (e.g. with respect to specific SDG, targets, and specific goals) as one of the normative business goals or business priorities, and related to the other priorities (e.g. values of founders, customers and other stakeholders) – specifying the basic system of priorities for business model generation. The workshops were conducted online using a collaborative workspace and a standardised sequence of activities. The BI provider presented their basic idea and the state of development. The moderators then facilitated a walk-through for the initial ideas and their sustainability-oriented reframing and ideation. Using standardised templates from the BIK [12] (Figure 2-3), participants generated and prioritised ideas for different business model components and refined and challenged alternative business model sketches.

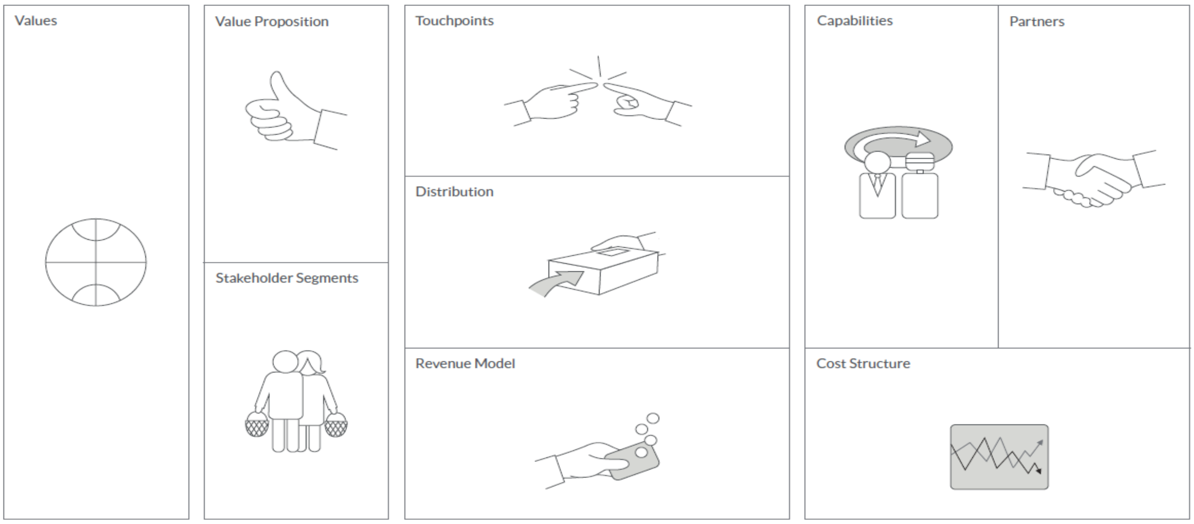


**Figure 2-3 Idea pool of the Business Innovation Kit (BIK)**

At the end of the workshop, at least one business model sketch was selected for the follow up and fine-tuning. Results from each workshop were documented and enriched with insights from follow-up desk research to further explore the viability of the business models and its critical or open issues to be solved. Refinement of the workshop results included:

- Prioritisation of one business model to begin with in the first release and refined business model components (especially capabilities, revenue model and cost structure).

- Enrichment of the model with secondary data and figures, e.g. from market research and competitor analysis from desk research.
- Preparation of empirical validation (e.g. through customer feedback and insights or test market studies) and financial planning.

For each BI and the results from the reviews, workshops and follow-up desk research, a comprehensive report was created and provided to the owners of the BI to document the business model sketches and to trigger more in-depth inquiry into their critical aspects and future potentials (see Appendix 7.2).

#### 2.1.3.3 **Generic Process Model (3)**

Third, building on lessons learned from these workshops and experiences with the templates to facilitate them, a generic process model (see Appendix 7.1) was created and distributed to the other BI owners as a blueprint to run similar activities autonomously in a self-directed manner.

The generic process model enables BI owners to create and consolidate SBMs for their 5G-VICTORI service ideas. It consists of five overarching steps (see Figure 2-4) and is complemented by a number of resources and templates that contain further support and instructions. One person in the idea owners' organisation can facilitate the process. They will need at least one week to prepare and facilitate this process, and another to analyze and refine the workshop results, but will also learn a lot about sustainable business modelling. In the end you should have one or several business models to communicate and proceed with, and a profound shared understanding also about its / their maturity respectively the need for further experimentation and investigation.

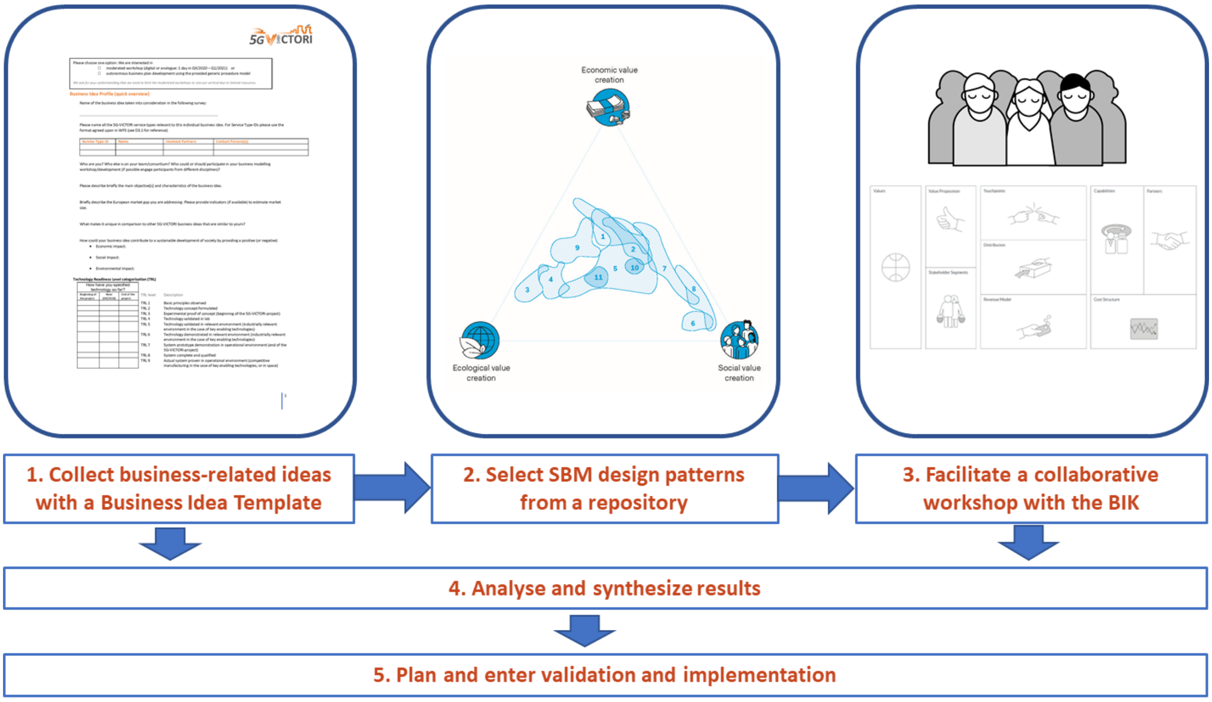


**Figure 2-4 Overview of overarching steps in the generic process model**

Within the moderated workshop and the generic process model a values-based business modelling tool (named BIK [12]) was used to create sustainability-oriented business models. The BIK and its values-based business model canvas were developed to facilitate values-based and sustainability-oriented business model innovation. The toolkit builds on a didactic approach that supports self-guided ideation and innovation processes in mixed teams through the definition of values providing a “common ground”, exemplification through cases and business model patterns, ideation for single business model components, and modelling relations across components and models. The methodology underlying this tool supports values-based and thus also sustainability-oriented modelling in collaborative settings [11].

#### 2.1.3.4 Review of Ecosystem Implications (4)

Fourthly, drawing from previous analysis of the emerging ecosystems and emerging new roles and from lessons learned from three SBM workflows, we reviewed and documented potential implications of the emerging ecosystem for provisioning roles and vertical business models.

Within the emerging 5G ecosystems, different roles and individual actors (companies) are highly dependent on one another in their value creation, delivery and capture (i.e. in their business models). New processes, activities and operations also define new roles, relationships and interfacing options. This interdependence as well as the ongoing evolution of 5G ecosystems as a whole create new business opportunities for participating firms but also provoke competitive tensions and uncertainties as to how value creation activities (roles), revenues and liabilities will be distributed among them. At the same time, **competitive tensions** (e.g. between Telecom Operators and 5G Service Providers) provoke fears in potential ecosystem members of becoming obsolete, losing control over value generation, or losing market shares. **Uncertainties** regarding investment and operational costs, regulation policies and revenue sharing further amplify these concerns.

From a **strategic management perspective**, the formation of 5G ecosystems requires firms to **clarify what** is the optimal distribution of actor roles and balance their interests with other stakeholders. They also need to specify the configuration of the value network through which they will create and distribute value among all ecosystem members. From a **normative management perspective**, 5G ecosystems can be formed through collaborative exploration and elaboration of values (e.g. sustainability and resilience of the ecosystem, accessibility, end-user experience) (see Figure 2-5). By defining their shared values and making them explicit [13], stakeholders can **clarify why** their collaboration is perceived as valuable, and create individual business models catering to these values. Sustainability-orientation as a common value of different ecosystem partners helps to balance diverging interests and mitigating tensions among them while leveraging potentials for environmental, social and economic value creation.

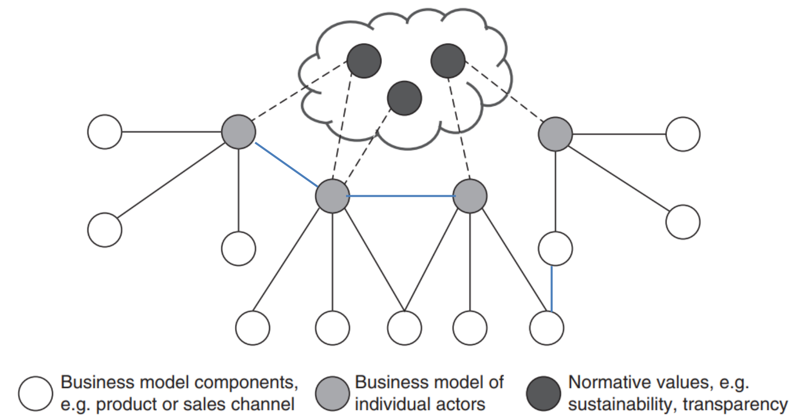


**Figure 2-5 Visualisation of networks based on values such as ecological, social and economic sustainability and resilience of the ecosystem (adapted from [6])**

Our review of Implications of 5G Ecosystem Developments for Sustainable Business Modelling draws from previous analysis of the emerging ecosystems (drivers and challenges) and emerging new roles [14] and from lessons learned from three sustainable business modelling workflows with three vertical business ideas. Mapping ecosystem characteristics onto generic business model components, it anticipates the impact, opportunities and potential barriers of the emerging provisioning and vertical ecosystems on individual actors and their potential business models (results are presented in section 2.2).

#### 2.1.3.5 Refinement Workshops (5)

Finally, refinement workshops were prepared, conducted and documented with representatives from the provisioning roles and the three vertical business idea owners in order to update and refine the business models and set the course for their validation. The first goal was to specify initial assumptions about sustainability potentials and risks in different business model components, also considering implications from 5G Ecosystem Developments. The second goal was to define (qualitative) methods and/or quantitative metrics to validate desirability (from a customer point of view) and viability (from a business perspective) of the BIs.

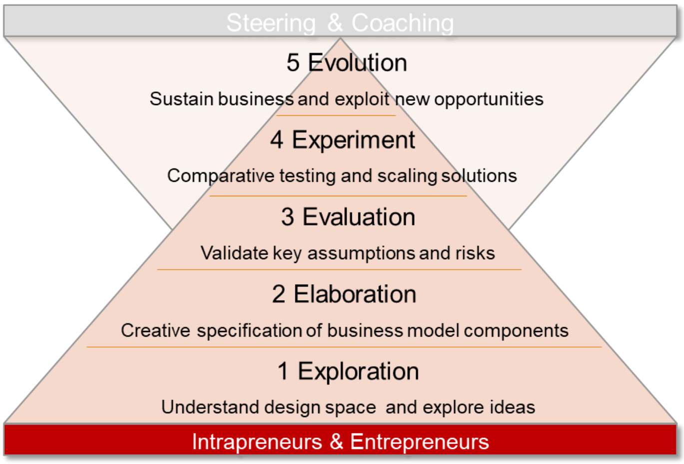


**Figure 2-6 Lean venturing framework to create new business [14]**

Working with a framework of five stages (see Figure 2-6) to further specify the BI idea and to validate critical assumptions for new business ideas, suitable methods were defined for each vertical BI to advance their business models through methods such as customer journey specification, benchmarking, customer development interviews, A/B testing, cohort studies, etc.. However, due to the technology readiness level (between 3 – experimental proof of concept up to 7 – system prototype demonstration in operational environment) of the UCs, many aspects of systematic customer research and quantitative experimentation on business model components is still pending.

In addition to the business idea refinement workshops, a workshop concentrating specifically on ecosystems was also prepared and facilitated. The focus here was on the telecom operator perspectives and in particular on the fields of railway and smart city environments. Different possible ecosystem configurations were examined and various scenarios mapped. In a second step a business model canvas (BMC) approach focusing on the ecosystem context was applied (results are presented below).

The final activity in the business modeling workstream was a consortium partner workshop in April 2023 in Berlin, where we provided an update on European frameworks implications for sustainable business modelling and ecosystem development, gave an overview of the generic process model and its tools, and conveyed first-hand experience applying the tools.

**Table 2-1 Business Modelling Workshops in 5G-VICTORI**

| # | Date | Title of Workshop | Participating Partners |
|---|---|---|---|
| #1 | 10.09.2020 (1 hour) | 5G-VICTORI **Business Plan Interview** with **UHA** | **UXBerlin**, **IZT**, **UHA** |

| | | | |
|---|---|---|---|
| #2 | 23.03.2021 (1 hour) | 5G-VICTORI **Business Plan Interview** with **ICOM** | **UXBerlin**, **IZT**, **ICOM** |
| #3 | 25.03.2021 (1 hour) | 5G-VICTORI **Business Plan Interview** with **ADMIE** | **UXBerlin**, **IZT**, **ADMIE** |
| #4 | 23.04.2021 (3.5 hours) | 5G-VICTORI Business Modelling Workshop – **Pervasive vCDN services adaptive to network resources for railway environments** | **UXBerlin**, **IZT**, **DCAT**, **TRA**, **ICOM, COSM, UoP** |
| #5 | 31.05.2021 (3.5 hours) | 5G-VICTORI Business Modelling Workshop – **On Demand Private Network for Industry 4.0 capabilities** | **UXBerlin**, **IZT**, **ADMIE**, **UoP**, **ICOM** |
| #6 | 17.06.2021 (3.5 hours) | 5G-VICTORI Business Modelling Workshop – **Future Mobility / InsurTech for multi-modal mobility** | **UXBerlin**, **IZT**, **UHA** |
| #7 | 23.09.2022 (3 hours) | **Workshop on Business Ideas in 5G-Ecosystem Evolution –** Spot on Telecom Operators | **UXBerlin**, **IZT**, **COSM**, **Orange**, **ORO** |
| #8 | 28.09.2022 (1.5 hours) | 5G-VICTORI Business Modelling Refinement Workshop – **On Demand Private Networks for Industry 4.0 capabilities** | **UXBerlin**, **IZT**, **ADMIE** |
| #9 | 29.09.2022 (1.5 hours) | 5G-VICTORI Business Modelling Refinement Workshop – **vCDN services for railways** | **UXBerlin**, **IZT**, **ICOM** |
| #10 | 17.11.2022 (1.5 hours) | 5G-VICTORI Business Modelling Workshop PART I – **Urban Hawk's Simulation Business Ideas (formerly InsureTech)** | **UXBerlin**, **IZT**, **UHA** |
| #11 | 25.01.2022 (1 hour) | 5G-VICTORI Business Modelling Workshop PART II – **Urban Hawk's Simulation Business Ideas (formerly InsureTech)** | **UXBerlin**, **IZT**, **UHA** |
| #12 | 24.4.2023 (1.5 hours) | **Sustainable Business Model Design:** a generic process model for 5G vertical service providers | Open to whole consortium |

**Note:** only the main, facilitated workshops are listed here, in-between calls and meetings additionally took place throughout the project.

## 2.2 5G Ecosystem implications, business models and benefits

This section sums up the selected results from the collaborative workshops and co-creation activities with consortium partners from the provisioning ecosystem and vertical industries.

### 2.2.1 5G ecosystem implications

Modularity of 5G and beyond 5G technologies enable a dynamic business ecosystem with a higher number of interdependent actor roles, actors, and business relationships. This leads to the challenge of identifying and designing SBMs in highly dynamic and complex ecosystems. An ecosystem can be defined as "a dynamic and largely independent set of players that complement each other to create interconnected offerings which have more value when consumed as one integrated experience" [14].

Even though there is high uncertainty around actual 5G ecosystem evolution in different markets and regions, different development scenarios have been described [13] and their implications are taken into consideration for modelling new business within vertical industries and the provisioning system. We extracted implications from previous works (especially [13] & [16], [18], [19]) in order to facilitate reflection on their relevance, associated risks and to mitigate competitive tensions (e.g. between Telecom Operators and 5G Service Providers). Selected implications were used in the refinement workshops with the owners of the BIs. Figure 2-7 provides an overview of these potential implications of future 5G ecosystem in general with regards to the different sustainability-related business values and business model components (a more comprehensive presentation contains details for each component from the workshop with Telecom Operators, see Appendix 7.2.4).

From a sustainability point of view, 5G ecosystem implications begin with a challenge: despite the efficiency potentials of 5G networks, without active intervention, a substantial increase in consumption and related GHG emissions is expected [15] [16]. “Mobile operators, their partners, and the entire ecosystem will not achieve the sustainability targets, without an end-to-end collaborative, committed and orchestrated effort” [16]. To establish sustainability as a core value for 5G ecosystem formation, several measures should be taken:

- Sustainability criteria and KPIs can be integrated into the assessment system for involving ecosystem partners and complemented with green pricing.
- Several standards (ibid.) can be used to define indicators and measures that ensure energy efficiency of 5G provisioning ecosystems (e.g. through energy-saving software, distributed architecture; AI-driven architecture and operation; upgraded equipment; renewable energy and carbon sink investments).
- 5G vertical ecosystems can provide vertical sector firms with opportunities to curb emissions (e.g. deployment of 5G sensors in the power and industrial sectors, improved utilisation of low-emission travel modes in the transport sector).

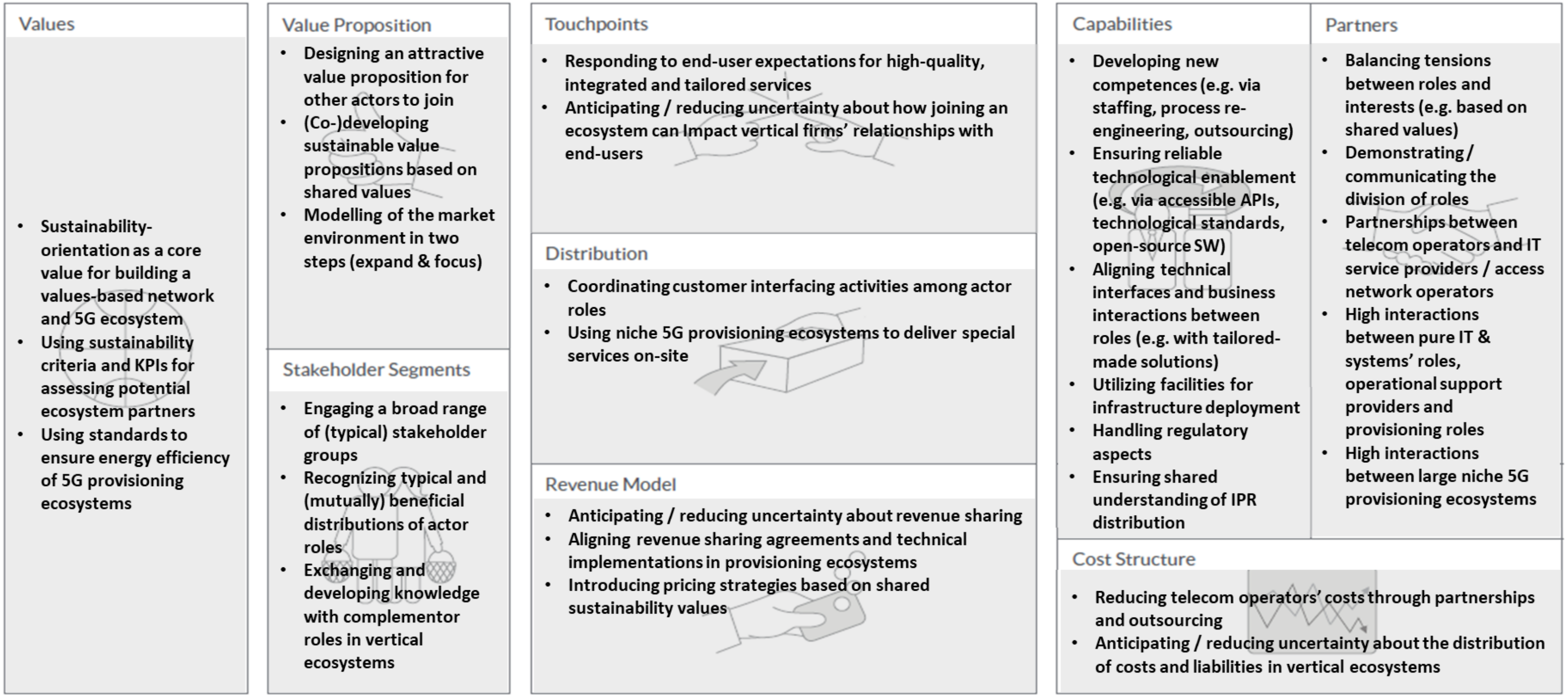


**Figure 2-7 Overview of Implications of 5G Ecosystem Developments for Sustainable Business Modelling**

### 2.2.2 Cost structure and techno-economic analysis

It shall be noted that no matter the final ecosystem formulation, the cost structure (i.e. the structure of costs per network segment (RAN, Edge, Core) and layer (Infrastructure, Network, Network Service provisioning, Service Orchestration, etc.) will depend highly on the techno-economic analysis of the roll out of the selected network deployment option. To this end, delivering 5G network deployments to meet the service requirements is not a straightforward task. In practice, many factors need to be considered, such as area specifics, deployment feasibility, long-term service roadmaps, traffic demand and growth patterns/forecasts, as well as infrastructure availability, scaling capabilities and the associated costs. The scaling capabilities and the identification of these costs need to consider also the various deployment phases (over time), in order to estimate the critical, high-cost factors and to extract deployment guidelines at early network planning stages. Performing techno-economic analyses is an equally complex task, the underlying reasons being many and versatile depending on the scope, scale, system, technologies in focus, etc.

Therefore, as reported in [1], a methodology has been proposed for techno-economic evaluation of large-scale 5G and B5G network deployments and it has been implemented as a parameterisable tool. The tool is generic and can model any deployment based on 5G-VICTORI technologies and deployment options. Moreover, it can be extended to include additional technologies and can be used for their techno-economic evaluation. In the context of the project, the tool was used to model explicitly the railway and smart city environments (non-restrictive usage of the tool) as the project UCs referred to these environments.

The tool was then filled in with numerical values for the **Athens-Patras railway route** as a case study, which was presented in detail in [20]. It provided significant results that can be extrapolated beyond this deployment case study, which are related to various deployment alternatives that can be used as guidelines for the stakeholders that will undertake network deployments, and for the rest of the ecosystem stakeholders to evaluate the cost structure of the solution. In particular, considering Greenfield Optical network deployments versus Brownfield ones, the cost of fibre deployment for a pure optical deployment is a critical cost factor that can determine further the selection of the network cost. Given common average fibre deployment prices, lack of fibre deployment along the target route may result in an increase of network deployment cost reaching even 4 times the cost of the whole network deployment. The aforementioned cost escalates greatly with distance, thus as a general guideline, it is advised that for long-reach deployments, wireless solutions and existing fibre niches, etc., need to be considered. This cost shall be especially assessed by the stakeholder undertaking the infrastructure provider role in the 5G ecosystem. Apparently, this cost is passed on the other stakeholders of the ecosystem affecting the viability and stability of the ecosystem.

Furthermore, the selection of Functional split (FS) and the existence of fibre deployment affects the transport network cost. The cost of using eCPRI -even in the case of high-capacity fibre links- is almost 80% higher than that of all other eCPRI schemes (A to IID). Thus, massive rollout of low level eCPRI splits should not be considered as norm. In cases where hardware infrastructure deployment for BBU processing is restricted by the site space/topology, etc., virtualised Baseband Unit (vBBU) deployment shall be considered at edge or at cloud sites. This cost shall be assessed in common by the stakeholder undertaking the network service provider and the infrastructure provider role in the 5G ecosystem.

Considering the usage of wireless technologies at transport network segments, in general, in areas where fibre deployment is already existing, using wireless technologies increases the cost, depending on the FS. However, considering the cases of no fibre deployment, the usage of wireless technologies appears more cost efficient even with FS eCPRI E. Compared to previous deployment analysis, this is a significant conclusion that highlights the performance and cost efficiency increase over the years. In other words, as a generic guideline, the analysis confirms that deploying wireless systems is a valid transport network alternative to optical transport in cases of: (a) lack of existing fibre deployment, or (b) in cases of long-distance deployments, or (c) where fibre deployment is not feasible due to the terrain/location of deployment; such cases being remote, rural locations. From the same perspective, considering the 5G-VICTORI proposed on-board 5G network deployment as a last mile expansion of the transport network segment, from a techno-economic perspective it has been revealed that besides the obvious techno-economic overheads –stemming from the extension of the transport network to a last mile transport network segment (as analysed in [1]), techno-economic benefits can be achieved via the minimisation of the number of RAN nodes. The benefits can be seized, especially in cases of: (a) deployment at non-populous railway tracks, (b) deployment at rural areas especially using Sub-6 GHz nodes, (c) sharing of the transport network infrastructure with multiple mobile network operators, etc. Thus, as a generic guideline, this option shall be taken into account in such deployment cases. This cost shall be especially assessed by the stakeholder undertaking the infrastructure provider role or virtualisation infrastructure service provider role in the 5G ecosystem. Apparently, this cost is passed on the other stakeholders of the ecosystem affecting the viability and stability of the ecosystem.

From another perspective, an analysis was provided in [1] focusing on the techno-economic evaluation of various options with regards to distribution of network functions across edges. The scenarios examined were ranging from: (1) purely decentralised deployment where vBBU processing is performed at the Edge along with the application offloading – only internet traffic is routed via a main UPF node; to (2) partially decentralised deployment where only vBBU processing is performed at Edge along while all traffic is served by a central UPF; to (3) completely centralised deployment where all vBBU processing and all application traffic is processed at a main/ central processing location. From the comparative analysis results it was revealed that the centralised or decentralised deployment of vBBU processing have no impact on the Total Cost of Ownership (TCO) for CPRI schemes A to IID, while the TCO increases by 80% for eCPRI E when vBBU processing is centralised compared to decentralised deployment. The impact of application offloading at the edge is also marginal in terms of cost, however apparently this will depend on the estimated traffic generated by the specific applications. Therefore, as a guideline we can suggest that decentralised network deployments will be preferred where low level FSs need to be adopted at the access network segment, as well as in cases where the deployment is expected to serve data-rate intensive applications, consumed within the vertical premises. This cost will affect the economics of all the stakeholders of the ecosystem thus shall be assessed in a coordinated way within the ecosystem.

The ecosystem formulations to appear in the short term will differ per case depending on the engaged vertical industries, on the location/ country, on the market, on specific local regulations, etc., the list being non-exhaustive as analysed in [21] and [22]. Therefore, techno-economic analysis of any deployment needs to be performed on a per network segment and layer basis, so that the costs are decomposed per network segment and layer thus per stakeholder/entity to undertake the role/ deployment and operation of each segment/ layer, etc. The provided techno-economic analysis tool enables such cost decomposition and can be used to assess the relevant costs at business modelling phases (i.e. the cost structure of the relevant stakeholder/value proposition canvases).

### 2.2.3 5G business models

This section summarises the status of three (3) vertical business models and their plans to validate critical assumptions in their envisioned business models. We present each BI with title and description, intended benefits, essential business model components, and next steps for validation. The full reports with refined results from each of the business modelling and refinement workshops are available. Relevant feedback from one of the project partners illustrates the approach taking the participant point-of-view: *„The short series of three workshops was really valuable for us. It helped us to specify the social, ecological and economic benefits of the mobility services that we are developing, to compare different business and revenue model designs and to review 5G ecosystem implications. We came up with two alternative business model sketches, and identified critical issues for each to enter the market. This has armed us with not only knowledge but critical analysis skills and methods we can carry forward. It was also deeply interesting and good fun!“, (John Tapsfield & Robert Sugar of Urban Hawk).*

#### 2.2.3.1 On Demand Private Networks for Industry 4.0 capabilities

***Description in a nutshell (what, who, how)***

On Demand Private Networks for Industry 4.0 capabilities allow retrofitting industrial sites and infrastructure with 5G networks to enable a range of new UCs. The BI is provided by a joint venture from Greece, consisting of **ADMIE** S.A. (Research, Technology and Development Department, Information Technology & Telecommunications Department, Transmission System Maintenance Department), which facilitates the integration of industrial protocols and sensors, and the Network Architectures and Management group from the University of Patras (**UoP**), which provides the networking and computational resources and orchestration. Patras also provides the Patras 5G Autonomous Edge solution, a portable **box**, containing everything from the 5G New Radio (NR) and 5G Core, Network and Service Orchestrations including a Virtualised environment based on OpenStack technology (see Patras 5G Wiki, 2021). It has the capacity to deploy a 5G network on demand as well as to host cloud-based applications, thus enabling end-to-end 5G private connectivity on-premise (e.g. in remote locations).

*Business modelling workshops*, with participants of **ADMIE**, **UoP**, **IZT** and **UXBerlin** were conducted in June 2021 and September 2022. Two alternative business models were created: One focuses on customised solutions for fixed plants of industrial clients or utilities with a negotiated pricing. An alternative idea focusses on temporary standard implementations with run-time pricing and / or a pay-for-success business model especially for pilot clients. The business idea is **transferable** to a variety of different UCs even beyond the industrial domain (e.g. firefighting, rescue, research, transportation, festivals, leisure events, tours). For an overview of the components of the business models see Figure 2-8.

***Values, patterns and intended ecological, social and economic benefits***

Core values of the joint venture are efficiency, security and safety. *Resource efficiency and productivity*, *result-oriented service* and *pay-for-success* [2] are relevant SBM patterns in order to bring the solution to the market. Potential contributions to sustainable development can be achieved at least in three domains:

- Enhancement of process and energy efficiency in industrial sites (e.g. through on demand private network deployment, integration of low-energy sensors, predictive and condition-based maintenance): Enhanced industrial efficiency reduces CO2 emissions, resulting in cost savings and contributes to the affordability of several manufactured products’ and (utility) services. It can also improve the safety of personnel, e.g. during maintenance procedures.

- Facilitating seamless transition to more sustainable Industry 4.0: The integration of both legacy and state-of-the-art equipment contributes to seamless and economically viable transition towards more sustainable Industry 4.0.
- Temporary on Demand 5G Coverage in Remote Areas: Enabling 5G connectivity in elsewise isolated, off-grid locations contributes to improved safety and well-being of remote communities and ecosystems (e.g. through prevention or recovery in disaster areas management). In the refinement workshop it was decided to pursue this BI an alternative for implementing the already tested core technology for other UCs, wherein the required level of customisation is lower, and the solution can be more readily provided.

Key value propositions of the business model are linked to the sustainability potentials of the solution, i.e. to enhance energy efficiency of industrial plants or utilities through: 1) on demand private network deployment; 2) integration of state-of-the-art, low energy sensors; 3) enabling third-party optimisation of power consumption and 4) prediction of spikes in energy demand; as well as to optimise the utilisation of equipment through 5) predictive maintenance and 6) virtualisation. Data security is an important requirement for industrial clients that can harm the marketability of the solution if not adequately adopted and communicated.

***Objectives and essential business model components***

Responding to these requirements and client needs, the on demand 5G private network solution provided through the Patras SG Autonomous Edge aims to fulfil the following objectives:

- Provision of an end-to-end portable platform for the support of Industry 4.0 applications.
- On-premise 5G private network deployment compliant with Industry 4.0 standards (latency, capacity, reliability, security).
- Support of different Industrial Internet of Things (IIoT) protocols and backwards compatibility with legacy industrial protocols and equipment.
- Support of edge computing capabilities for time critical applications.
- Offer flexible and expandable solution with the integration of low-cost wireless sensors, enabling the transition of legacy facilities to smart factories.
- Provide customisable real-time monitoring and advanced analytics, according to client needs.

Detailed reports with revised and enriched results from the business modelling workshops are available in Appendix 7.2.2 and 7.2.5. The following canvas provides an overview of the key aspects of the vCDN BI for the railway environment.

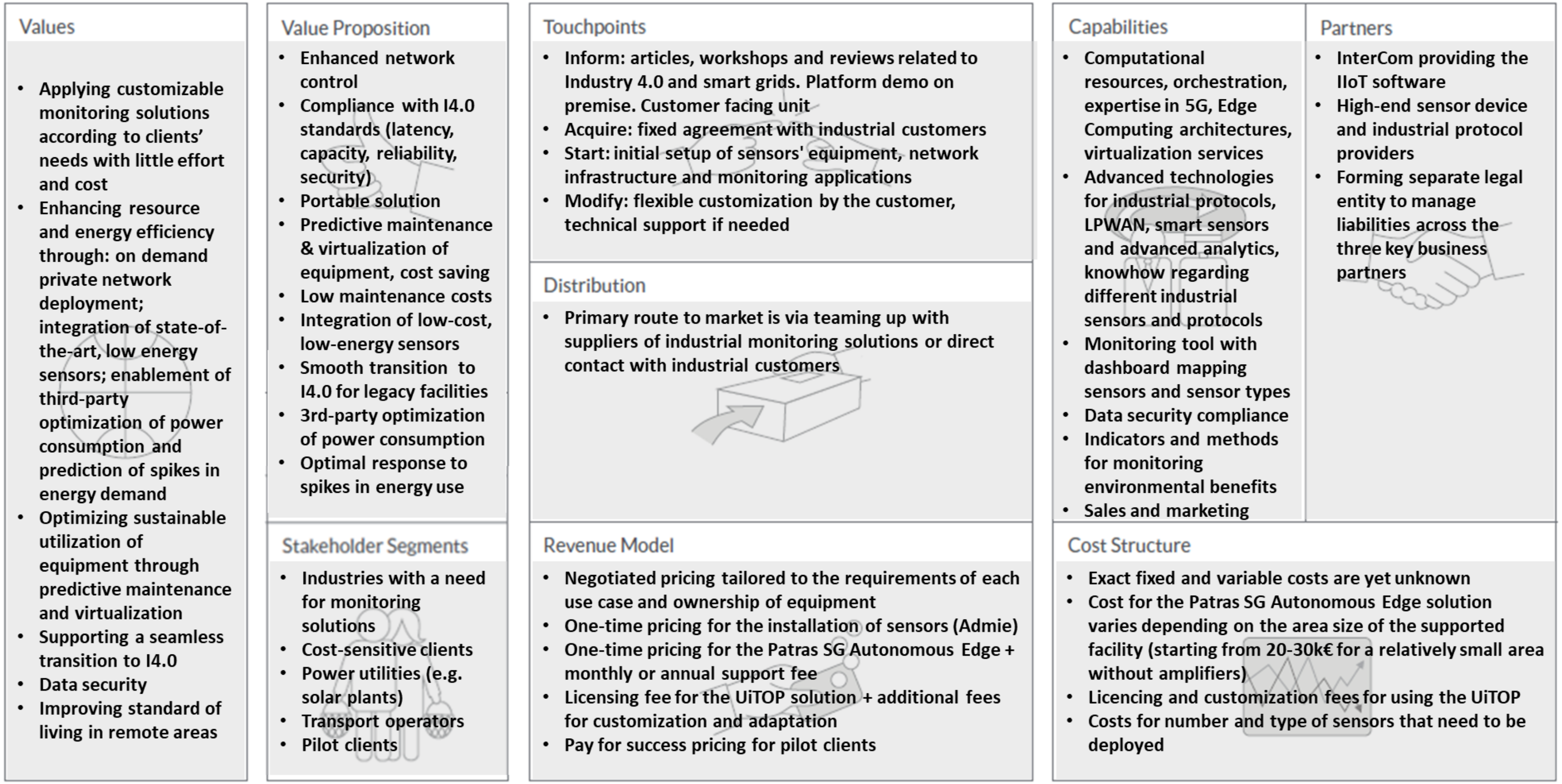


**Figure 2-8 Business model component overview of On Demand Private Network for Industry 4.0 capabilities**

***Critical assumptions and next steps for validation***

- Due to resistance to innovations in the energy transmission market, the value proposition is the essential component requiring validation and clear communication of its advantages compared with legacy solutions. Identifying and testing highly promising applications is a pivotal next step to demonstrate the solution's advantages. Another strong argument for the solution's advantages can be provided by monitoring and defining KPIs for its energy efficiency.
- However, indicators and methods for monitoring and proving the environmental benefits still need to be defined (e.g. based on standards for the energy efficiency of equipment and services using ETSI, ITU-T, 3GPP, or ATIS standards [16]). Impact assessment and benchmarking of environmental parameters are required to validate viability and communicate positive impacts with stakeholders.
- The relationships among the collaborating parties require further coordination and contractual agreements. A single client-facing unit should be formed to approach clients and create the client journey while representing the interests of the three parties. Redistribution of revenues among the three project partners and how it may be expanded to other application domains (i.e. beyond industry 4.0) require further elaboration.
- Alternative revenue models regarding whether the solution will be sold as an infrastructure extension or a use-oriented service should be validated with respect to different markets or customer segments (e.g. through methods of stakeholder and competitor analysis or expert interviews).
- Development and sharing of new competencies should be coordinated to ensure sufficient expertise for interfacing across partners and clients' application domains. Detailed contractual agreements or an independent legal entity should be established to address potential trust and liability issues (also see interoperability facilitator in ecosystems whitepaper 2021).
- Detailed reports with revised and enriched results from the business modelling workshops are available.

#### 2.2.3.2 vCDN (virtualised Content Delivery Network) services for railways

***Description in a nutshell (what, who, how)***

The BI builds on the technical capability of bringing large volumes of high-quality target content on-board a high-speed moving train during its short-time stops along its journey, so as to achieve video continuity and high-quality maintenance at all times of a passenger's journey on the moving train, even in areas where there is no network coverage. Passengers select their content of preference through a CDN application installed on their devices (smartphones, tablets, laptops), which has access to the content caches through the train's local area network (e.g. Wi-Fi). Feasibility of the proposed vCDN solution for high-quality multimedia content distribution in railway environments has been successfully tested Patras 5G-VICTORI demo in June 2023. Similar usage scenarios can be also applied in other cases of any moving vehicle/vessel e.g. such as the case of passengers on ships (cruise ships, passenger ships, etc.). In this case the CDN servers on-board the ships can be automatically updated with new content via 5G connections when the ships arrive at a port, and the content can be distributed to passengers via the ship's local area network; similarly to the case of the railway demo. For an overview of the components of the business models see Figure 2-9. In such cases, the railway operator or the ship operator or the CDN provider (or even in some ecosystem business formulations the telecom operator) can hold the role of the service provider to the end-users/passengers.

*Business modelling workshops with* participants of **ICOM**, **COSM**, **UoP**, **IZT** and **UXBerlin** were conducted in March 2021, April 2021 and September 2022. Following up on results from the first workshop, focus of developing the BI has been placed on enhancing the value of our solution's ecological and energy efficiency, by attracting more passengers to use public transport instead of private vehicles.

***Values, patterns and intended ecological, social and economic benefits***

In the context of making public transport more appealing to passengers and promoting its use over private transport, a potential new vision has also been considered as a future extension to the business model. Specifically, the proposed vCDN solution for high-quality multimedia content distribution could potentially also be used in public buses, trams and metro lines, apart from railways – also in mobility hubs such as railway stations. In this way, it will be more likely to target the entirety of the most common means of public transport and attract a larger number of passengers (also to utilise prefetched rather than individually accessed content). This new vision, if added, could therefore contribute to the sustainability enhancement of the business idea, as it would further reduce energy consumption and $CO_2$-emissions of the whole system (*resource efficiency & productivity pattern [2]*).

The solution is energy efficient because it allows passengers to acquire content from a single connection to the CDN provider, instead of requesting content individually. The *energy efficiency* of the solution can add a strong argument to the value proposition for the passengers as well as for the railway operators, who may benefit from lowering their environmental footprint. Taking an individual (rather than an ecosystem) perspective, some railway operators may consider that the CDN solution will increase their overall energy consumption which, according to usual business models, is being outsourced to individual passengers and their data plans, but there are alternative business models as well. Nevertheless, the currently engaged railway operators are positive regarding the solution's environmental benefits and consider favorably the prospect of attracting more passengers due to their provisional data shower capabilities associated with their transportation services and their brand.

***Objectives and essential business model components***

The objective of vCDN business model is optimised to make public transport and mobility more attractive through quality multimedia content along the passenger's journey. Various business model formulations can be foreseen for the delivery of this value proposition. The solution providers are still open to different revenue models, and need to decide for one to start with (see Figure 2-10). For now, a preferred revenue model is deemed the scenario in which passengers pay a fixed price to the railway operator, the railway operator pays the network operator for the connectivity along the railway infrastructure and also the service provider for the vCDN installed at the railway premises and the service provider pays to the content provider(s).

Detailed reports with revised and enriched results from the business modelling workshops are available in Appendix 7.2. The canvas in Figure 2-9 provides an overview of the key aspects of the vCDN BI for the railway environment.

**Values**

- Encourage more sustainable travel options
- Sustainable Development Goals 9c (ICT Access) and 11.2 (safe, affordable, accessible and sustainable transport)
- Improve the accessibility of content for passengers with special needs
- Quality of service
- Enhance network efficiency and reduce energy consumption and emissions from data centres
- Create economic value for business partners (content providers and railway operators)

**Value Proposition**

- Seamless, uninterrup-ted multimedia streaming for passengers
- Reduced need to prepare travel
- Access to 5G services without a 5G plan
- Service bundling
- Economically and environmentally viable maintenance
- Unveiling new markets for partners

**Stakeholder Segments**

- Digital (vCDN) service provider
- Passengers
- Railway operators
- Network operators
- Content providers

**Touchpoints**

- Promotion through articles, blog posts, reviews, events, recommendations from railway operators and content providers
- Integrating mobile app with other apps from the railway operator (timetables, ticket sale) to reduce adoption barriers.

**Distribution**

- ICOM's own distribution channels (subsidiaries, branches)
- Cooperation with railway operators
- Interaction between network operator and vCDN service provider as a distinct entity

**Revenue Model**

- Fixed price included into the standard ticket price or paid additionally for the extra service
- Extra payment for a "green service offering" e.g. with CO2 offsetting and access to exclusive content included in the price
- Primary revenue stream running from the passengers to the railway operators and then on to the business partners

**Capabilities**

- Advanced knowledge of virtualization, 5G and slicing concepts
- Access and support for integrating the solution to the railway infrastructure
- Monitoring and complying with standards aligned with interoperability (APIs)
- Measuring environmental parameters
- Availability of quality multimedia content
- Identifying best market entry
- Licensing and contractual agreements

**Partners**

- Railway operators
- Content providers
- (3rd party) Network operators
- Marketing team

**Cost Structure**

- Fixed costs for the operation of the service (i.e. solution development, equipment, deployment, marketing, maintenance)
- Variable costs dependent on the number of end users (e.g. WiFi bandwidth, usage on-board).
- Prioritization of service quality and value

**Figure 2-9 Business model component overview of vCDN for railways**

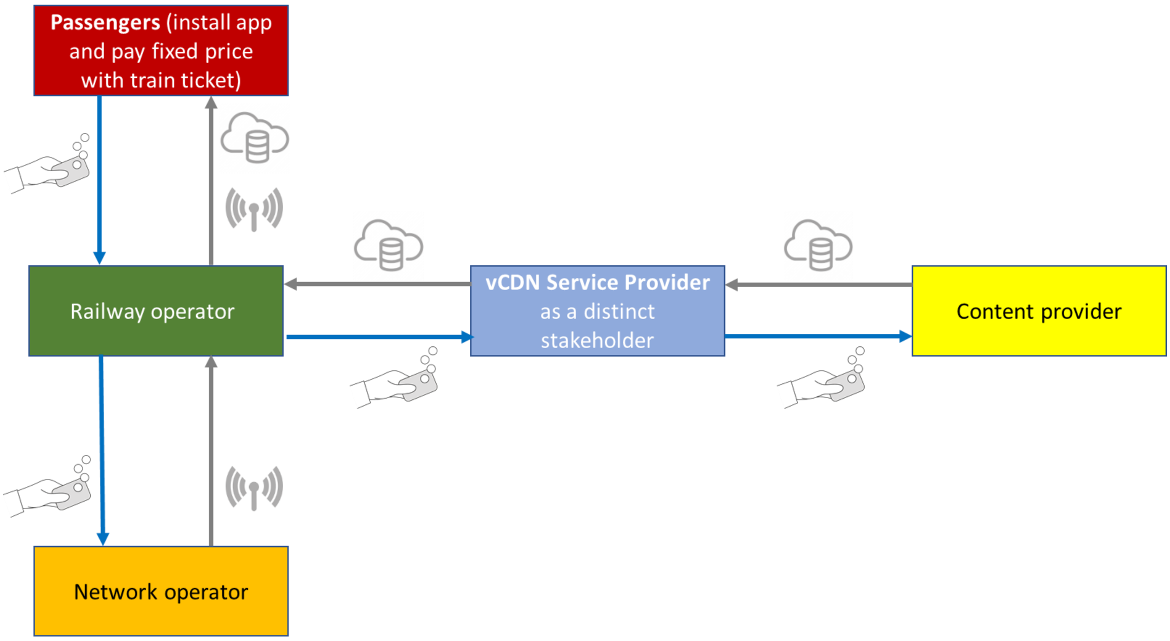


**Figure 2-10 Potential exchange of services and payments among the actors**

***Critical assumptions and next steps for validation***

- The central value proposition is making uninterrupted, high quality multimedia content accessible for passengers. They need to adopt and appreciate the new solution and for instance install or utilise an app to do so. Validation of business-related assumptions should focus on this value proposition (also spelling out the customer journey) and the revenue model (including delivery costs). Energy consumption for different scenarios should be measured to prove environmental benefits. Field trials performed in June 2023 have proven the solution high performance and efficiency.
- Exemplary cost calculations can be made on a per deployment basis, using the techno-economic analysis tool developed in the context of the project [1] and [20]. In general the total solution of the deployment and provisioning costs will vary depending on the number of channels/ content requested and transferred via data showers, the network deployment option that will be rolled-out, the Business-to-Business agreements between the vendors and the stakeholders providing the infrastructure/ service/ solution/ applications and so on. These exemplary costs will then need to be fed to the cross-validated business model exercise in order to assume/ identify a viable cost-sharing structure for all the stakeholders formulating the relevant ecosystem. That could also constitute the basis for the relevant revenue-sharing models between those stakeholders.

#### 2.2.3.3 Urban Hawk's Simulation Business Ideas

***Description in a nutshell (what, who, how)***

Urban Hawk (**UHA**) is pursuing a range of promising BIs with different corresponding use cases of their technological developments. The challenge persists to find the right focalisation and refining the most viable business model.

The initial intention of **UHA** was making multi-modal travel journeys more efficient and safer through real time passenger data that enables advanced trip planning and tracking and feeds into simulations for different purposes. A currently developed application facilitates multi-modal transportation, provides users with assistance in customised journey planning as well as automated recommendations based on 3D spatial data rendering. It also allows claim validation for insurances.

*Business modelling workshops with* participants of **UHA**, **IZT** and **UXBerlin** were conducted in July 2021 and November 2022 and a follow-up session in January 2023. The technological solution is being developed into a platform (Polaron) that is accessible through a browser. An API-driven roll out and beta testing are planned for 2023.

***Values, patterns and intended ecological, social and economic benefits***

The major challenge to find a viable path for market entry was already identified in the 2021 workshop, essentially: Which business models to pursue and to start with. From the (now significantly advanced) technological point of view, the solution enables numerous possible applications and corresponding UCs to be pursued. This creates a wide spectrum of ideas to be considered and brings a major challenge of finding the right focus and a sense of direction for the venture from the very early stages of development. Figure 2-11 shows value propositions with key benefits on all three dimensions of sustainability, with the placement in the triangle indicating which dimensions it predominantly addresses. Further prioritisation of the venture's values and the benefits that it can provide to clients helps to establish and strengthen this sense of direction. SBM patterns including *Resource Efficiency and Productivity* [3] and a *Green Freemium* model for pricing intermodal passenger mobility have been considered along the way.

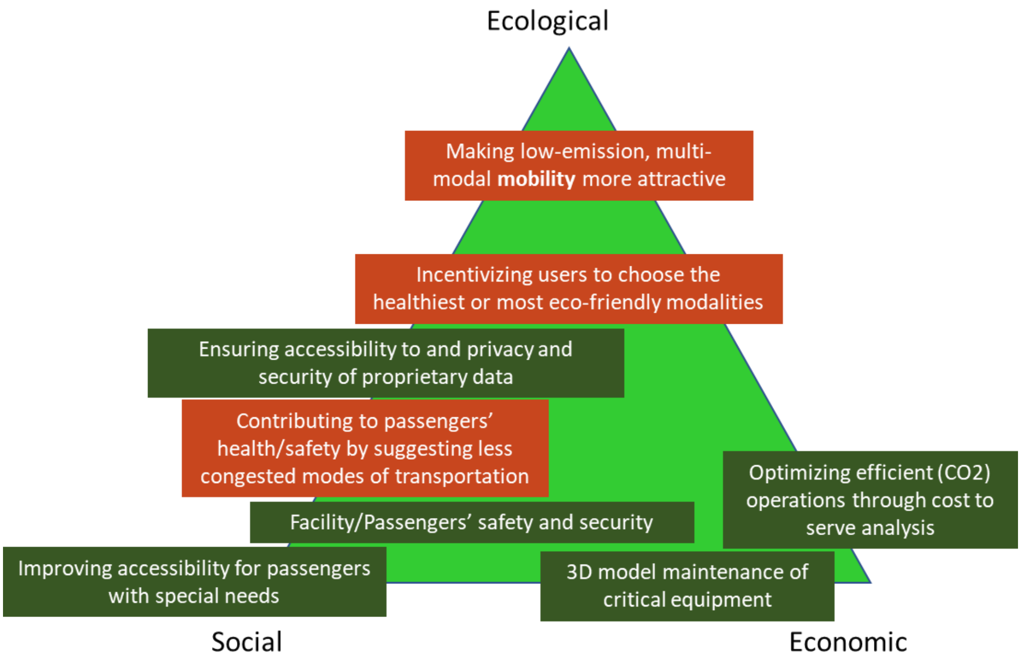


**Figure 2-11 Key sustainability benefits of the business idea (those newly specified 2022 in green boxes)**

***Objectives and essential business model components***

Several relevant **value propositions** and stakeholder groups have been specified. Potential value propositions include:

- Efficient mapping of facilities (e.g. stations) to update obsolete CAD data for multiple purposes.
- Making proprietary data of facility owner that is not accessible on public platforms such as Google maps, available for new services (e.g. creating spatial awareness) to users, including users with special needs, such as firefighters, police, disabled, etc.

- Commissioning third party developers for access to the Polaron solution or models it generates.
- Suggest optimal routes to passengers based on simulations and statistics, e.g. allowing passengers to utilise limited transfer time at stations to buy commodities or food, without being concerned that they might miss their connection. Tracking and prediction of demand waves to manage delays and improve passenger experience.
- Enabling end-users to use their smartphones for generating 3D models, thereby creating new passenger experiences. For example, passengers can record specific data and recall it in case of travel issues, such as to specify the location of lost luggage.
- Energy efficiency and reducing CO2 emissions (also see Resource Efficiency and Productivity pattern [3]): Heating modelling, optimizing energy consumption, operation and traffic management and lighting management. Running simulations to monitor energy efficiency across different conditions, e.g. seasonal changes, diurnal cycles, varying levels of generated energy from renewables. Real time 3D simulations can also be used to monitor the performance of thermal systems or emission reduction technologies or processes and account for inefficient implementations (e.g. faulty equipment, need for insulation) or energy losses (e.g. from open windows).
- Another potential is the monitoring of railway vehicles' energy consumption (during acceleration and breaking) through simulations as opposed to conventional hardware sensors, which require high effort and special permissions to be installed on trains/stations.

The passenger multimodal transport experience that was developed as the core BI is transferrable to other types of industries, which provide promising business opportunities. (New) value propositions can be of interest to other industries, such as logistics, maritime ports, nuclear power plants.

Detailed reports with revised and enriched results from the business modelling workshops are available in Appendix 7.2.3 and 7.2.7. The following canvas provides an overview of the key aspects of the vCDN BI for the railway environment.

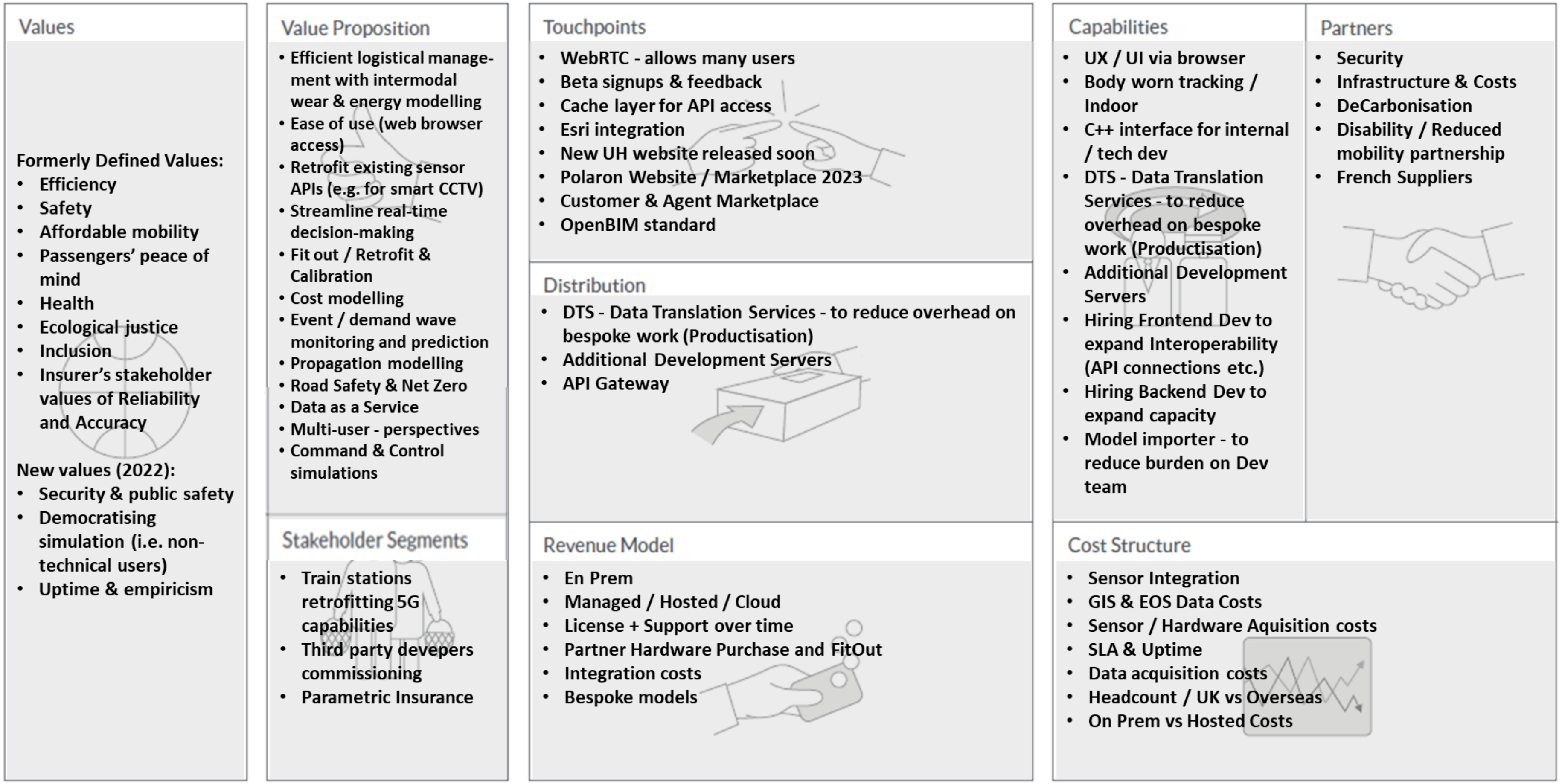


**Figure 2-12 Business model components for UHA's simulation business with new values introduced in 2022**

***Critical assumptions and next steps for validation***

- Initial interviews have been conducted to explore customer needs and potential partnerships with hardware providers. Further stakeholder feedback needs to be collected, e.g. through expert interviews, field interviews, surveys, e.g. with station owners, insurance providers, and other potential clients as well as end users and public and standardisation authorities. Several assumptions can be evaluated, such as:
  - What is the business potential of value propositions related to decarbonisation, e.g., monitoring of railway vehicles' energy consumption (during acceleration and breaking) through simulations?
  - How does new legislation (Protect Duty) affect insurance providers and facility owners, and their need for real-time 3D simulations? How to manage liabilities across different stakeholders and modes of travel?
- Letters of intent have been submitted by investors from different industries and initial deals are underway. Depending on the industrial background of investors and the respective business models that will be pursued, **UHA** will expand and compartmentalise its business structure to manage different projects and associated costs independently. A new European satellite office in the EU is planned to facilitate relationships with European investors, partners, and clients.
- Different agreements will need to be established to address varying levels of data sensitivity across stakeholders and potential clients.
- Cost estimations and benchmarking should be performed in relation to alternative revenue models (on-prem, edge-based, cloud-based, freemium, etc.) to scrutinise the trade-offs between them.
- A key point of uncertainty is related to the viability of the cost structure and how to manage it to accommodate a scaling user base. This poses the need for mapping costs in relation to different persons or different types of users (e.g. operating at different times of the day) as well as business cases (addressing different clients and industries).

### 2.2.4 Overview of ecological, social and economic benefits

**Specific Example of Energy Efficiency through the 5G-VICTORI solution in Rail**

In response to the 5G-VICTORI Reviewer's recommendation, we have performed a high level study trying to identify the benefits of 5G in the energy efficiency/cost of the railway sector through the delivery of specific 5G enabled rail services.

More specifically, 5G networks can assist transport/rail networks to optimise their operation and reduce power consumption. This can be achieved through the deployment of smart energy metering platforms that can be installed on-board a) optimising the use of breaking energy and, b) maximising the power quality of the power grid. Based on the former approach, 5G networks can be effectively used to enable coordination and cooperation of the different railway subsystems (rolling stock, stations, substations and the grid, etc.) enabling efficient usage of transport and infrastructure. Recent studies showed that the combination of 5G networks with IIoT platforms and AI can be successfully used to address capacity limitations of current railway systems and improve overall system's performance. An example can be found in [1], where applying these technology solutions the optimal train speed profiles can be detected reducing energy consumption in railway systems by 10%.

**Table 2-2: PF charges in large commercial connections in Spain**

| $PF: cos\phi$ | TF (€/KVArh) |
|---|---|
| $0,80 \leq cos\phi \leq 0,95$ | 0,041554 |
| $cos\phi \leq 0,8$ | 0,062332 |

5G networks can be also used to optimise the power quality of the energy grid and reduce relevant energy costs. Usually, energy pricing is done by a combination of different types of pricings models including the ***Time of Use (ToU) based pricding***, power demand (PD)-based pricing. For example, connection fees can be calculated based on demand-based pricing reflecting the rated power of the equipment to be installed. At the same time, real-time pricing for the actual energy demanded in kWh can be applied. An additional parameter that is also considered in energy billing is the Power factor (PF). The PF is used to measure how efficiently electrical current is being converted into useful power. Low power factor can cause performance issues for network users and negatively impact network equipment. Billing models based on PF introduce specific penalties to the consumers as a counter measure to correct their power factor. Based on PF levels, various charges can be applied. A two-level approach currently used in Spain for large commercial connections is shown in Table 2-2.

A similar approach is applied in large commercial connections in Greece, where in case the PF drops below 0,95 the charged demand in increased by the following factor:

$$\left(1 + \left[\frac{0.95}{cos\varphi} - 1\right] * 1.6\right)$$

However, to optimise the grid for the PF specialised equipment, power quality meters, are required that can be used to monitor, analyse the quality of the grid and optimise the operation of the system. However, for these devices to capture high-speed impulsive transient they need to collect measurements with 6 MHz sampling rate (100,000 samples per cycle) per channel[2]. Through the adoption of 5G systems rail operators and infrastructure can have a real time view of the quality of whole system, optimise the power quality of the grid thus reducing their energy costs for up to 30% as in the case of Greece.

**Consortium wide discussions/conclusions**

Alongside the field trial in April 2023 in Berlin, we conducted a final workshop open to the whole consortium. Its goals were to provide an update on the new EU CSRD and its implications for sustainable business modelling and ecosystem development, to inspire and facilitate self-directed utilisation of the generic process model and its tools, and to convey first-hand experience applying the tools to individual (future) services and their business models. Following a review of all business modelling activities and a walkthrough the generic process model, participants from five organisations (**ICOM**, **RBB**, **TRA**, **DCAT** and **ADMIE**) mapped

[1] A. Achilleos, et. al., "Multi-objective Optimization of Train Speed Profiles Using History Measurements", Smart Cities, Green Technologies and Intelligent Transport Systems, 2021, https://link.springer.com/chapter/10.1007/978-3-030-68028-2_17

[2] Power Xpert Meter 4000/6000/8000 power quality and energy meters, https://www.eaton.com/us/en-us/catalog/low-voltage-power-distribution-controls-systems/power-xpert-meter-4000-6000-8000.resources.html

their intended (ecological, social and economic) benefits onto a template. Without going into the individual business models, Figure 2-13 below exemplifies these benefits (including those intended by UHA) that can be achieved through the new UCs created in 5G-VICTORI.

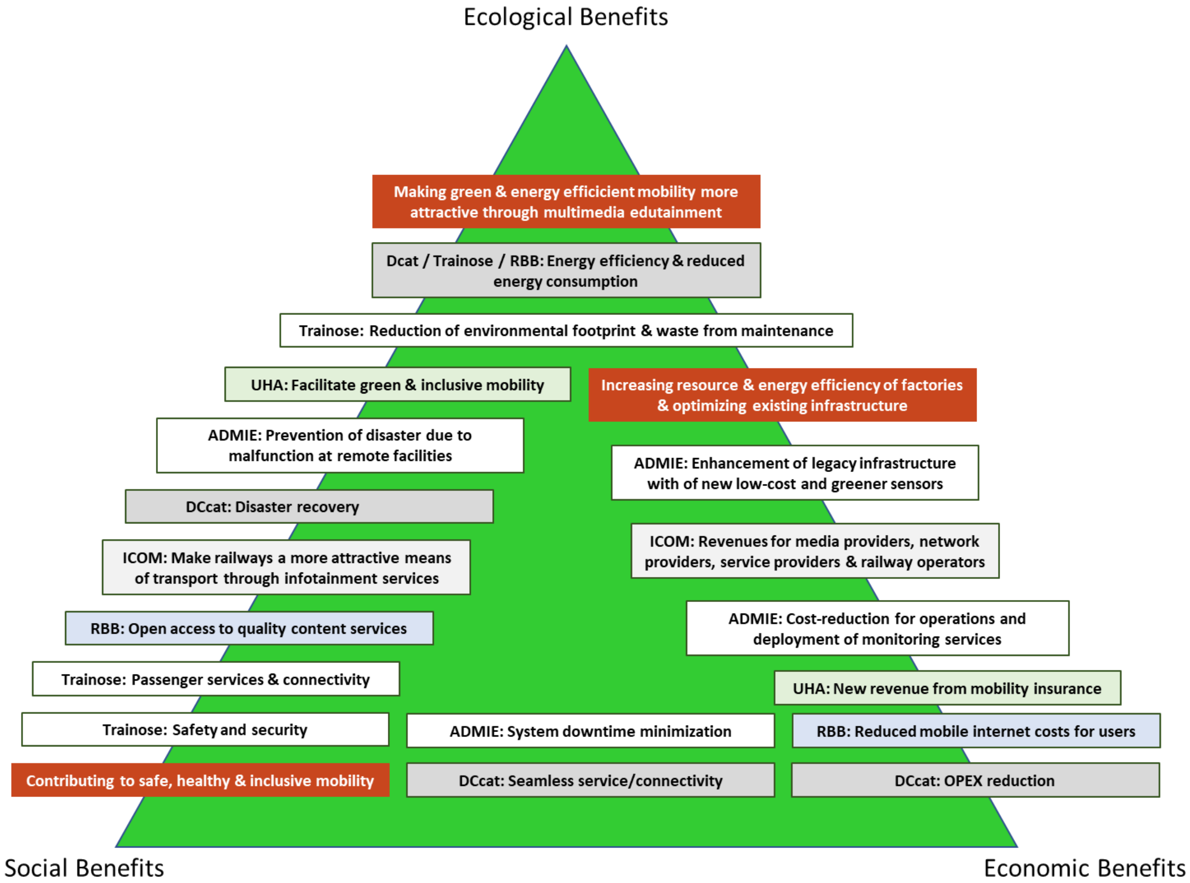


**Figure 2-13 Intended ecological, social and economic benefits of the BIs (overarching benefits from different BIs in red boxes)**

### 2.2.5 The road ahead

Given the early stage of development, **business models** rest on **assumptions** all of which need to be further specified (especially expected investment and operational costs), validated (especially with respect to partnering and stakeholder engagement), adjusted or even pivoted during the upcoming steps of (test) market introduction.

User-centered methods like field research, professionally facilitated co-creation with early adopters, experience prototyping and evaluations should be applied to ensure widespread adoption by users, customers and clients. To this end a first draft of a user experience questionnaire was developed (see deliverable D3.7 [1]). Substantial effort will be required to design and facilitate rewarding **customer journeys** and to meet expectations at each customer touchpoint.

# 3 Exploitation strategies

## 3.1 Types of exploitation and exploitation outcomes

Exploitation activities in 5G-VICTORI are those that are intended towards maximising the value from the technologies and other outputs of the 5G-VICTORI-project. They constitute the second part of Task 5.3. The project follows the definition from the Horizon 2020 Rules for participation, which defines this task as focusing “on the actual use of the results, translating research concepts into concrete solutions that have a positive impact on the public’s quality of life”.

The project-level exploitation strategy of the 5G-VICTORI project involved the following steps: initial definition of goals in the Grant Agreement (GA) [23], update of goals and first progress made (with a focus on business modelling) in 5G-VICTORI’s Milestone 10 (MS10) document [24], periodic updates on progress, final exchange on (in a workshop format) and documentation of outcomes.

A successful exploitation strategy faces several barriers. Measures we took in 5G-VICTORI to avoid these barriers include:

- To go beyond a sole focus on technical objectives and also focusing on the needs of users and other stakeholder, we added a broad perspective in different tasks in 5G-VICTORI, including considerations of end-users, business users as well as the general public in, for example, the UC assessment and the impact assessment. This supports alignment and helps reflect on how the functionalities developed are likely to affect stakeholders. This also made sure that potential values and benefits for broader groups beyond the typical community were considered.
- To promote identifying what the most valuable key results of the different UCs could be, workshops moderated by external business modelling experts were held, reflecting on value proposition of BIs, discussing alternative ideas, etc. (see section 2). To support consideration of what can be seen as the most valuable key results of the project overall, the topic of exploitable results was repeatedly discussed at general meetings and within other multi-partner discussions.

**Types of exploitation:** The values created through 5G-VICTORI encompass a range of different kinds – accordingly we differentiate between different types of exploitation and exploitation outcomes.

In the Grant Agreement (Part B) three main exploitation types of the project results were identified:

- **Commercial exploitation**: involves the commercial deployment of services tested in the 5G-VICTORI vertical UCs by utilisation of the project technology for the development of 5G products integrating advanced services upon their commercial availability in the mass market, or the exploitation of the 5G-VICTORI platforms towards experimentation for third parties.
- **Technology exploitation:** re-utilisation of the technological know-how acquired for the development of innovative 5G products and the provision of advanced services built on top of them.
- **Scientific exploitation:** stems from the research carried out during the project lifetime.

With regards to all three of these types, there exist shared activities across multiple Consortium members, i.e. joint exploitation activities (on different levels, see below), as well as individual exploitation activities. The relative focus on types of exploitation differs of course across different partner types (SMEs, large firms, research institutes). Several of the project's outcomes have a broad focus that spans all of the three types of exploitation

**Exploitation levels:** Exploitation in 5G-VICTORI takes place at three levels**: individual exploitation level, joint exploitation level** and **general project level**. While the first level is important and captures individual uses of the project output for specific partners own scientific and commercial development, the structure of the 5G-VICTORI consortium, as well as the focus of the project that has the common infrastructure at its core, lends itself particularly well to joint exploitation. The consortium consists of very diverse vertical industries, large and small technology providers, R&D centers and universities. The different perspectives on exploitation, different expertise, know-how, technical contributions, output and product offerings brought to 5G-VICTORI by the diverse partners interact and contribute to joint and project level exploitation outputs. Joint exploitation levels or frames beyond the general project level include joint exploitation by partners at the platform level, the vertical/industry level, and at the level of UCs and field trials.

**Exploitation outcomes:** To facilitate identifying exploitation potentials and documenting exploitation activities and results, exploitation outcome categories were defined and possible exploitation outcomes were identified and sorted by outcome category and type of exploitation. This is displayed in Figure 3-1.

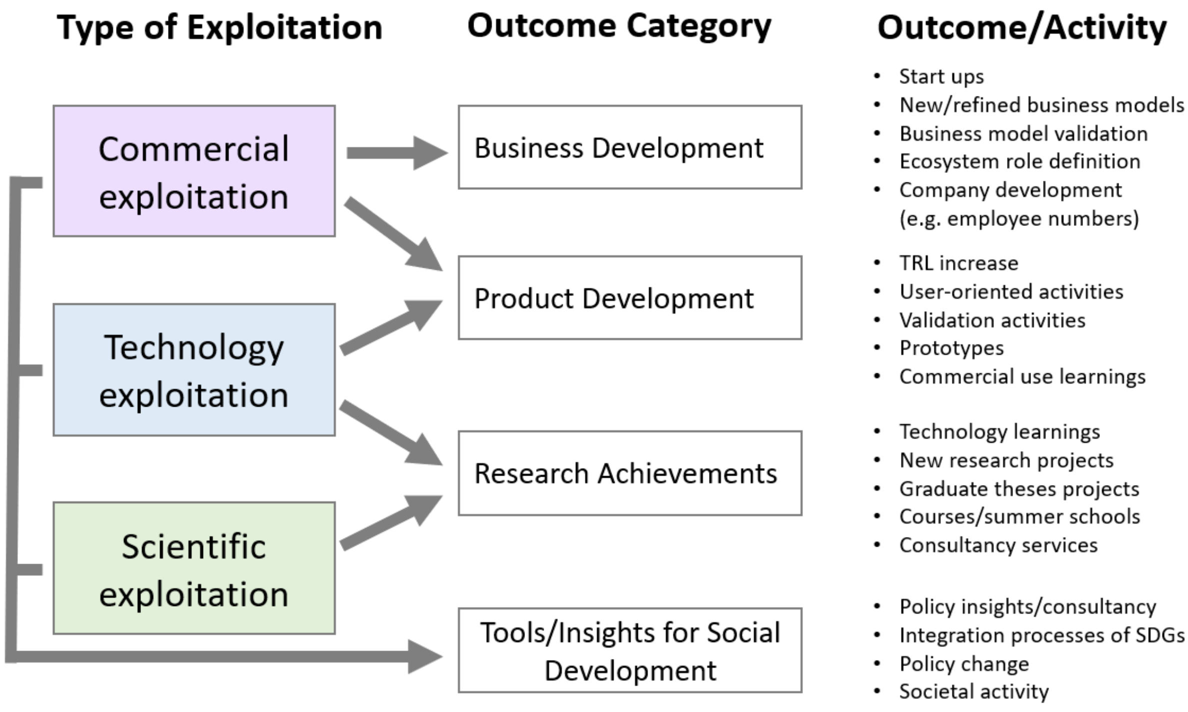


**Figure 3-1 Exploitation outcome classification**

The following sections identify the main assets created by the project overall (section 3.2), identify further exploitation outcomes with broad value for different stakeholders (section 3.3), and document exploitation outcomes and activities by partner (section 3.4).

## 3.2 Main assets created

Considering the 5G-VICTORI project as a whole, there are several assets that were jointly created throughout the course of the project, which have been generated mostly by multiple beneficiaries. These are 5G-VIOS, the current and future exploitation outcomes expected for the four testbeds (Bristol, Alba Iulia, Berlin, Patras) and the Mobility management function developed for **UC #1.1** in Patras.

These main assets include aspects of all three types of exploitation, yet most aspects can be classified as technology exploitation and scientific exploitation. While the **exploitation level** is joint exploitation and general project level, an essential feature of these main assets is that they also enable and foster individual exploitation. In terms of **outcome category**, the outcomes and activities that the main assets give rise to product development and research achievements.

In the following sections each of these assets, ongoing exploitation activities and exploitation plans for the future are presented:

### 3.2.1 5G-VIOS

The 5G-VICTORI Infrastructure Operation System (5G-VIOS) [21][25] is the cross-domain service orchestration platform within 5G-VICTORI that enables vertical users and Small and medium-sized enterprises (SMEs) to use a common infrastructure, which allows for easy cross-vertical collaborations and synergies in order to offer enhanced value propositions.

5G-VIOS is responsible for the Life Cycle Management (LCM) of Network Slices, on top of the orchestration solutions of the individual facility sites, enables dynamic inter-site connectivity, inter-domain orchestration, and supports the on-boarding, end-to-end monitoring and management of inter-domain services allowing mobility UCs.

The 5G-VIOS has the capability to efficiently exploit and interact with the available underlying technologies such as MANO platform, SDN controller, and the monitoring platform available at different facility sites. 5G-VIOS architecture has adopted a cloud-native and microservice-based design, allowing individual components to be developed and extended in parallel, providing flexibility and adaptability.

The current TRL is 4-5. It is therefore not yet being commercialised. After further steps towards finalisation, the idea is for network/service operators would be to integrate 5G-VIOS into their orchestration platforms. This is particularly attractive forr service operators that have interactions with multiple network operators, or network operators that have multiple types of networks (e.g. fixed, wireless, private/public), so that they can orchestrate the services more efficiently.

In the near future, 5G-VIOS will be included in a Git Repository. It is not yet released, since currently the functionalities are being made somewhat more robust following the Patras Trials. Within the next months it will be released. This will be accompanied by the release of a ‘user manual’, which is meant as support material to integrate 5G-VIOS in an external user’s premises and is currently being released.

5G-VIOS will also be used and built on in the project REASON [26], which has just started and is looking to extend 5G-VIOS. The 5G-VICTORI beneficiaries **DCAT** and **UNIVBRIS** are participating in this project.

### 3.2.2 Bristol Testbed

The work carried out in the 5G-VICTORI Bristol testbed during the course of the project has led to the following three main outcomes:

a) elevation of the skills in the research team: i.e. experienced and skills added to the research team in designing and constructing the nomadic node as the centre piece of the technology for this solution,

b) creation of a nomadic node: i.e. the creation of the features to enable the nomadic node inside a boat in motion maintaining the service continuity using a moving base station. This activity required extension and major reconfiguration of the cells on the testbed to map the journey on the water towards the moving edge in the network.
c) enabling the inter-cluster UCs demonstration was an engineering challenge to connect 5G-VICTORI testbeds across national borders making use of 5G-VIOS.

In somewhat more detail, what was demonstrated was broad coverage, seamless mobility between countries as well as within a city and multi-tenancy networking. Moving from one edge to the other, services were also moving with the end-users to provide seamless mobility within the low-latency specification of each UC. The disaggregation of the 5G core and the CP-UP split allowed us to deploy Session Management Function (SMF) and UPF instances at each edge, enabling all the user and application data to be processed within each edge. This reduced the round-trip-time and number of hops between the user and the serving application to achieve a low-latency service provision. 5G network slicing was not practically implemented in the testbed, given the limited number of UE devices and the single slicing UC supported at the time by the gNB software. However, the network architecture design integrated 5G network slicing, even though it could not be practically implemented.

Concerning future plans for the testbed, it adapts to any UC under investigation in configuring the cell node and once the UC is demonstrated the testbed is reconfigured for other projects. There are instances that multiple projects can be served with the same testbed configuration in creating isolated slices of the infrastructure as a service for experimentation. The applications demonstrated in 5G-VICTORI were under licenses from the project partners and these will be removed from the testbed now that the project is complete and closed. However, the capability of network features and lessons learnt will remain as part of the testbed. Through 5G-VICTORI, we have gained experience in the testbed team to create a nomadic node and associated network slices as well as recording the capability achievable through such a UC. This platform will now be used as a tool for research and experimentation towards future networks of B5G or now towards 6G development.

### 3.2.3 Alba Iulia Testbed

The E2E 5G SA testbed implemented and demonstrated in Alba Iulia Municipality (**AIM**) is a successful Open RAN/Open Core 5G SA implementation in a live environment running on top of the testbed the real Municipality UCs and provides one of the first real life deployments of open-source 5G network (O-RAN and Core). 5G slicing has been implemented, multi-slices are available and have been validated supporting different applications and UCs with different requirements have been enabled (eMBB or ultra-low-latency).

The testbed includes option 2 networks tested and validated, the 1$^{st}$ open RAN/Core live environment validation and implementation (based on OAI), by using Radio spectrum N78 [50 MHz], interconnected to an Edge computing (K8s & OpenStack), using open components infrastructure for integration (5G-VIOS). The testbed provides several key innovations in 5G SA, such as service slices creation and UEs association to slices, service slice performance (Bandwidth/Latency) and Traffic prioritisation.

The complete 5G SA testbed was installed in **AIM** for use during the 5G-VICTORI project. Since then it has been moved into the 5GLAB (https://5glab.orange.ro/) facility in Bucharest in the same setup, where different 5G testing and validation activities are continuously performed. The 5G SA setup as implemented AIM will remain up and running in the lab context and it will be used for 5G SA business UCs development, proof-of-concept (PoC), and different demonstration and UC validation activities, benefiting from the openness of the system. The new UCs are requiring more interaction with the 5G networks (metrics and KPIs, dynamic deployment and configuration), which will be fully tested by using the testbed.

The testbed will be further exploited in Orange Romania (**ORO**) research projects and for new 5G SA business cases implementation for commercial scope. Further research activities building on the 5G SA testbed availability and functionality in relation with the 5G SA envisioned UCs in several directions are planned, such as:

- Joint exploitation of the testbed solution within different research streams, focusing on 5G/6G capabilities and security actions (network exposure, APIs, metrics).
- Exploitation with the public administration, new solutions development and integration in the 5G SA context, focusing on public safety and power/energy consumption (real time LV monitoring, real time video streaming with EDGE computing processing).
- Exploitation with SMEs and start-ups developing applications on top of the 5G infrastructure, by benefiting of results from the PoC/Demos, introducing AI/ML algorithms for further data processing, with immediate results for end consumers, as energy metering analytics, energy optimisation or safety public personal transportation in dense/crowded areas.
- Exploitation together with SMEs, development of the novel 5G SA toolbox and hardware kits for massive Machine Type Communications (mMTC) type of services and communication.

### 3.2.4 Patras Testbed

π-NET, with full legal name “P-NET Emerging New Generation Networks and Applications”, is a private company incorporated as a Competence Center in the Region of Western Greece. It is a partnership of twenty two shareholders representing big and established companies, SMEs, public and private higher and lifelong education institutions, research organisations, consulting, and entrepreneurship support companies. Three partners of-5G VICTORI Greek cluster (**UoP**, **IASA** and **ICOM**) have been involved in the establishment of the Competence Centre to foster the expertise that has been gained within the project.

π-NET aspires to become an international research and innovation driven Competence Centre for emerging smart networks and services with emphasis on strengthening vertical value chain, especially in the areas of Energy, Factories of the Future and automotive with he opportunities that have emerged through 5G-VICTORI. It aims to become a common resource and shared facility offering access to knowledge and expertise and attracting talents. One of π-NET’s ambitions is that the creation and planned valorisation of the π-NET facilities will serve as a blueprint for the creation of similar 5G islands for experimentation and support of verticals all over Greece, enabling interconnection and strong collaboration among research teams.

π-NET’s mission is to develop technological solutions and innovative interventions leading to exportable products and services of high added value, while capitalizing on the strengths and potential of the Greek ICT ecosystem, based on methodologies and models that have been developed in projects like 5G-VICTORI. Synergies and cross-fertilisation between industry, academia and civil society drive the Centre’s R&I efforts and the creation of positive societal, economic, and environmental impact. The development of new and disruptive business models aims to fuel a productive regional impetus

Starting with an advanced 5G and beyond infrastructure, π-NET aims to develop an open regional B5G near-to production network, interconnected with other public/private networks, and integrated with partners’ technologies and vertical industries facilities that can exploit the experience and knowledge gained from the partners collaboration in the field. Qualified engineers and access to resources and infrastructure will support R&I activities and provide the capacity to develop prototypes, pilots, and demonstrators. A number of services and mechanisms to share resources, knowledge, results, and expertise will be developed to accelerate scientific and technological progress and innovation.

### 3.2.5 Berlin Testbed

The 5G-VICTORI Berlin testbed stems from the efforts of the partners Fraunhofer FOKUS (**FhG**) (mainly) and **IHP**. The 5G testbed developed by **FhG** in the precursor of 5G-VICTORI, i.e. 5GENESIS, which was mainly deployed in the lab and at the **FhG** building, has evolved over the last years towards a nomadic, i.e. local and temporary, fashion of it. Experience has been gained in the Berlin cluster ecosystem in setting up and managing 5G networks that span beyond these two partners.

Nomadic networks stemming from the 5GENESIS Berlin Testbed are being deployed in EU and national projects such as ALADIN, which is intended to ensure safer forest fire fighting in the future through needs-based 5G networking of emergency services and resources. A nomadic 5G network at *Schönhagen Flugplatz* in Brandenburg is serving this purpose.

Additionally, the 5G testbeds at **FhG** and at **IHP** are being upgraded towards 6G in support of ICT and vertical requirements and UCs, in the projects listed below:

- 6G-SANDBOX (EU), **FhG** is developing further its testbed towards a 6G testbed that will combine digital and physical nodes to provide fully configurable, manageable and controllable end-to-end networks for validating new technologies and research advances for 6G. For this purpose, the **Open5GCore** is being further developed towards 6G.
- CampusOS (DE), **FhG** will build a modular ecosystem for open 5G campus networks based on open radio technologies and interoperable network components. This is intended to enable manufacturer independence and more competition and innovation in order to strengthen the digital sovereignty of companies in Germany.
- Open6GHub (DE), where both **FhG** and **IHP** contribute to design a holistic 6G system that meets the requirements of users and society after 2030. An organic 6G core network is being researched and developed, in which the highest requirements for reliability and flexibility are taken into account (FhG). In addition, IHP works towards the development of an integrated sensing and communications (ISAC) framework.
- 6G-RIC (DE), where **FhG** and **IHP** contribute towards the creation of a high-performance test infrastructure, which should enable the testing of new technology components under realistic and open conditions.
- BeGREEN (EU), where the radio part of a 6G network is being optimised for energy efficiency by means of leveraging ISAC strategies (IHP).
- 6G-SENSES (EU), **IHP** will contribute to build up a multi-technology 6G RAN front-ends and architectures for improved spectral efficiency and sensing capabilities.

These testbed upgrades will be calling for partnerships together with 5G-VICTORI partners in exploiting these assets towards PoCs/Demos, the introduction of AI/ML algorithms for further training and optimization of the networks and towards the support of vertical services with stringent requirements as it is envisioned in 6G for future SNS calls.

### 3.2.6 Mobility Management Function

The solution that was developed is generic and technology agnostic and focuses on the handover management across multiple heterogeneous networks in a Rail environment, that are deployed on the track-side and facilitate the track-to-train communication. P4 programming and SDN was used to configure network switches in the network, with the aim to present the applications that run on the train with a seamless handover experience. The proposed mechanism comprises a P4-based session management process and has been evaluated both in a scaled-down testbed environment as well as in a real operational environment.

The solution and the tools developed can be applied to other scenarios as well besides Rail e.g. in a cross-border scenario where the moving vehicle (Train, car, truck, etc.) has to perform a controlled handover to a new operator's network. It is also the intention and future plan to release the developed tools as an open source software so that other researchers can use them and/or extend them in other mobility scenarios.

### 3.3 Further broad assets

Within 5G-VICTORI there has also been the creation of several assets by different constellations of partners or individual partners (and partly based on collaboration with the consortium as a whole), which provide broad value to the general community or society as a whole. Thus, the level of exploitation here is individual and joint in terms of exploitation activity, but partly with the potential for future exploitation by other actors/the general community. The types of exploitation which these assets belong to are mainly commercial and scientific exploitation. The outcome categories are product development, research achievements as well as tools for social and business development.

**Table 3-1 Further broad assets**

| Asset | Description |
|---|---|
| BubbleRAN Start-up | During the 5G-VICTORI project, the startup BubbleRAN[3] was created as a spin-off from the 5G-VICTORI Beneficiary EURECOM (**EUR**). Bubble RAN commercialises the multi-vendor 4G/5G Open RAN and leverages the OpenAirInterface (OAI) code base. The results of development, integration and pilot in collaboration with Orange Romania carried out in the context of 5G-VICTORI in AIM allowed BubbleRAN to validate the performance of the OAI Software Alliance software stack with commercial AW2S RUs in a production environment. The CEO is Prof. Navid Nikaein. More detail can be found in the section on exploitation activities and outcomes by partners (3.4.3). |
| π-NET Competence Center | The π-NET Competence Centre is a public-private partnership (co-financed by Greece, the EU and the private sector) designed to bridge the gap between supply and demand of innovation and technology transfer for smart networks 5G & beyond and services. The inception of which was coordinated by **UoP** being the funding members as well **ICOM** and **IASA**. It provides an advanced Lab Infrastructure allowing to test technological solutions before investing and supporting verticals in discovering opportunities that adopting 5G technologies and solutions could bring to businesses. The π-Net infrastructure allows for integration with the specific infrastructures, user equipment and services for verticals. It also supports innovation and entrepreneurship in the smart networks 5G & beyond community by offering consulting and mentoring. |

[3] https://bubbleran.com/

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| SBM tools for the 5G Ecosystem | During the course of the project, sustainability-oriented business modelling tools were refined and geared to 5G Ecosystem contexts by **IZT** and **UXBerlin** (much more detail on this can be found in section 2 on Business models). A generic process model for sustainability-oriented business modelling in this context was created (see Appendix 7.1). These refinements and insights were also disseminated beyond the 5G-VICTORI consortium, e.g. through participation in the 5G-PPP WG Business Validation, Models, and Ecosystems (BVME). |
| Methods for SDG oriented impact and use case assessment | A broad UC and impact assessment that also includes social and environmental sustainability in the context of a technical project presents a novelty. Accordingly, the methodological approaches to these aspects as applied by **IZT** constitute important pioneer work in this field and created novel insights and ideas for refining social and environmental UC and impact assessment in 5G and Beyond 5G projects in future projects. |
| Energy metering tool | To realistically evaluate the energy performance of the 5G-VICTORI solution, a city scale analysis was carried out by IASA that adopts the 5G-VICTORI architecture and its technical capabilities to support real traffic requests recorded for the city of Milano available online through [27]. The performance of the 5G network that supports these requests is captured through an experimental infrastructure (lab scale) that was purposely set up for this evaluation including both 5G RAN and 5G core solutions. All system building blocks were monitored using Prometheus node exporters, while metrics characterising the performance of either physical or virtualised compute nodes were extracted and stored to a time series database. In addition to this, the power consumption of the physical infrastructure was monitored using metered outlet Protocol Data Units (PDUs). An intelligent/semantic management plane that interacts with all building blocks of the system enabling appropriate decision making for optimal system performance was introduced. This was achieved through a purposely developed intelligent management framework relying on a set of building blocks aligned with the ITU-T Y.3172 standard providing a set of microservices including: i) design of custom Machine Learning (ML) pipelines and ii) orchestration of ML pipelines through the ML Function Orchestration (MLFO). |
| Techno-economic analysis tool | A method for techno-economic evaluation of large-scale 5G and beyond network deployments was developed by **COSM** and has been implemented as a parameterizable tool. The tool is generic and can model any deployments based on 5G-VICTORI technologies and deployment options. It can further be extended to include additional technologies. Within 5G-VICTORI, the tool was applied to railway and smart city environments (non-restrictive usage of the tool). For more details see section 2.2.2 and [1]. |

### 3.4 Exploitation activities and outcomes by partner

This section lists exploitation outcomes as well as completed, ongoing and planned exploitation activities per partner. The partners are sorted into SMEs (3.4.1), network operators and major vertical industry companies (3.4.2) and research institutes/universities (3.4.3). Note that one part of the exploitation is the screening and development of business models, with a strong focus on sustainability-oriented business models. Since this aspect is discussed in section 2, it is for the most part skipped in the entries below.

The focus of exploitation naturally differs across the type of partners, with SMEs and companies focusing more on commercial and technological exploitation and research partners more on scientific exploitation and, depending on the field of research, on technology exploitation. At the beginning of each section listing the exploitation activities by partner group a brief summary of the main outcome categories and outcomes/activities in the respective group will be given.

### 3.4.1 Small and medium enterprises

Overall, exploitation activities by SMEs are concentrated on **commercial** and **technology exploitation**. The main outcome categories are **product** and **business development**. Activities and outcomes present in all SMEs were **validation activities, prototypes, TRL increases** and **commercial use learnings**. Partly, SMEs also had a focus on developing and refining (new) **business models, business model validation** and **user-oriented activities**.

**Table 3-2 Exploitation by partner – SMEs**

| Partner | Exploitation activities |
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| MATI | The **main outcome** for MATI is the development of an immersive Application for mobile devices for the presentation of immersive AR/VR content services to train passengers arriving at train stations. Within 5G-VICTORI the application was developed and field-tested.<br><br>The **problem addressed** originally was the lack of an interactive guide for travellers as they move between the station where they arrive and their first destination (e.g. hotel), which allows them to gather useful location-based information regarding the place they have arrived. The **solution** is the immersive application, either delivered as AR to wearables (AR/Smart Glasses) or to the end-users 5G-enabled mobile devices. The application presents the route for travellers to follow as well as relevant information along the route (e.g. content highlighting points of specific interest).<br><br>From the perspective of **technological** development during the first phase of the project, the application was developed and was functioning with example content in the lab. In the later phase of the project the application was brought together with the network, fine-tuned, and tailored to the specific requirements. Here important learnings were how to make the integration of the necessary modules to partners' infrastructures easier and do this even remotely and exploiting edge computing and caching on the edge.<br><br>The **TRL achieved** is 7. At the end of the project, it is expected to have the potential to reach **TRL 8**. Since January 2023, the technologies developed are already being exploited commercially.<br><br>During the course of the project, the **commercial exploitation plans** have **shifted focus**. As described above, initially MATI had identified tourism as a target market sector and aimed to use the results of this project to develop products and services for this sector. However, this sector was damaged considerably by the pandemic and other external factors and potential prospects have become weary of investments in any asset or technology or service that is not considered essential for their immediate survival, making |

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| | it harder to bring the immersive application to the market. Therefore, while MATI still aims to target the Tourism Market, we expect that we will not see meaningful progress in the near future. However, the application also has considerable potential in other market comparable sectors, where the goal is also to deliver content to moving people. One of these is immersive enterprise solutions in HR tasks such as group training on location, H&S training in facilities and similar tasks. The technology developed is currently being incorporated into **products** in this market sector. One example is a VR based health and safety training application for a factory. The approach is not through an off-the-shelf product but by using the core of the technology that was developed in 5G-VICTORI and adapting it to implement individual projects, customised for different situations. Several such projects area already confirmed and completed, the technology is already in commercial use.<br><br>In terms of **joint exploitation**, there has been close cooperation with **UNIVBRIS** and **DCAT**. Beyond working on 5G-VICTORI related trials together, we have contributed to dissemination events, such as workshops that show the result to industry stakeholders and present potential uses of 5G based applications to companies. Working with **DCAT** is particularly beneficial, because as network specialists, they have a lot of knowledge on networks themselves and this can enrich our knowledge as application specialists, creating a productive complementarity and overlap of topics. **UNIVBRIS** has also used insights from our joint work in publications.<br><br>Recently there have been discussions and knowledge exchange with **UHA** regarding capabilities for building streaming platforms and applications can be used, especially for immersive technologies. There have also been discussions with **UoP** regarding how a remote lecture infrastructure could be useful for them.<br><br>In terms of **future exploitation**, a focus is on further exploring the possibility of delivering localised content to people on move in industry settings. There appears to be a lack of solutions and a variety of problems to which applications such as ours can present a solution. One example is visually supported remote warehouse management |
| **PXI** | The **main outcome** for **PXI** is paxCDN, a CDN on-board for streaming apps delivery and Wi-Fi bandwidth optimisation.<br><br>The **problem** this addresses is that, for mobile environments, such as in trains, despite significant investment made to install Wi-Fi in vehicles, passengers usually have minimal, if any, access to the streaming content they want to watch. Cellular bandwidth and existing Wi-Fi systems in-vehicle can simply not cope with the volume of data requested by passengers looking for watching their media streaming services onboard.<br><br>This is where paxCDN comes into play as a **solution**. paxCDN enables clever management of the media data requests from passengers while onboard. paxCDN implements an "automated caching" of supported content on the server of a train. The passenger's streaming app is thus served by the train's cache instead of going to the internet (and congesting the cellular bandwidth), without the user being aware of that. Content is hosted closer |

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| | to the users, so it is accessible with high quality reception and without interruption regardless of external connectivity. paxCDN frees up the cellular bandwidth capacity of the vehicle because the supported media content is now delivered to passengers locally from the embedded vehicle's server. From a transport operator perspective, this translates into enabling passengers to watch their streaming services onboard like at-home, while preserving their vehicle's existing cellular bandwidth for other uses.<br><br>Overall, paxCDN enables virtually unlimited Wi-Fi bandwidth onboard for passengers to seamlessly stream favourite media apps, without blocking the bandwidth for others and without increasing broadband data charges for transport operators. By way of clever rail data management, the onboard CDN is part of the solution enabling existing in-vehicle Wi-Fi systems to work properly while offering better services and experience to travellers (they want to watch their own streaming services).<br><br>The **TRL achieved** is 7. Next TRL levels will be achieved once the service is in operation at a customer.<br><br>Regarding the **go-to-market strategy**, the next steps towards the market are partnering with the main media streaming services, which is a key element to enable authorised caching of the media content and therefore impactful results. **PXI** had numerous contacts and discussions with major streaming services over the past 2 years, yet the interest by media streaming players in targeting transport audiences alone has still to be confirmed and the business model validated.<br><br>An alternative can be the endorsement by selected ISPs companies looking to offer better internet service onboard vehicles. In this framework, paxCDN is currently part of two major on-going bidding projects for fleets of long-distance trains (details and names cannot be disclosed under tenderers' confidentiality conditions). |
| **ZN** | The **main outcome** for **ZN** is a **solution** for simplified and automated reconfiguration of multiple network switching devices across multiple domains for the management of layer 2 connectivity requirements. This was integrated into Zeetta Automate (a 5G slicing solution).<br><br>Zeetta Automate was deployed at 3 edge sites, in the 5GUK test network, to configure layer 2 traffic across these edges as part of the 5G-VICTORI field trial. Working in collaboration with **UNIVBRIS**, layer 2 traffic routing was automated for 3 different locations, each hosting a network domain. The 5G-VIOS controller, developed by the university, sent instructions to the Zeetta Automate solution in each location as needed to update layer connectivity to connect applications using the network. The Zeetta Automate solution monitored configured network switch port activity passing statistics collected to the central processing server in 5G-VIOS. The outcome of the multi-site capability for simplified slice management across domains was exploited in the architecture and design of the new configure, assure and adapt concept introduced in Zeetta Automate in Q4 2022. As result of 5G-VICTORI, Zeetta has defined the needs of edge orchestrated slicing and how the differ from the needs of customer service provided slicing.<br><br>The **TRL achieved** is 7. |

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| | Regarding **commercial exploitation**, the features of Zeetta Automate developed to support the 5G-VICTORI project join other features in the product in the domain controller function. These features as part of the greater **product** are being marketed **for proof-of-concept use** within customer premises at present.<br><br>Zeetta used 5G-VICTORI as a UC example when engaging with investors, system integrators and customer prospects. Zeetta Automate was demonstrated to multiple global mobile network operators, tooling solution providers and system integrators. These demonstrations validated the need to manage network services across multiple devices, from multiple vendors, using different technologies (LAN, Wi-Fi and 5G) access multiple domains and locations. **ZN**'s roadmap as a result of 5G-VICTORI outcomes is designed using the concepts of configure, assure, and adapt for networks from day 2.<br><br>Regarding **further exploitation**, from demonstrations to prospective clients, Zeetta identified an emerging market need, within the enterprise market, to manage network connectivity from an application perspective to realize value from the network slicing feature introduced into 5G Standalone NPN's.<br><br>During 5G-VICTORI **ZN collaborated** with **UNIVBRIS.** Beyond this the 5G-VICTORI project highlighted features to **ZN** where collaboration and partnership are beneficial, for example, **ZN** partnered with third party active probe suppliers creating an easily adapted framework for exchange of supplier solutions. |
| **UHA** | The **main outcome** for **UHA** is the development of an Edge Connected Simulation that can calculate routes, journeys and thresholds for insurance-based events and mitigations. This is then delivered to an embeddable or web based immersive Application for mobile devices for the presentation of interactive content services to, for example, train passengers arriving at train stations, flights and other insured and non-insured events. Within 5G-VICTORI the application was developed and field-tested in Bristol, Berlin and Computer Vision applications provided to support mobile analysis of Bus Passenger events in Romania via Orange in collaboration with **DCAT** and **UNIVBRIS**.<br><br>The **problem addressed** originally was the lack of an edge sensor driven simulation and digital twin for travellers as they move between different types of transport, primarily stations. By providing a spatial simulation that can combine data from location-based information it is possible to predict disruption, trigger events and provide a multi-user planning tool for both customers and consumers. End-users can access this via 5G-enabled mobile devices allowing for the application to calculate the route, disruption and potential remediation in real-time. This allows Polaron to present the route for travellers to follow as well as relevant information along the route (e.g. different routes and options – including tailoring to reduced mobility passengers).<br><br>From the perspective of **technological** development during the first phase of the project, the application had to be developed from TRL 2-3 and was functioning in a lab environment. In the later phase of the project the application was brought together with the network, and a custom WebRTC |

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| | component allowed for data and network components to be moved between different edges using 5G-VIOS containers, and incrementally more users added. Multiple bespoke components had to be developed in Polaron to ensure inter-operability with the open source Web-RTC ICE service and an Open Source container has been provided to the group.<br>As Polaron matured it was possible to expand the types of data that could be ingested – from full 10 cm scanned models of Berlin Central Station, to Nerfs, Photogrammetry and Phone based scanning, as well as large terrain and transport datasets and even LEO-Infrared Data as a predictor of heat-wave based disruption and transport planning and triggered customer events and mitigations to both travel, protests and events as well as some POC on climatic change.<br>There were important learnings and some challenges in integrating into different partners' infrastructures, but through this we've been able to push data to Unity edge based rendering systems from **FhG**, push and pull data and cached information and mine performance analytics over P2P and Edge based routed traffic. This has been done both in person and remotely and the performance has dramatically improved by exploiting edge computing and caching on the edge as well as showing that the network component's location in relation to a user – plays as much a part as the simulation (as 5G connects to fibre) and how a CDN might be exploited for both data input and data provision (not everything needs to be live and can be cached / pre-calculated to be delivered into 3rd party tools).<br>The **TRL achieved** is **7**. It is expected to reach **TRL 8** soon, with further investment. **UHA** is in the process of assembling our investment materials focussing on the insurance, risk and through feedback on the project – gaming & serious simulation (essentially the interface of the former).<br>During the course of the project, the **commercial exploitation plans** have **shifted focus**. As described above, initially **UHA** had identified multi-modal transport planning as a target market sector as well as more traditional insurance markets. However, having engaged with numerous insurance markets it appears that the granularity we offer is deemed to be excessive (in all but climatic work). However, one Parametric focussed Insurer has taken a strong interest – in particular due to the more cohesive nature of EU Rail networks and interfaces into embedded insurance products. This pivoted our plans toward using the simulation to drive trigger metrics based on multiple parametric triggers encoded into spatial data (i.e. the circumstance and location of the end user). Working with **IZT** and **UXBerlin** on Business Models changed a lot of the initial model towards being part of larger data structures as a service provider rather than an E2E model – which affords us far greater interoperability.<br>The pandemic and other **external factors** including the conflict in Ukraine prevented the scanning of Berlin Central Station. Additionally, when scanning public infrastructure there are some challenges in privacy, security and exposing / sharing data amongst different operators – best evidenced by much larger projects such as the UK's CREDO programme's extensive efforts to provide a legal framework between different utility providers.<br>Therefore, whilst **UHA** still aims to target the Travel and Insurance Market, it is expected that the pathway to revenue and navigation of such challenges |

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| | and regulation means that a diversified application that can be embedded is more attractive and there has been some dialogue with defence and security applications and investors, as well as presenting to a EU and UK based Amazon Web Services (AWS) scale up programme in the Geographic Information System (GIS) space. However, having seen so much progress on persistent digital twins from larger dedicated scanning companies, a representative approach to data and simulation that leverages this data seems to mitigate these risks.<br>In terms of **joint exploitation**, there has been close cooperation with **UNIVBRIS** and **DCAT** and a close working relationship with **FhG**. Beyond working on 5G-VICTORI related trials together, we have contributed to dissemination events, such as **FhG**'s Media Web Symposium, EuCNC, the UKEAA and NPL lead for other 5G based applications.<br>**UNIVBRIS** have been incredibly supportive– and accommodated a lot of headaches encountered in delivering our WebRTC edge based networking relay component into their system as well as providing analytics and performance data and debugging as well as organising the field tests aboard "The Mathew" and scanning the M Shed museum in Bristol. **DBH** were also instrumental in providing site access and technical support for testing and supporting our efforts with **FhG** as well as Edge based testing of deployable 5G-Nodes across the Berlin Rail network at multiple different sites.<br>Recently there have been discussions and knowledge exchange with **MATI** regarding capabilities to ingest 360 video to produce Neural Radiance Fields and full volumetric models of a space based on our work with Stereo Neural Cameras and in dialogue with an Ex Imperial University Start-up.<br>In terms of **future exploitation**, a focus is on further exploring and expanding the layers of data and complexity of the simulations – in particular the performance of the GIS in its use of Spatio-Temporal data to deliver on the real-time performance of the 5G network – which has been shown to be more than adequate to supply real-time simulation and calculations based on large scale, frequently updating and edge based sensor data and hybrid architectures permitting both localised and cloud based simulations offering resilience and edge based processing benefits. There has been some dialogue regarding follow-on applications both within the 6G and GIS space. |

### 3.4.2 Network operators and major vertical industry companies

In sum, exploitation activities by network operators, companies in the different verticals involved in 5G-VICTORI and other vertical actors (such as **AIM**) focus on **commercial** and **technology exploitation**, but **scientific exploitation** activities play a substantial role as well. The main outcome categories are **product** and **business development** and research achievements. Activities and outcomes present among almost all partners in this group are **validation activities, prototypes, technology learnings, TRL increases** and **commercial use learnings**. Several partners also put a focus on developing and refining (new) **business models, validating** these **business model**, defining their **5G ecosystem role** and **user-oriented activities**. Some partners in this group also had new **research projects** as outcomes.

**Table 3-3 Exploitation by partner – major companies**

| Partner | Exploitation activities |
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| **ADMIE** | The **main outcome** for **ADMIE** is the development of a unified portable solution for on-demand 5G private network and Industry 4.0 services provision.<br>Related outcomes include:<br>• Development of the end-to-end portable solution for provision of 5G connectivity, as well as IoT data analytics for industries.<br>• Integration of 5G technology and equipment in legacy industrial systems.<br>• Parallel execution of different services on top of the same infrastructure.<br>• Local breakout to support privacy and low latency KPIs.<br>The **problem addressed** is the lack of existing Industrial IoT (IIoT) platforms offering competitive solutions with support of 5G technology along with the ability to be integrated in existing network infrastructure. Especially for remote, hard-to-reach facilities, solutions with easy deployment and scalability are needed. The **solution** is the provision of an end-to-end portable platform with inherent support of 5G connectivity for deploying advanced Industry 4.0 services. Specifically, the platform supports on-premise 5G Private Network deployment, compliant with Industry 4.0 standards (latency, capacity, reliability, and security), edge computing capabilities for time critical applications and a set of different applications for real-time infrastructure analytics and monitoring. It also supports different IIoT protocols and backwards compatibility with legacy industrial protocols and equipment. It is a flexible and expandable solution with the integration of low-cost wireless sensors, enabling the transition of legacy facilities to smart factories. Overall, the solution is customizable real-time monitoring and advanced analytics, according to client needs.<br>The **TRL achieved** is **7**.<br>The solution, i.e. the IoT platform along with its industrial protocol adapters and analytics, has been **presented** the Maintenance and Telecommunication Departments of ADMIE. Response has been positive, in particular for its use for non-critical information at remote locations.<br>**Further exploitation** activities are identifying more industrial protocols that can be supported by the solution and considering new types of sensing devices with 5G connectivity support.<br>The work in 5G-VICTORI was done **jointly** with **UoP** and **ICOM**. Continued collaboration is needed to further develop the portable solution and to identify other industrial protocols and additional IIOT services necessitating 5G technological capabilities. |
| **Alstom** | The **main focus** of **Alstom** within 5G-VICTORI was Rail Signaling in a 5G System using 5QI based QoS settings and signaling in RAN. A main goal for **Alstom** was to get insights on how Rail Signaling and CCTV behaves together with other services over the same 5G system, using the same air-interface spectrum for all services. Of particular relevance were Network Slicing and QoS. During the project it turned out that Network Slicing could not be supported in the Berlin cluster. Regarding QoS, however the following **insights** were gained through test results in 5G-VICTORI:<br>- Rail Signaling should use QoS over the 5G air interface, as it makes Rail Signaling better off when the air-interface is loaded. |

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| | - The Future Railway Mobile Communication System (FRMCS) standard includes QoS and the 5G standard contains 5QI settings. Test results show that QoS is needed.<br>- Cameras using H.264 cannot be real-time trusted, as pictures can be delayed up to 60 s after a backhaul interruption. Onboard systems deploying cameras must have control of the moving pictures delay.<br>- A real system must use another solution, like having cameras with MPEG pictures sent to an onboard server, having full control of the delay, this needs to be discussed with the hard-wear providers.<br><br>For the Berlin IHP Lab Field Demo, a real CCTV camera was used, but a Hawkeye software with Wayside and Onboard Probes were used for Rail Signaling. However, the 5QI settings were done in Open5GCore, which makes it more realistic with a real system.<br><br>The **TRL achieved** is 4. |
| **AIM** | The **main outcomes** for **AIM** are the **solution** tested with success using 5G Infrastructure for the first time in the city, validation of 5G deployment in the Operation environment with real UCs: energy metering in 3 public buildings – one school, the city hall and one museum -, mobility UC in our first electric bus.<br>The development, integration, and deployment carried out in the context of 5G-VICTORI project allowed **AIM** to study and analyse together with project partners in the context of the **FR/RO** Cluster the viability, challenges and risks of an Open Source based solution for 5G.<br>The outcome of the project was **presented** to the **AIM** administration. The FR/RO facility cluster exploit the two UCs for Mobility/Public Safety and Smart City/Energy metering. The TRL achieved at the end of the project is 7.<br>Potential exploitation following the validation with **AIM** on the two UCs is to **replicate the UC model in other cities** from Romania with public administration. For this, the real-time LV energy metering solution tested within 5G-VICTORI brought Alba Iulia the chance to replicate the successful story. A new project on LV energy efficiency was approved including the smart metering for energy solution in the public building on the Elderly home hosting 100 aged people of **AIM** which are complementary together with other smart solutions for energy efficiency and renewable resources such as heat pumps. The proposed solution is based on the 5G-VICTORI experience. A project is under implementation financed by Innovation Norway and will bring an estimated reduction of costs 30,000 euros per year. The specific objectives of the project are:<br>• OS1: 47,93% reduction CO2 emissions reductions generated by the building of Home for the elderly, in Alba Iulia, (the equivalent of 162 tons of CO2 emissions), by the year 2024, through an innovation process in the field of geothermal and solar energy, by developing and implementing a microgrid technical solution during 22 months;<br>• OS2: Increase from 0 to 1174 MWh/year in energy production from RES at the level of the building of Home for the elderly, in Alba Iulia, by the year 2024, through implementing a microgrid technical solution during 22 months;<br>• OS3:11,76% reduction of annual savings from renewable energy production within the local budget of Alba Iulia Municipality , (the equivalent of 9440 Euro reduction, from 80217 Euro/year in 2019, to 70777 Euro/year |

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| | in 2024), by developing and implementing a microgrid technical solution during 22 months;<br>• OS4: Enhancement of the administrative capacity of one public entity in Alba Iulia, by the year 2021 by organizing 2 types of trainings of operating personnel, during 3 months<br>• OS5: Encouraging and stimulating an energy efficient indoor environment and also a more responsible civil society, by promoting and disseminating the project activities and outputs, during the entire project implementation 22 months.<br><br>This project received the recognition of the Romanian Municipalities association (AMR) for excellence in energy efficiency, so the Project – with the solution extended from 5G-VICTORI is an example of good practices for Romanian Municipality, officially awarded at the end of 2022.<br><br>This project received the recognition of the AMR (Romanian Municipalities association) for excellence in energy efficiency, so the Project – with the solution extended from 5G-VICTORI is an example of good practices for Romanian Municipality, officially awarded at the end of 2022.<br><br>Future steps from the R&D perspective, network flexibility, agility, and reliability are still open and need to be addressed in the context of 5G and upcoming 6G, working closely with 5G-VICTORI partners – mainly close to ORO – for other projects to continue the great work but also with **UHA**, **EUR**, **Orange**, **ORO**, etc. |
| **COSM** | Two **main outcomes** for **COSM** from the participation in 5G-VICTORI are:<br>**A.** The extension of a commercial TV infrastructure with multi-level CDN capabilities to provide high quality media services in dense, static and mobile environments.<br>**B.** The development of a techno-economic analysis tool for the evaluation of large scale deployment options at vertical environments.<br><br>Concerning **A**, **ICOM**'s multi-level CDN platform was integrated as an extension to COSMOTE TV commercial CDN infrastructure to provide media services in dense, static and mobile environments (especially addressing the railway environment) leveraging edge deployments. The **problem** this addresses is the following: Provisioning Media services in mobile environments is very challenging. Some of the challenges to be faced (the list being non-exhaustive) relate to: 1. provisioning of network/service coverage along roads, railway tracks, etc., with the required KPIs in terms of latency, datarates & availability, 2. Mitigating service outages and delays stemming from the fact that current CDN deployments are based on distributed architectures deployed at central locations but are not extended close enough to the last mile. 3. Incorporating media services (as 'business services') as part of the FRMCS services. The **solution** offered through the innovation is 5G NPN deployment at railway premises and integration of INTRACOM's 3-level CDN platform as an extension to a commercial TV (COSMOTE TV) CDN infrastructure to provide media services in the railway environment leveraging edge deployments.<br><br>The **TRL achieved** is 6.<br><br>The solution was **presented** to other departments of **COSM**. Moreover, the relevant COSMOTE TV business departments were completely engaged in the work performed to integrate **ICOM**'s CDN platform. The relevant **COSM** |

departments undertook the design, and deployment of the niche COSMOTE TV infrastructure. Their feedback was positive especially because of the challenge that addresses and the exhibited opportunity for collaboration with a vertical industry. Its innovation was recognised; and the costs will be further analysed in detail on a per vertical deployment case (e.g. cost of multi-edge deployments). Further trailing is considered as next step before proceeding with larger deployments.

The deployment/ network design/ evaluation -related work done in the context of the Media UC will serve as **paradigm** for similar future CDN deployments at facilities/ locations of various transportation industries. However, the timeline is not finalised for now, given the fact that it depends on the 5G SA network roll-out to vertical industries. Moreover, the deployment/ network design/ evaluation-related work done in the context of the railway UC will serve as paradigm in case of involvement of **COSM** at the deployment of FRMCS at railway environments. Know-how and expertise gained from 5G-VICTORI project related to network planning and deployment options along roads/tracks will be fused to the latest R&D activities of **COSM** in the context of 5G-SEAGUL and TRACE EU funded projects, and in similar activities. Further research will focus particularly on multi-edge deployments for large scale deployments.

The solution was also presented at various conferences of the Industry and Research communities and paper publications in their relevant proceedings (e.g. Athens INFOCOM, AIAI 2021, AIAI 2023, etc.)

With respect to **B**, **COSM** developed a fully parameterised techno-economic analysis tool in order to:

- evaluate - from a techno-economic perspective - alternative options (as instantiations of the architecture blueprint) when deployed at scale at various verticals' environments,
- obtain analytical, comparative cost results to identify key factors (KFs) influencing cost, and
- extract deployment recommendations for medium and large-scale deployments.

The **problem** addressed here is the challenge of evaluating from a techno-economic perspective alternative options (as instantiations of the architecture blueprint) when deployed at scale at various verticals' environments, in order to extract recommendations at pre-planning phases. The tool developed provides a **solution,** enabling network operators to run various network deployment scenarios. The tool models each network segment distinctly – namely, access, transport, edge / core, services- in terms of technologies used, scaling rules, network operator principles followed, costs and scaling of costs etc., and provides as output results: 1. dimensioning of each network segment and 2. The corresponding costs (CAPEX/OPEX/TCO) – broken down per segment, per technology and cumulative.

The tool concept and principles were **presented** internally to the company departments, and the methodology was well appreciated by the engineering departments. B. The methodology was further disseminated via presentation in AIAI 2023 Conference – 5G-PINE Workshop, and as paper publication in the relevant proceedings.

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| | Regarding **joint exploitation**, in the context of 5G-VICTORI, **COSM** has partnered with a number of industry and academic partners. As far as the partnership with academic partners is concerned, new opportunities have emerged to further work on 5G network architectures and deployments, UCs, demos in the context of EU-funded R&D (H2020/Horizon Europe, DIGITAL, CEF) projects with **IASA**, **IHP**, **UTH** and **UoP** (e.g. 5G-COMPLETE, SLICES-SC, PHOENi2X, TRACE), while future proposal submissions are sought to maintain and strengthen these partnerships. The investment put by **COSM** for the realisation of the Media UC is planned to serve as a basis for more demonstrators of interest both in R&D projects and/or pilots with commercialisation potential. Regarding the partnership with commercial partners, **ICOM** is a strategic partner of **COSM** in network solutions delivery. In this context, the trialed mmWave and 3-level CDN solutions will be further examined for potential adoption by the relevant commercial departments of the company; with timeline and conditions adhering to the strategy and plans of the company. |
| **DBH** | The **main outcome** for **DBH** are several solutions of the industry partners that enable rail specific use cases both for future passenger services as well as railway internal and railway critical services. Deutsche Bahn in total gained insights on technical capabilities and **solutions** developed in the 5G-VICTORI program that can and will be used to develop the future digitalisation of railway operations and mobile passenger services. This is especially important for DB's program "Digitale Schiene Deutschland" ("Digital Track Germany", https://digitale-schiene-deutschland.de/en) and the planning of future 5G infrastructure.<br><br>As mentioned by other partners, solutions developed during the 5G-VICTORI program already play a significant role in bids to call-for-tenders of Deutsche Bahn. In general, train passengers expect content delivery on board of trains with a good performance and end user experience. The need for and use of mobile Apps to conveniently plan and conduct end-to-end train journeys, navigate easily through unknown stations and cities as well as the usage of content during the ride will increase and this will significantly influence passengers' perception and preferences of using railways for their travel needs in future. The 5G-VICTORI partners developed and demonstrated working solutions to address those needs and to achieve a new level of service quality. If railways are more attractive to passengers for long distance and commuter journeys, this will also help to increase sustainability and to strengthen Germany's economic situation in total.<br><br>Furthermore, the technologies developed in 5G-VICTORI help to improve efficiency and performance of all processes and transactions in railway passenger and cargo operations. This applies not only for ETCS and other safety related use cases, but also in areas like predictive maintenance and infrastructure monitoring and surveillance. Rail specific 5G-VICTORI solutions can be used by the technology partners to offer commercial solutions based on these new capabilities. As an example, DB *Fahrzeuginstandhaltung* (i. e. "train maintenance") already uses a 5G private network solution based on the "Nomadic Node", developed by 5G-VICTORI partners, in their Krefeld maintenance workshop to improve communication between trains and workshop and to speed-up maintenance processes.<br><br>**DBH** therefore forwards and promotes insights and results of 5G-VICTORI within the DB internal community involved in future digital strategy, planning processes |

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| | and deployment projects, especially in 5G related context. We are convinced that 5G will drive the digitalisation of railways in general and 5G-VICTORI provided a platform to enable new solutions for this target. |
| DBN | The **main outcome** for **DBN** is standardisation documentation which takes into account its communication and connectivity needs with low latency and high reliability as well as its legal requirements stemming from EU and German law (e.g. obligations concerning critical infrastructures, safety, information security, functional autonomy and independence on FRMCS, network quality and performance).<br><br>The **problem** addressed is how to develop an approach to standardisation which would enable **DBN** to take part in pertinent standardisation groups and have those groups consider and address its FRMCS-related technical and financial needs as well as legal obligations arising out of the General Railway Act (*Allgemeines Eisenbahngesetz* - §4). Other concerns pertain to the creation of a FRMCS version that at least supports voice, ETCS, ATO GoA2, and real-time critical video, and which is architecturally future-proof towards further releases. As per the **solution**, the required approach is being achieved with a form of coordination and collaboration between workings groups of various standardisation bodies, which enabled **DBN** to exert influence and have those platforms adopt and address its needs and concerns. Thanks to that approach, within the framework of ETSI, UIC and ERJU, **DBN** has achieved to validate the first set of FRMCS specifications by developing and testing prototypes of the FRMCS ecosystem, for both trackside infrastructure and on-board. It has also managed to validate the latest available railway-relevant 5G specifications covering significant portions of railway operational communication requirements, including the core technological innovations for rail expected from various 5G-related standardisation releases.<br><br>The **TRL achieved** is 5.<br><br>The results of standardisation activities are already available to the interested stakeholders, including the partners and can be utilised for the purpose of **joint exploitation**. Apart from that, some of the achievements were referenced here: https://digitale-schiene-deutschland.de/ Furthermore, DBN is in regular exchange with the partners on various occasions offered by 5G-VICTORI and 5G PPP. **DBN** will keep up with its ongoing efforts towards joint exploitation in the future. The gradual introduction of FRMCS into the railway infrastructure and the systems surrounding it goes a long way in fulfilling the business objectives of **DBN**. An infrastructure that enables connectivity needs of digital railway systems yield more quality of rail operation, satisfaction of customers, and revenue for partners and further stakeholders alike. |
| ICOM | Through its participation in 5G-VICTORI, ICOM developed a virtualised multi-level CDN solution for the efficient and uninterrupted provisioning of high-quality Video on Demand (VoD) and IPTV multimedia services in high mobility environments, such as railways, for infotainment purposes, utilizing 5G network capabilities – this solution is the **main outcome** for **ICOM.** The **solution** relies on the concept of "data shower" which, utilizing the high data rates offered by 5G networks, proactively brings large volumes of fresh, high quality target content on-board a train CDN cache, when the train acquires 5G connectivity with the train station during the short-time stops along its journey. This way, video continuity and high- |

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| | quality maintenance are guaranteed at all times of a passenger's journey, even in areas where there is no network coverage. The solution is based on ICOM's commercial fs\|CDN™ Anywhere product, which was extended and modified in order to be more modular and distributed, consisting of several components that are more dynamically deployable and automatically integrate-able. The developed solution follows virtualisation principles and is NFV-compatible. Finally, appropriate mechanisms were deployed for the connectivity detection when the train approaches the station.<br><br>The **TRL achieved** is 6.<br><br>The solution specification and the UC requirements have been **presented** to the business departments of **ICOM**, and there has been active participation in the customisation of product services in order to support the use case specific scenarios. Discussions have taken place regarding the incorporation of the innovations with respect to the extremely modular and distributed deployment of the virtualised CDN services into future-proof roadmap of fs\|CDN product, possibly within the next two years, with a focus on cloud-native deployments over converged computing and (next generation) networking infrastructures, customised for vertical requirements.<br><br>**Future exploitation** includes examining if our solution can be also applied in other cases of the transportation vertical. An example is the case of ships (cruise ships, passenger ships, etc.) whose content servers can be automatically updated with fresh content via 5G connections when they arrive at a port. Another direction to be studied is the possibility for our service to be offered jointly with other services (e.g. at restaurants/cafes).<br><br>**Joint exploitation:** Building on successful collaboration in 5G-VICTORI and other 5GPPP projects, **ICOM** is continuing the active partnership with **UoP** and **IASA** (i.e., the testbed infrastructure provider for the use case) in scope of the π-Net partnership (https://www.p-net.gr/) that aspires to become an international research and innovation driven Competence Centre for emerging smart networks and services. Expertise and experience gained through the use case preparation, deployment and validation activities are expected to fuel future collaborations in relevant initiatives, with **ICOM** providing all the backhaul network infrastructure connecting the Cloud at **UoP** with all the sites hosting the relevant UCs executed in Patras facility, as well as an advanced Edge Computing platform services over this innovative infrastructure. |
| **KCC** | The **main outcome** for **KCC** is the successful integration of our Mission Critical Communication Services (MCx) solutions and the deployed communication technologies, specifically 5G-SA but also mmWave and Sub-6GHz, all used for back haul from On-board Devices and Gateways to Track-side Gateways and Mission Critical Services.<br><br>The Future Railway Mobile Communication System (FRMCS) is based on MCx and evolves MCx. As Mission Critical Services based on GSM-R evolve towards FRMCS, both a parity of existing GSM-R voice services and new voice and data services such as Telecom On-Board Architecture (TOBA) are developed and deployed using modern data access networks. Deployments of 5G-SA networks at major railway operators, to be used for tests and trials, are planned to start in 2025. In the Berlin cluster, the development addressed the effort to deploy and |

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| | test voice and data services using **FhG**'s 5G-SA core network combined with **IHP**'s nomadic node and different access solutions. In the Greek cluster, a similar deployment was done using 5G, mmWave and Sub-6GHz access networks provided by the **UoP** and the **UTH**. Valuable information was gained as to how the MCx services perform in the field, including FRMCS-specified KPIs and performance of critical voice services in handover scenarios. In addition, the sensor data UC enables acquisition of on-board sensor data that can be used to monitor, analyse and maintain mobile assets.<br><br>Furthermore, over the course of the project, **KCC** made several contributions to 3GPP Standards focusing on introducing new service layer functionality (voice and data) and additional change requests required by FRMCS within the context of Mission Critical Services already specified within 3GPP. Other aspects were standards contributions to better support low latency communications via Mission Critical Services.<br><br>The **TRL achieved** for the combination of MCx / FRMCS services with a 5G-SA network deployment is **7**.<br><br>**KCC** is already deploying MCx / pre-FRMCS solutions based on LTE 4G in our customer networks. LTE employs QoS priorities and Guaranteed Bit Rate (GBR) to guarantee bit rates over dedicated bearers. Moving towards 5G-SA, 5QI and GBR using QoS Flows must be exploited to raise the QoS of the FRMCS voice and data services and to guarantee a user experience which is expected from Mission Critical users. The implementation of 5QI, GBR and QoS Flows is being jointly investigated by **KCC** and **FhG**. The nomadic node from **IHP** is being considered as a possible deployment model for tests, trials, construction environments and emergency situations where an MCx network must be deployed in a relatively short amount of time.<br><br>**Subsequent research and validation activities** build upon the valuable results achieved in 5G-VICTORI, and focus on integration of 5G-SA for FRMCS. This is continued together with **DB** *Digitale Schiene Deutschland* in MCx 5G Erzgebirge (Digitalen Testfeld Bahn) and in 5G-RACOM. |
| **Orange** | The **main outcome** for **Orange** is the development and demonstration of the Cloud-Native Open Source 5G Platform. More specifically, the feasibility of the automatic deployment of the OAI 5G SA network infrastructure based on 5G RAN and 5G SA Core network infrastructure on as-a-service basis supporting day-0 and day-1 operations, with operation of different 5G UCs, was proven. Before the project, a similar infrastructure including 5G was deployed in non-standalone mode (in the 5G-EVE and 5G-TOURS projects). During 5G-VICTORI, it was deployed in standalone mode and the possibility of integrated usage by multiple UCs (media and public safety) with AI/ML algorithms to guarantee the required performance KPIs was demonstrated. Particular focus was put on the performance with respect to end-to-end latency and prioritised uplink data traffic for public safety services and fast network service instantiation.<br><br>A further outcome is the openness of **Orange's** 5G facility to verticals for testing their services use-cases in one E2E 5G framework to develop new services offers made possible thanks to 5G Networks.<br><br>The **TRL achieved** is 6. |

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| | The solution developed is planned to be integrated into a **commercial product** within 2-3 years.<br><br>Through the work in 5G-VICTORI **Orange** has further gained insights regarding achievable 5G KPIs and defining beyond 5G and 6G KPI, an activity to which Orange has contributed via liaison with the 5G-PPP TMV (Test, Measurement and KPIs Validation) working group.<br><br>**Future exploitation** centers on the evaluation of KPIs, and more 5G application prototypes. As partners, **Orange** (France) and Orange (Romania) –**ORO** - collaborate closely on exploitation of software infrastructure and applications developed in the France/Romania clusters, which could lead to further research and/or commercial exploitation by the Orange Group. |
| **ORO** | The **main outcome** for **ORO** is the 5G SA Option 2 solution deployed in a real live environment, as the 5G SA has been implemented within the Open-RAN/Open-Core framework. The solution has provided the real 5G SA communication services and experimentation capabilities with the 5G slices for at least two implementations: eMBB and URLLC services. The achievement is not only related to the 5G services implementation but also to the use cases running on top of this implementation for the two use cases: real-time LV energy metering solution and real time media service delivery and prioritised communication, with valuable business opportunities. Based on this experience, commercial pilots are considered, several business opportunities being identified, targeting to optimize their energy consumptions including also the positive impact of solar panels, municipalities and private company transporting their employees.<br><br>The development is addressing several technical and services **problems**, in relation to the use cases running on top of the development. One problem addressed is the provided infotainment/video services in dense, static and mobile environment with prioritised communication to Command &Control Centre and AI recognition and identification of emergency situation by creating two network slices. Another problem is related to LV energy metering services for the municipality infrastructure, energy analytics for predictive and proactive maintenance for the LV infrastructure. The technical problem is addressed by the 5G network deployment and instantiation, service slices creation and UEs association to slices and service slice performance monitoring.<br><br>The **solution** is the 5G Services deployment for 5G RAN and Core (OAI) in containerised environment (5G NSA), Common Core, 5G service provisioning to the users, service slice creation and UEs association to proper slice, agent application that auto-associates UEs to slices based on NSSAI (the IMSI or selected PLMN), 5G RAN video traffic prioritisation through Open RAN intelligent controller, triggered by event.<br><br>The **TRL achieved** is 7.<br><br>The technical implementation and the supported UCs have been presented with support of partners in different actions, focusing on: 5G-PPP Working Groups, Orange Group affiliate and business departments focusing on the use cases work-shops, participation in different industries conferences.<br><br>**Future exploitation plans** will be oriented on the 5G SA technology implementation for further services implementation in the area of Open-RAN, |

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| | results achieved in the project being further exploit also in other R&D actions for different topics, 6G networks or Security topics. |
| RBB | The **main outcome** for **RBB** is a solution that enables local caching of media services for continuous, cost saving and energy efficient media provision on trains. Specific results are the proof of feasibility of local train caches, updated via 5G short range transmission and all technical implications and efforts.<br><br>The development addressed several **problems** including restricted access to media services in areas with no/low mobile coverage, the cost of media delivery and is possibly more energy efficient. This was achieved by developing multi CDN media delivery support to enable local caching of media services on trains and using novel **solutions** (5G and mmWave) to transfer the large quantities of data involved at speed between caches. Media used on the trains is delivered via Wi-Fi from the on-board cache. A Mediathek Prototype including MPEG SAND integration was developed, the latter additionally enabling an efficient way of balancing media traffic within the local train network. The proposed approach of using the existing Mediathek, instead of creating a new extra service or app just for use in trains worked well and required few changes to the web application.<br><br>The **TRL achieved** is 7.<br><br>The main results have been **presented** to the ARD working group on Internet Streaming. They wish to further investigate the implications and potential cost savings of the development for various media services for live stream and on-demand video. Incorporation into existing products and services depends on outcomes of further technical tests, involving key RBB and ARD facilities. The service idea has also been presented to and discussed with colleagues from Tagesschau, the national daily news service produced by the ARD.<br><br>As content and media service owner and providers, data rights management and protection, especially in multi-CDN environments remains challenging and constitutes an area of **further activities**. A further avenue for investigation is the potential of the development to reduce energy consumption for media streaming both on the network and the presentation side.<br><br>Regarding **joint exploitation**, RBB is working together with Berlin cluster partners to further develop and test aspects of local caching solutions for media services in trains a view to implementing them as part of its regular service offering and those of the ARD. Specifically, further investigation will be conducted with **PXI**, but potentially also with **FhG** and **IHP** as technology providers and **DBH** as train operator. |

### 3.4.3 Research institutes/Universities

Overall, exploitation activities by research institutes and universities focused on **technology** and **scientific exploitation**, but partly also on **commercial exploitation**. The outcome categories are mostly **product development, research achievements** and **tools/insights for social development**, but to some extent also **business development**. Many partners in this group had as their main activities and outcomes **validation activities, prototypes, technology learnings, TRL increase, new research projects** and **commercial use learnings.** Further exploitation activities and outcomes among several partners were (academic) **courses** and **summer schools**, **consultancy services**, the creation of a **start up** and the **integration of SDGs** and creation of tools for sustainability assessment.

**Table 3-4 Exploitation by partner – research institutes/universities**

| Partner | Exploitation activities |
|---|---|
| **DCAT** | The **main innovation** stemming from 5G-VICTORI for **DCAT** is an inter-domain service orchestration platform for automating future networks.<br>The **key outcomes** of **DCAT** have been the design, development and demonstration of this platform, the 5G-VIOS platform. This enables inter-domain network and service orchestration with a common Network Repository Function, service Monitoring and migration across edges and an AI-powered Resource Profiling and Management mechanism.<br>The 5G-VICTORI Infrastructure Operating System (5G-VIOS) is responsible for the Life Cycle Management (LCM) of Network Services, on top of the orchestration solutions of the individual facility sites, enabling dynamic inter-site connectivity, inter-domain orchestration, and supports the on-boarding, end-to-end monitoring and management of inter-domain services allowing mobility UCs. 5G-VIOS has the capability to efficiently exploit and interact with the available underlying technologies such as MANO platform, SDN controller, and the monitoring platform available at different facility sites. These features enable flexible and automated service deployment and on-demand networking for different use-cases with different requirements.<br>The **TRL achieved** is 4-5.<br>The platform was **presented** at different conferences including EuCNC 2022, 2023, The Edge Event. Feedback was generally positive, interest was expressed in particularly regarding the applicability in hybrid cloud environments, i.e. how it could be linked/used for example in public/private cloud deployments.<br>As a follow-up of 5G-VICTORI, we have won a **new R&D project**, funded by the UK Government, named REASON, to continue our research on inter-domain network orchestration. 5G-VIOS development is a **joint work** with **UNIVBRIS**. We intend to continue the joint development of it and we are both part of project REASON. 5G-VIOS is planned to be an open-source solution and disseminated wider once complete.<br>Key challenges that need to be addressed in the **future** are Open APIs for data management and observability, particularly with the driver of Open Networks (e.g. OpenRAN), as well as moving forward from Network Service/Slices based management to Task Oriented Networking. |
| **EUR** | The main outcomes for **EUR** are:<br>- Validation of OAI 5G deployment in the Operation environment with a realistic UC.<br>- Interoperability with a commercial radio unit.<br>- Development and enrichment of the OAI code base.<br>- The creation of a **start-up, BubbleRAN**, commercialising the multi-vendor 4G/5G Open RAN and leveraging the OAI code base. |

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The development, integration, and deployment carried out in the context of 5G-VICTORI allowed EUR to study and analyse the viability, challenges and risks of an Open Source based solution for private 5G. This has led us towards a vendor-neutral affordable solution for a subset of UCs where high-availability is not part of the requirements. Based on the insights, we designed a multi-vendor 4G/5G Open RAN platform able to adjust the network definition as the requirements changes over time.
Specific innovations include the design and implementation of RAN slicing, improved OAI 5G code base and its interoperability with commercial components, novel RAN intelligent controller design and implementation.
The TRL achieved is 6.
The outcome of the project was presented to the EUR administration and the exhibition of the solution received very promising feedback. It resulted in the creation of the start-up BubbleRAN, which gives rise to new R&D opportunities.
Future steps from the R&D perspective, network flexibility, agility, and reliability are still open and need to be addressed in the context of 5G and upcoming 6G. Security in the context of cloud-native and Open RAN is another topic that will be considered in this context.
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<tr><td>FhG</td><td>
Along with IHP, the work of 5GENESIS (Berlin facility) is further exploited in 5G-VICTORI.
The main outcomes for FhG are:
<ul>
<li>Test and improve the interoperability of the Open5GCore with a wide range of radio technologies. Open5Gcore pdated to release the provision of the PCF with a legacy Rx reference point.</li>
<li>Modification of the PCF allowing for MCX services.</li>
<li>Integration with Keysight Hawkeye.</li>
<li>Operation of IHP’s nomadic 5G node.</li>
<li>Establish a geographically constrained, flexible and customized 5G network.</li>
<li>The implementation of 5QI, GBR and QoS Flows jointly investigated by KCC and FhG</li>
<li>Validation of the split rendering of high complex photorealistic 3D scenes on the Edge of the 5G Network</li>
</ul>
FhG will feed the know-how and outcomes from the 5G-VICTORI participation in the following directions:
<ul>
<li>Continuation of the operation of the FhG FOKUS fixed and nomadic 5G neetworks of the Berlin Platform for its use scientifically, and as a research and experimentation testbed in various research and development projects.</li>
<li>Continuation of the established partnership with IHP in future 6G actions (see section 3.2.5 for details).</li>
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| | • Usage of the Platform for further evaluation of 5G/beyond 5G/6G technologies developed internally for the migration to 6G networks in 6G-SANDBOX.<br>• Exploitation of the Platform to PhD and Master students for future research in collaboration with IHP's.<br><br>FhG is involved in different teaching activities at German universities, especially in the fields of advanced web technologies at Technical University of Berlin. Relevant UCs and project results are topics for current and future lectures. |
| I2CAT | The **main outcome** for i2CAT is the development of a RAN Controller and Slicer Manager for managing pop-up network slices with heterogeneous RAN. The network management **solution** combines the RAN Controller and Slice Manager technologies, which is able to provide end-to-end network slices in multi-RAT deployments, including 5G SA scenarios. The solution allows to deploy heterogeneous pop-up slices in less than 1 minute, including the configuration and orchestration of the RAN, the deployment and configuration of the 5G Core – supporting Multi-Operator Core Network (MOCN) – and S-NSSAI slicing scenarios, and the instantiation of isolated control and data plane functions. The innovation allows to simplify and automate the provision of heterogeneous network slices, including technologies like 4G, 5G NSA, 5G SA and Wi-Fi. Through the Slice Manager and RAN Controller, the end user is able to deploy a network slice by selecting the target radio access nodes, configuring them, and defining the service parameters. The solution is very relevant for NPN and Neutral-Host scenarios, allowing to reuse the infrastructure by enabling RAN sharing through MOCN and 5G slicing approaches.<br><br>The main novelty of this solution is that it joins the management of RAN, 5G Core and transport network slice subsets, providing a framework being able to deploy end-to-end 5G slices in a practical way and considering commercially available and open-source 5G software and hardware. In particular, within the scope of 5G-VICTORI the solution has been integrated with Amarisoft radio products, Wi-Fi 6 Linux-based Access Points and the Open5Gs open-source Core. The solution is compliant with 3GPP and NFV-MANO specifications regarding slicing, and uses the NETCONF protocol to configure the RAN nodes as specified by the O-RAN Alliance.<br><br>The **TRL achieved** is 6.<br><br>The concepts, results, and implementations of the solution have been **presented** in different conferences, journals and workshops and were well received.<br><br>Further, the solution was transferred to i2CAT's spin-off, NEUTROON, being part of its MVP (https://i2cat.net/neutroon-is-the-first-i2cat-spin-off-in-the-5g-field/). Also, it has fueled the incorporation of i2CAT in several international and national **R&D projects**; for instance, in recent SNS projects such as NANCY and BeGREEN.<br><br>**Future** possibilities regarding **technological exploitation** include integration with O-RAN based architectures (e.g., RICs, disaggregated |

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| | RAN) and incorporation of AI/ML mechanisms to enhance the provisioning of the network slices. **Market exploitation** of these opportunities will be pursued through license transfer agreements, as could be the case of the aforementioned spin-off, NEUTROON, which is currently working on integrating O-RAN and AI/ML in its products. Additional exploitation of the project results will come through the use of these results in subsequent R&D projects belonging to the phase 2 of the SNS program. |
| IASA | Through the 5G-VICTORI work, IASA has extended its know-how and experimental capabilities in 5G and Beyond systems. Through the project involvement, IASA was able to design, develop and evaluate a novel and open 5G architecture able to flexibly and efficiently support a large variety of verticals over independent and in some cases interconnected 5G platforms. In addition, through the project participation, IASA developed a 5G lab based experimentation test-bed integrating a variety of RAN and core networks with emphasis on open source solutions including OAI and Free5GC. The lab testbed also includes a multi-technology SDN controlled transport network. This experimentation has facilitated showcasing the proposed 5G architecture and performing detailed evaluation for a number of different UCs. The relevant results have been published in 5 international scientific journal articles and over 10 conference papers and presentations in various events. Part of this work has also provided a variety of contributions to the 5G-PPP White Paper, View on 5G Architecture Version 4.0, October 2021.<br><br>In addition, in the context of 5G-VICTORI, a fully operational 5G-enabled platform has been developed providing tools to monitor the condition of the railway track, analyse the collected data prescribe of optimal maintenance plans that can jointly optimise the payoff for the Infrastructure Managers and the Rail service providers. The main building blocks of this platform can be packaged and hosted in containerised environment and operate over the 5G-VICTORI infrastructure with the required QoS levels. The platform can be readily integrated in any 5G-enabled railway system using appropriate Application Programming Interfaces (APIs). The main components developed in support of the Hellenic Train UC (**UC #4**) that can be industrially exploited include:<br><br>- A 5G-enabled Data acquisition platform for track monitoring. The developed data acquisition system relies on a variety of sensors to monitor the status of the railway system. This includes vibration, acceleration, energy metering sensors and an industrial camera to take snapshots from the track. Features such as dynamic sampling rates, precise synchronisation of measurements collected across distributed channels and data acquisition platforms and, correlation of measurements coming from heterogeneous sources are natively supported by the 5G-VICTORI platform. This is achieved through the establishment of end-to-end slices providing sufficient network capacity to transfer the collected measurements from the platform installed on-board to the cloud-based data management system.<br>- A set of microservices providing Descriptive, Predictive and Prescriptive Analytics functionalities for the railway operators. |

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| | These services are responsible to provide diagnostic analytics in order to provide pointers to the exact locations where defects may exist, estimate the evolution of track defects over time and recommend a set of optimal maintenance plans that need to be performed. The operation of the overall system is orchestrated using the 5G-VICTORI orchestrator allowing the optimal sizing and placement of the microservices in the edge nodes.<br>The overall system offers significant advantages compared to existing systems as:<br>- It operates in the form of microservices resulting to lower owner and operational costs<br>- Has the Ability to inter-work with existing deployments using 5G open APIs<br>- Is fully customizable / reconfigurable solution.<br>- Offers very Fast deployment times.<br>- No "vendor lock-in": It can work with any component.<br>The system prototype has been already demonstrated in an operational environment as extensive field trials have been conducted in the Hellenic train network, **TRL 6-7**).<br>The platform has been already presented in the relevant industrial fora (International Congress and Workshop on Industrial AI and eMaintenance 2023, Luleå, Sweden) and special issues Intelligent Asset Management" in the International Journal of System Assurance Engineering and Management of Springer (in progress)<br>In the context of the activities above several PhD research students and a number of MSc students were trained and involved in the relevant research activities. Specifically, 3 PhD students were supported by 5G-VICTORI and on has graduated during the project lifetime.<br>The insights gained in 5G-VICTORI have created the bases for **new** industrial and academic research and created a new extended network of strategic collaborators. More specifically, during the 5G-VICTORI lifetime, **IASA** became a founding member and a stakeholder of the π-NET Competence Centre together with **UoP** and **ICOM**. π-NET focuses on 5G and beyond communications networks for the enhancement of vertical value chains, funded through the Business Programme "Competence–Entrepreneurship-Innovation 2014-2020" co-funded by Greek government and EC. Through this involvement IASA will collaborate and interact with the wide spectrum of the π-NET members and stakeholders including a number of ICT industry, SMEs and Academia as well as vertical industry players. Finally exploiting its activities and networking in 5G-VICTORI IASA has become the project and technical coordinator of the Horizon Europe project 5GTACTIC (Topic DIGITAL-ECCC-2022-CYBER-03-SEC-5G-INFR) and also participates in the consortium of 2 6G IA projects 6G SENSES (HORIZON-JU-SNS-2023-STREAM-B-01-02) and ECO-eNET (Topic: HORIZON-JU-SNS-2023-STREAM-B-01-03). |

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IHP has, in the framework of 5G-VICTORI, strengthened the 5G (RAN+Core) knowledge that originated in the former ICT-17 project 5GENESIS. The work carried out in the Berlin testbed and the acquisition of a carrier-grade 5G system for installation at IHP to perform the Berlin field trials, together with the partnership with FhG in deploying (nomadic) 5G systems, has enriched the expertise of IHP employees to an extent that future B5G or 6G developments built in-house can be integrated together with a 5G platform.
In this context, the 5G system deployed at IHP will serve for assessing different 5G deployments that could perfectly accommodate the latest technological IHP developments related to the development of novel mmWave and THz systems, integrated sensing and communication (ISAC), advanced MIMO systems, etc. The expertise gained in the project in analysing and assessing the requirements and demands from the verticals can ease the participation of IHP in actions that have also to do with the evaluation of future services in such infrastructure.
Additionally, IHP has expanded the portfolio of mmWave modules and circuits, with additional expertise in dealing with COTS systems for their operation in in vertical constrained environments with harsh operating conditions. Skills have been gained in analysing their disadvantages in terms of accessibility, flexibility, etc., which allows IHP building up improved systems to those developed in the framework of the 5G-PICTURE project, that are being now revised for use in 6G initiatives, featuring ISAC, high data rates and featuring enhanced beam steering/tracking capabilities.
In summary, IHP will feed the know-how and outcomes from the 5G-VICTORI participation in the following directions:
<ul>
<li>Continuation of the operation of the IHP site of the Berlin Platform for its use scientifically, and as a research and experimentation testbed in various research and development projects.</li>
<li>Continuation of the established partnership with Fraunhofer FOKUS in future 6G actions.</li>
<li>Usage of the Platform for further evaluation of 5G/beyond 5G/6G technologies developed internally for the migration to 6G networks with IHP novel mmWave/THz/photonic developments.</li>
<li>Exploitation of the Platform to PhD and Master students for future research in collaboration with IHP’s joint labs: Humboldt University, University of Cottbus, Technical University of Berlin, etc.</li>
</ul>
The work carried out in the (3GPP) 5G front, IHP is participating in one SNS Phase-1 project (BeGREEN), and in the Horizon Europe COREnext project, as well as in an SNS Phase-2 project starting in 2024 -6G SENSES (HORIZON-JU-SNS-2023-STREAM-B-01-02). In addition, IHP is involved in several German 6G initiatives (6G-CAMPUS, Open6GHub, 6G-RIC, 6G-Takeoff, GreenICT). This involvement ensures the usability of the 5G platform and the nomadic version for integration of 6G technologies.
</td>
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| | |
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| IZT | The main outcome for IZT is method advancement and gained know-how in combining our expertise in sustainable development and sustainability assessments with a focus on 5G and beyond technology.<br><br>Including sustainability aspects in business modelling is essential today in order to create viable future-oriented business, given customer demands, but also the compliance with official guidelines. Regarding business modelling in the 5G ecosystem context no tools focusing on how to integrate sustainability in this particular context were available. **To address this problem**, IZT together with UXBerlin developed a generic process model containing sustainable business modelling tools adapted to fit the 5G technology and ecosystem context. These tools were applied in various workshops with partners of the Consortium, to aid them in finding suitable business models and becoming aware of, shaping, and working towards realising the sustainability potentials of their services.<br><br>The solution developed and the insights generated were also **presented** to the wider community through engagement in the 5G-PPP Working Group BVME Sub-Group, shaping the discourse on business modelling towards sustainability beyond 5G-VICTORI and contributing to two white papers: “5G Ecosystems” and “5G and Beyond 5G Ecosystem Business Modelling”.<br><br>**Further outcomes** for IZT were the application of tools for social and environmental sustainability assessment to the 5G technology and ecosystem context, both to specific use cases and services as well as to wider upscaled developments. Methodologies used, such as scenario methodology, are documented in the deliverables and can provide insights on further integrating sustainability dimensions into assessment of 5G and 6G technological developments for the larger community as well as for public stakeholders. This provides an approach towards addressing the problem of taking sustainability into account in the development of new technologies as early as possible and gaining a systematic overview over potentials and risks and resulting implications for how the respective technological development should be shaped.<br><br>In terms of **joint exploitation**, the creation and application of sustainability-focused business modelling tools was done with participation of various partners, in particular with UHA, COSM, Orange, ORO, ADMIE, UoP, ICOM, TRA, **DCAT**. Through the documentation from the workshops as well as the generic process model, all partners can further exploit the tools by applying them to business modelling processes and developing them further to fit their specific needs |
| UNIVBRIS | The **main outcomes** from UNIVBRIS engagement in 5G-VICTORI are:<br>1. Collaboration with **DCAT** on designing and developing various components of 5G-VIOS such as Monitoring and Profiling at the domain level as well as the cross-domain level.<br>    o More precisely, the design and development of a method for predicting the optimum configuration of resources using |

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| | ML techniques embedded into the Profiling component of 5G-VIOS<br>2. Design and development of the "5G-UK Measurement and Monitoring tool", using open source solutions.<br>3. Providing an E2E monitoring of NSs and infrastructure and UEs at the edge level which gathers data from the "5G-UK Measurement and Monitoring tool, i2CAT Slice Management Monitoring, Zeetta Automate monitoring Elastic Search, as well as the Application NSs through Nomadic node and storing them at the Edge Monitoring's Elastic search automatically utilising Metricbeat solution.<br>4. Creating a concept for a Nomadic Node based on multi-access technologies for moving vessels to support the seamless connectivity and mobility of users while walking or on boat.<br>5. Leading Bristol cluster partners to demonstrate the Digital Mobility UC including its 3 applications; **MATI** App1, MATI App2, and UHA App3 at Bristol.<br>6. Collaborate with 5G-VICTORI partners to demonstrate the Digital Mobility use case across 5G-VICTORI clusters and setting up the inter-cluster connectivity among clusters including Berlin-Bristol and Patras-Bristol.<br>The results were **published** in six papers (for details see D5.3 on Dissemination).<br>**UNIVBRIS** has also contributed to the 5G-PPP White Paper, View on 5G Architecture Version 4.0, October 2021 (especially the chapter 2.6.4; E2E network architecture extension for digital mobility).<br>The insights gained in 5G-VICTORI have created the bases for **new** industrial and academic **research**. During 5G-VICTORI there was close collaboration with Bristol partners: **i2CAT**, **DCAT** and **Zeetta** on integrating their solutions into the 5GUK test bed to demonstrate Digital Mobility Use case**.** Also, the impact of this research has moved on towards **joint projects** with other partners from 5G-VICTORI such as **DCAT** on the intelligent orchestration of network services across multi domains.<br>The **UNIVBRIS**' 5GUK test bed is a multi-site network connected through a 10 km fibre with several active switching nodes, enabling collaboration in engaging 5G/6G community to cooperate in future Horizon Europe. |
| **UoP** | The **main outcome** for **UoP** is the development of SA private 5G network solutions with various 5G core implementations and backhaul alternatives for vertical industries.<br>Further important outcomes include:<br>- Co-design and co-development of vertical industry 5G enabled services.<br>- Extension of the Patras 5G architecture to include 5G -VICTORI architecture elements.<br>- Extension of the Patras 5G facility to various vertical facility sites. |

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| | The **problem** addressed is that for 5G networks to support businesses utilised to full potential in vertical industries (in the area of Energy, Transport and Media) private networks that fulfil stringent requirements are needed. **Jointly** with the partners from the Greek cluster **UoP** has developed private network solutions combined with various backhaul alternatives, which enabled experimentation at large scale with various applications and 5G enabling technologies like, slicing, optimised MEC placement and optimised of data/control plane core function placement.<br><br>The **TRL achieved** is 6.<br><br>The outcomes were **presented** at conferences and a video was created.<br><br>From the collaboration in the 5G-VICTORI the Competence Centre π-net was created. |
| **UTH** | The main outcomes for **UTH** from the participation in 5G-VICTORI are:<br>• The design and development of a mobility management mechanism applied to a Rail UC (**UC #1.1**) for providing eMBB operational and business services.<br>• The design and implementation of an onboard network architecture for **UC #1.1**.<br>• Validation of a disaggregated RAN implementation deployed onboard.<br><br>UTH has developed a technology agnostic mobility management solution and demonstrated it in a realistic operational environment in the premises of **TRA** in Patras, where we showcased seamless handovers between mmWave (provided by **IHP**) and Sub-6GHz wireless technologies as the train was moving while satisfying the KPIs set by the services with respect to throughput, latency and availability. Furthermore, a 5G RAN SA was deployed on the train proving high-speed access to passengers supporting at the same time operational services such as MCPTT and real-time track monitoring. The whole solution was integrated with the rest of the infrastructure provided by **UoP**, **ICOM** and **TRA** for the backhaul network and cloud.<br><br>The work on mobility management has been published and received a runners up paper award (second place) in IEEE 5G for CAM 2021.<br><br>The **TRL** achieved is **6**.<br><br>UTH has strengthened the knowledge acquired from previous projects such as 5G-PICTURE with respect to software-based implementations of disaggregated 5G-RAN and Core, based on OAI and applied it to the 5G-VICTORI rail UC. The deployment used in the Patras field trials and the collaboration with the rest of the partners involved, namely **UoP**, **IHP**, **ICOM**, **COSM**, **KCC** and **TRA** (Hellenic Trains) has advanced the knowledge of UTH researchers and their expertise that will be exploited in future B5G and 6G projects.<br><br>**UTH** and the Department of Electrical and Computer Engineering will exploit 5G-VICTORI outcomes for providing hands-on experience to graduate students, since significant development and experimentation |

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| | work related to the orchestration and implementation of NFV-based 5G RAN and mobility management functions takes place at NITOS UTH testbed. Researchers and students will be educated through research conducted along the lines of 5G-VICTORI in the form of theses, fellowships or research internships in industrial or other academic partners. The knowledge and experience acquired by students will provide them with better job opportunities and will be the driving force for distilling know-how to industry. |

### 3.5 Innovation radar

**Table 3-5 5G-VICTORI Innovations identified by the Innovation Radar**

| Partners | Title of Innovation |
|---|---|
| **ADMIE**, **UoP**, **ICOM** | *End-to-End portable 5G platform for Industry 4.0 applications* |
| **COSM**, **UTH**, **ICOM** | *Multi-level virtualised CDN (Content Delivery Networks) solution for uninterrupted VoD (Video on Demand) and near-live up-to-date video content streaming services* |
| **DBN** | *FRMCS* |
| **EUR**, **ORO**, **Orange** | *Cloud-Native Open Source 5G Platform for vertical Market validation* |
| **FhG**, **IHP**, **PXI** | *Media-streaming pipeline utilizing multi-CDN (Content Delivery Networks) over 5G connectivity* |
| **UHA** | *Smarter mobility fused to real-time travel insurance* |

The Innovations shared at the end of the reporting Period (updates) are presented in Table 3-6:

**Table 3-6 5G-VICTORI Innovations at the end of the Project**

| SUMMARY OF PROJECT INNOVATIONS | |
|---|---|
| **1** | Unified portable solution for on-demand 5G private network and Industry 4.0 services provision (**ADMIE**) |
| **2** | Multi-level virtualised CDN solution for uninterrupted VoD and near-live up-to-date video content streaming services on railway environments (**ICOM**) |
| **3** | Immersive Application for mobile devices for the presentation of immersive AR/VR content services to train passengers arriving at train station (**MATI**) |
| **4** | Simplified and automated reconfiguration of, multiple, network switching devices across multiple domains for the management of layer 2 connectivity requirements (**Zeetta**) |
| **5** | Cloud-Native Open Source 5G Platform for vertical Market validation (**Orange**) |

| | |
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| **6** | Local caching of media services for continuous, cost saving and energy efficient media provision on trains (**RBB**) |
| **7** | RAN Controller and Slicer Manager for managing pop-up network slices with heterogeneous RAN (**i2CAT**) |
| **8** | An inter-domain service orchestration platform for automating future networks (**DCAT**) |
| **9** | Nomadic Node in support of delivering seamless connectivity and mobility of the services (**UNIVBRIS**) |
| **10** | A Novel Autonomous Profiling Method for the NFV Orchestrators (**UNIVBRIS**) |

# 4 Impact assessment

## 4.1 Approach impact assessment

As defined in the GA, the impact assessment has the goal of upscaling the project results to the national and the EU level. Overall, it is meant to cover economic, environmental, social and innovation aspects. It is also meant to identify contributions to SDGs and to include an assessment of the sustainability performance of 5G infrastructures [23]. All three pillars or dimensions of sustainability that lie at the base of the SDGs, environmental sustainability, social sustainability and economic sustainability (see Figure 4-1) [28] [29], are to be considered.

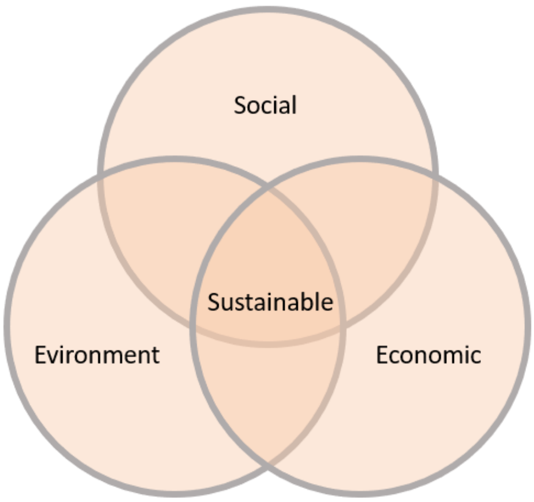



**Figure 4-1 The three pillars of sustainability**

As discussed in the introduction of this deliverable, all parts of this deliverable focus on some aspect of the impact the work within 5G-VICTORI had and is expected to have. Technological, innovation and economic results and expected impacts are discussed in the sections on exploitation and business modelling (sections 2 3). These are the direct impacts of the work that has been done in 5G-VICTORI.

In this section the focus differs in two ways: firstly, we focus on the environmental and social aspects, looking at the impact from the perspective of the SDGs. Secondly, we look at the upscaled impact of the project. This means we look at what impact on social and environmental factors can be expected in the hypothetical scenario of scaling up the work done in 5G-VICTORI to the national and EU level. Given that both the UC and the infrastructure elements are not yet deployed at scale, there are not yet any actual environmental and social impacts that can be assessed. What is assessed are therefore future potentials.

Put in terms of concrete steps of the analysis, we first analyse scenarios regarding the likely future impact of 5G infrastructure and services in general, though focusing on a subset of verticals and services that are close to the ones forming part of 5G-VICTORI. After studying the likely impact of these scenarios on SDGs we turn back to 5G-VICTORI and apply the analysis to the achievements of the project, discussing how they contribute to which scenario.

A method to analyse future potentials and possible impacts is scenario methodology. This is a well-known tool set, applied frequently in future studies. We apply this method to analyse potential impacts of upscaled 5G-VICTORI results on the social and environmental dimension. Roughly sketched, the method consists of constructing different future scenarios based on existing research, expert insights, literature on mega trends and future visions created by relevant stakeholders. Scenarios are created for the year 2030. We analyse two scenarios, one “**baseline scenario**” and one “**SDG advancing scenario**”. In both scenarios, 5G infrastructure and services are further deployed, yet they differ with regards to how much they contribute to advancing the SDGs. By comparing the different scenarios and analysing which factors are particularly relevant for a scenario to be realised, insights on how different factors interact and what courses of action could lead to which scenario can be gained. More details on the methodological approach are given below in section 3.2.

Technological developments related to 5G impact sustainability in two ways. On the one hand, they enable a range of UCs and services that have the potential of increasing sustainability, e.g. through increasing resource efficiency, making it possible to save energy or enhancing social wellbeing. This is sometimes referred to as indirect effects [15] [30] we term this “5G for sustainability”. On the other hand, technological innovation can also change the resource and or energy requirements directly, e.g. through requiring more hardware, consuming more energy or enabling more energy efficient production or operation. We refer to this as “sustainable 5G”. In the impact assessment we look at both aspects, since both need to be assessed and balanced in order to provide a sustainability assessment.

The impact assessment accordingly consists of two components. The first component focuses on sustainable 5G, i.e. on the infrastructure. KFs that shape future scenarios and capture sustainability of 5G infrastructures, mainly energy consumption and resource usage both in the production as well as in the usage phase, are identified. There are other aspects related to sustainable 5G, such as the impact of end user devices, however we do not look at these but focus instead on the direct 5G infrastructure. As described above the stated goal of the IA is to scale up to the national and EU level, but the infrastructure elements developed in 5G-VICTORI are not (yet) deployed at that scale. For this reason, we look at sustainability aspects of 5G infrastructure in general. This has the further advantage that we can draw directly on existing research and insights from project external experts. From the impact assessment based on general 5G infrastructure we identify the aspects that are most relevant for the work done in 5G-VICTORI. Most sustainability implications of 5G infrastructures refer to environmental sustainability, yet social sustainability is also considered. Such as potential implications for working conditions in hardware production or societal acceptance.

The second component is the part on 5G for sustainability. Here the focus is on the UCs and services developed in 5G-VICTORI. However, as mentioned above what can be assessed here given the TRL and stage of deployment is future potentials. Accordingly, we look at the potentials of UCs and series based on what was developed during 5G-VICTORI scale up to the general UCs areas/verticals and a national and EU level. With regards to 5G for sustainability both the social and the environmental dimension are important. The services are created to provide value to and enhance the experience of end users (professional or private), which can already constitute a positive social sustainability aspect. Beyond this, services can also have implications on third parties or societal aspects more generally and thus have the potential to benefit social sustainability goals (as formulated in the SDGs). This holds similarly for environmental sustainability: services can enhance processes, can make them less energy- and/or resource intense or they can enable business as well as private end users to act in more resource and/or energy efficient ways, which furthers the EU and the SDGs. Services can also lead to unintended behaviours of the end users or third parties, which may have either positive or negative environmental or social implications, an example here are rebound effects, such as an overall increase in energy usage due to more efficient energy use leading to lower prices leading to intensified usage. To the extent possible, these implications will also be considered.

## 4.2 Scenario methodology

### 4.2.1 Basics of scenario methodology

Scenario methodology stems from future studies and encompasses a broad set of approaches all of which aim at gaining some type of insight regarding future developments. Depending on their purpose and the available data basis scenarios can capture quite different levels of detail and be more or less quantitative. On a general level, a scenario can be described as a projection of the future, which also considers the different factors that lead to this projection [31]. Using such scenarios, consequences and strategic implications for actions and planning in the present can be identified and formulated. Scenario methods differ from trend forecasts, in that they do not (only) extrapolate from current trends, but they are open to all kinds of changes and possible shifts. It is also important to state that scenarios describe possible, plausible futures but do not constitute predictions. Typically, multiple scenarios are constructed and compared, where one of these can be a trend scenario, i.e. a scenario based primarily on current trends [31].

Scenarios can have different goals. Part of the goal of T5.3 is to assess the impact of the 5G-VICTORI project. As described in section 1, this is done in two ways: firstly, the specific outputs, results, and immediate consequences of 5G-VICTORI are assessed – this is done in the section on exploitation and business modelling. Secondly, and this is the focus of this section, we focus on the broader, less immediate impacts and potentials for impact. In particular, the potential impacts on societal and environmental sustainability goals are assessed. Since these broader, longer term impacts of 5G-VICTORI depend primarily on how outputs of 5G-VICTORI may be scaled up and how they interact with the broader context and frameworks, we go beyond examining at the immediate 5G-VICTORI project outputs and examine the impact of 5G technologies more broadly and then situating the contributions of 5G-VICTORI within these broader potentials.

The use of scenario methodologies can contribute to working towards different types of goals and can fulfill different functions [31]. Here employing scenarios serves an explorative function and a strategy or policy recommendation function. With respect to the former, constructing scenarios, as done below, can help to systematically explore what societal and environmental impacts are possible with respect to 5G infrastructure deployment and service and application development similar to what has been worked on in 5G-VICTORI. Identifying KFs that shape the scenarios, their possible development paths and how they interact can help to get a systematic overview of what path leads to which scenario and what risks and uncertainties exist. The second, and related, function describes opportunities to shape the impacts to be in line with societal goals (as formulated in the SDGs, see Figure 4-1). By working "backward" from the different scenarios, indications on what decisions will lead to which impacts can be gained. The systematic overview over KFs that are likely to shape the scenarios and possible consistent scenarios also helps in making informed decisions. It is important to repeat that scenarios are not forecasts. Scenarios are projections of potential futures, which can point to important factors and interdependencies of different aspects that need to be considered.

In this deliverable we construct two exemplary scenarios and compare these with respect to how strongly they further and are in line with the SDGs. From this we distil policy recommendation to realise aspects of the scenario that contributes to sustainability.


**Figure 4-2 The 17 SDGs (for sub-targets see Table 4-4)**

As stated above, scenario methodology describes a broad set of approaches. Nevertheless, several general criteria for a good application of scenario methodology can be identified:

- Plausibility: the described developments need to be realistic.
- Consistency: the developments and KF values within a scenario need to be consistent and not contradictory.
- Comprehensibility: The described developments and scenarios need to be comprehensible.
- Discriminating: the selected alternative scenarios need to be sufficiently different.
- Transparency: the assumptions made and decisions taken in the process of generating the scenario need to be explicitly and clearly stated.
- Integration: the possible interactions between different developments on different levels should be taken into account.

We do our best in presenting both the steps in constructing the scenarios as well as the scenarios themselves in a plausible, comprehensible and transparent way. We put a particular focus on examining interdependencies of the KFs that jointly shape the scenarios and ensuring their consistency, applying a tool that makes it possible to also capture indirect effects of KFs on each other. Through comparing an SDG advancing scenario to a baseline scenario the selected scenarios are sufficiently different. Note that they do not (necessarily) differ in the degree to which 5G infrastructure and services are deployed and utilised.

### 4.2.2 Details of scenario methodology

The specific scenario technique used for the impact assessment in Task 5.3 is a systematic-formalised scenario technique. This can be distinguished from scenario techniques based on trend extrapolation. The latter generates scenarios by extrapolation from existing trends and is very useful for providing insights about probable long-term developments of relatively stable factors. However, limitations are firstly the assumption of a continuous future and secondly the lack of looking at the complex interactions between different factors. We therefore apply a systematic-formalised scenario technique. Specifically, we use a form of cross impact analysis, cross impact balance (CIB) analysis, which focuses on capturing interactions between KFs and which scenarios are how consistent given these interactions. This contributes an integrative perspective, making it possible to capture interdependencies between different factors as well as different dimensions.

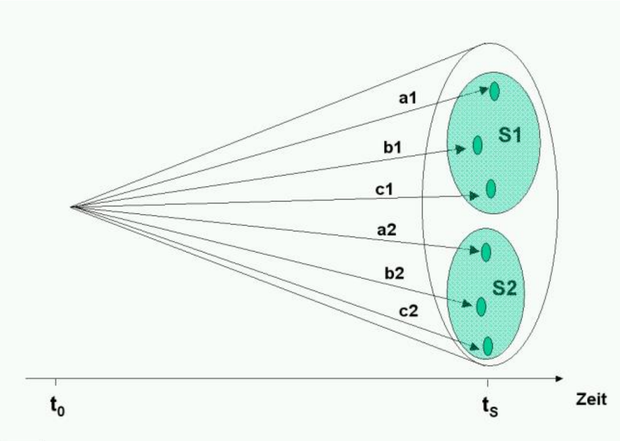



**Figure 4-3 The scenario funnel [31]**

Figure 4-3 shows the scenario funnel and gives an overview over the essential aspects of scenario analysis: from the present point in time (t0) possible scenarios (S1 and S2) in a defined future time point (t1) are identified. The scenarios are generated by defining KFs that shape the future developments one is examining (a, b, c) and their different possible values (a1 & a2, b1 & b2, c1 & c2).

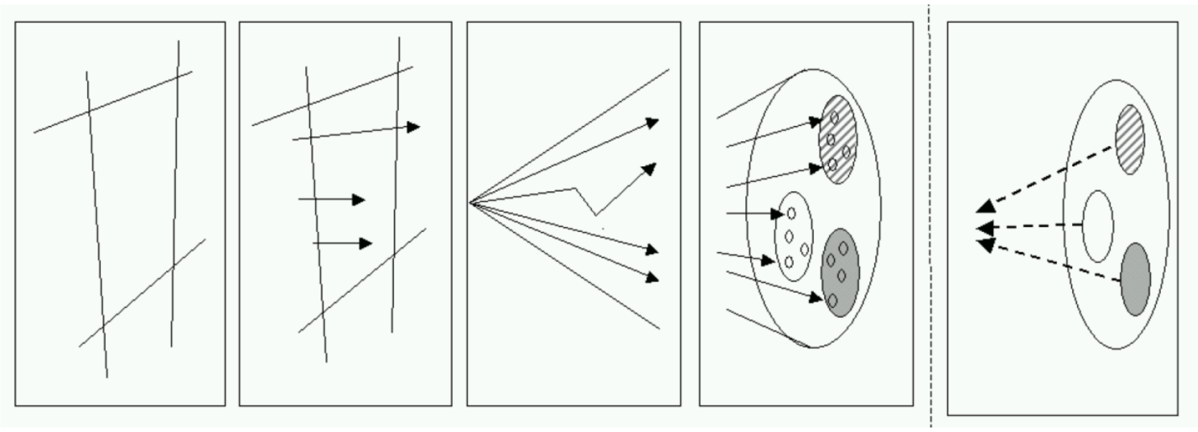


Figure 4-4 The steps of scenario methodology [31]

Scenario methodology generally consists of four steps, with a fifth (optional) step being the transfer of insights from the scenarios: 1) Definition of the scenario field, 2) Identification of KFs, 3) Analysis of KFs, 4) Generation of scenarios, 5) Transfer of scenario insights.

**Step 1: Definition of the scenario field**

In this phase the scope of the scenarios is delimited and what the focus of the scenarios is and what range of factors will be considered is decided on and made explicit.

**Step 2: Identification of KFs**

Here important variables, parameters, developments and events that are judged to be central to the scenarios are identified and described, on the basis of empirical and theoretical research. In the application of the scenario method in this deliverable the KFs that shape the scenarios are identified by using the following sources:

- The UC assessment (T3.4, documented in deliverable D3.7 [1]), specifically the environmental and social dimension.
- Previous research and literature reviews regarding the environmental and social sustainability potentials of 5G.
- Future visions including digital services and 5G by diverse stakeholders at national and EU levels.
- Mega trends (broad future trends which are likely in the medium term such as electrification) discussed in the literature.
- Expert interviews (project internal and external experts).

The GA states that the impact assessment is to be done on the basis of high level KPIs. However, we look instead at KFs that shape the scenarios. This is due because what we assess is the future potentials and the contribution of work within 5G-VICTORI to these future potentials. Since it is about future developments, no performance indicators are available. Instead we identify KFs, as is common in scenario analysis, which are different than KPIs in that they do not have a predefined value but are identified as important factors which shape the potential scenarios. Part of the scenario analysis is to see how they influence different scenarios and each other, and then to assess how the developments within 5G-VICTORI fit with these developments. Later on, after having the generated the scenarios and deriving insights and implications for action from that they could in principle provide the basis for identifying (high level) KPIs. The KFs that shape the scenarios should therefore not but confused with KPIs or with actual market developments. They are variables that are likely to shape the scenarios, i.e. future developments.

**Step 3: Analysis of the KFs**

The KFs identified in step two are analyzed with respect to their different possible developments, i.e. a range of different values for the factors is identified. As described above we also look at the interaction between KFs and use CIB to analyse which scenarios are consistent. The details of the CIB procedure and the software used are described below in section 4.3.3. The KF analysis uses the same sources as described in step 2.

**Step 4: Generation of scenarios**

From the range of developments and values of the different KFs several consistent and for the purpose adequate scenarios are constructed. The reasons for and the logic behind the scenarios constructed are explicitly stated. Two of the set of consistent scenarios are selected for comparison. Given that the dimensions on which the impact analysis of future potentials is to be done are environmental and social sustainability, we select scenarios that both expand the deployment and usage of 5G infrastructures and services, but that differ substantially in terms of consequences on these dimensions, one SDG-advancing scenario and one baseline scenario.

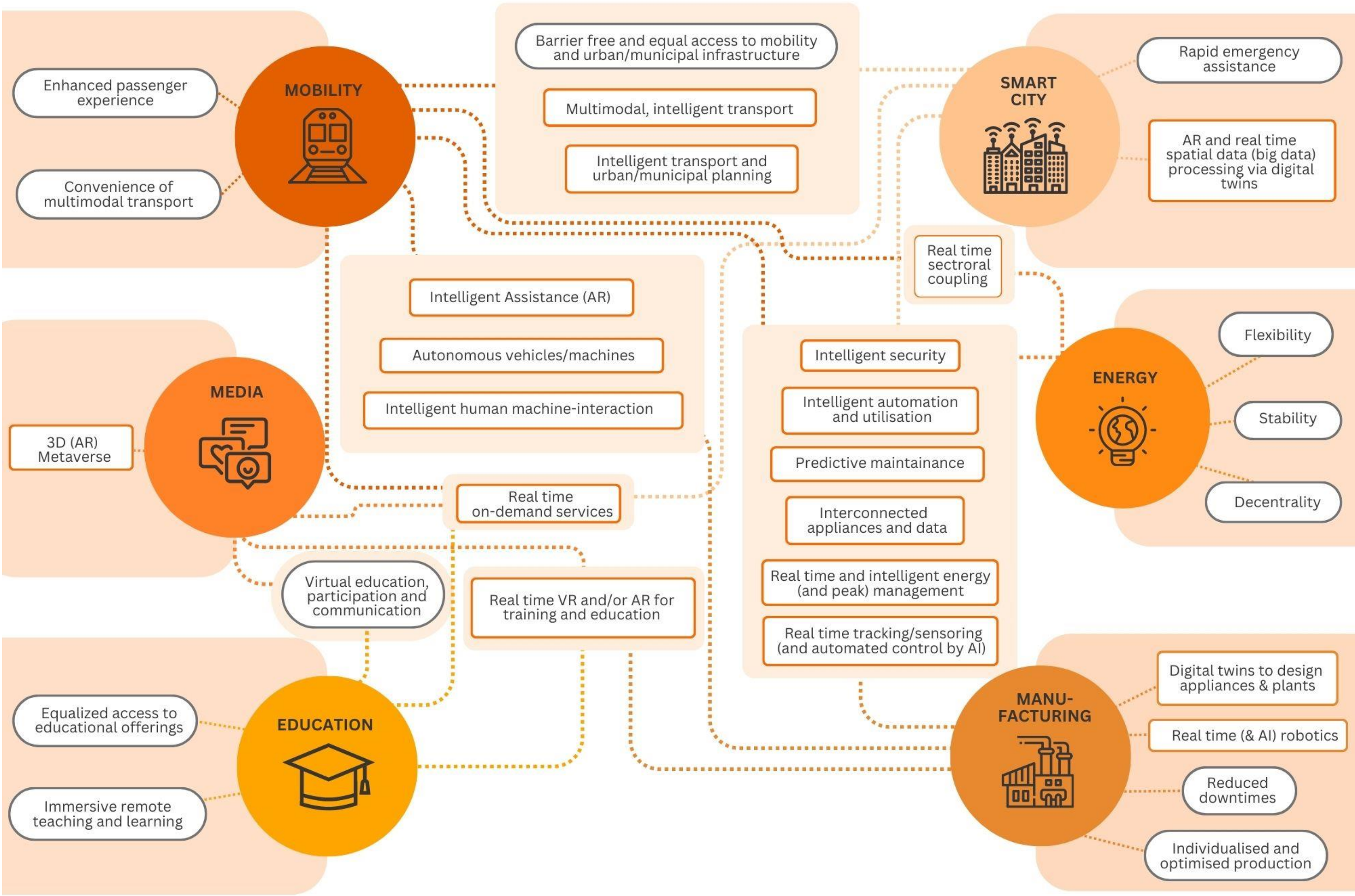
## 4.3 Scenario analysis

### 4.3.1 Step 1: Definition of the scenario field

An important part of the definition of the scenario field is given by the GA: the focus is on the social and environmental impact. We look at aspects of the infrastructure as well as at services. With regard to the services we start from those verticals that are part of 5G-VICTORI and from the UCs and services developed in the project. Accordingly, the verticals are: Factories of the Future (manufacturing), Energy, Mobility, Media and Entertainment. Since Education and Smart City are also touched upon by the 5G-VICTORI UCs we also include these. The focus is then broadened somewhat to take in to account future visions for these verticals from multiple stakeholders in different countries and on the level of the EU (see 7.3). For an overview of the verticals and related services and functionalities (squares) considered, as well as several value propositions (grey ovals) see Figure 4-5.

The geographical scope is the national level (with a special focus on those countries who are part of the project) and the EU level. We do not break down the impact by different countries, but rather look at how the deployment of 5G infrastructure and services at the level of a generic EU country can contribute to advancing the SDGs.

With respect to the temporal scope there is no frame given by the GA. We define 2030 as the temporal location of the scenarios. The reason for this is that it fits the cycle of mobile network generations – 6G is already being developed and deployment should be under way in 2030.



MOBILITY
Enhanced passenger experience
Convenience of multimodal transport
Barrier free and equal access to mobility and urban/municipal infrastructure
Multimodal, intelligent transport
Intelligent transport and urban/municipal planning
SMART CITY
Rapid emergency assistance
AR and real time spatial data (big data) processing via digital twins
Real time sectroral coupling
Intelligent Assistance (AR)
Autonomous vehicles/machines
Intelligent human machine-interaction
MEDIA
3D (AR) Metaverse
Real time on-demand services
Intelligent security
Intelligent automation and utilisation
Predictive maintainance
Interconnected appliances and data
Real time and intelligent energy (and peak) management
Real time tracking/sensoring (and automated control by AI)
ENERGY
Flexibility
Stability
Decentrality
Virtual education, participation and communication
Real time VR and/or AR for training and education
EDUCATION
Equalized access to educational offerings
Immersive remote teaching and learning
MANU-FACTURING
Digital twins to design appliances & plants
Real time (& AI) robotics
Reduced downtimes
Individualised and optimised production

### 4.3.2 Step 2: Identification of KFs

KFs fall into two categories: infrastructure KFs, i.e. KFs that shape infrastructure aspects and sustainability performance, and service KFs, i.e. KFs that shape service aspects and the sustainability performance of services. Building on the sources described in section 4.2.2, previous work in Task 3.4 and based on interviews with project internal and project external experts the following 15 KFs were identified.

**Table 4-1 Key Factors (KFs)**

| No | KF Title and Description |
|---|---|
| A | **"Demanded data rate and data volume"**<br>While the development of the relative energy demand (e.g. watts per unit of data transmitted) is decreasing, the demanded data rate and volume has increased and is likely to increase further with the development progress of telecommunication technologies. 5G technologies (channel bandwidths, MIMO, modulation methods, etc.) enable significantly higher mobile data rates and volume. On the demand side, functionalities and applications that require high volumes of data to be transmitted at high data rates, such as mobile streaming applications are increasing. With the higher data rates and volume, the computing effort of the analogue-to-digital conversion and the digital signal processing in the baseband unit also increases, with effects on the energy demand. Energy efficiency gains can only partly compensate for the increase in the demanded data rate and data volume. [15] [64] [65] [66] [67] [68]. |
| B | **"Energy required by CN (TCN)"**<br>The (transport and) core network ((T)CN) consists of optical network units, switches, wireless transport network units, router/gateways and core network server units. In the midterm, an increasing mobile data volume may lead to an increase in energy demand of this optical aggregation and transport networks, via which the data traffic is distributed. This applies in particular if mmWave technology is used, since, the higher data volume, the TCN share of the overall energy required is substantially higher. It also depends on the number of antenna locations that are connected to the 5G-System via microwave transmission/radio relay instead of fibre optics. [15] |
| C | **"Number of antenna locations"**<br>An increase in the number of antenna sites of the public telecommunication network, results in reduced energy consumption for each individual antenna, as the transmission power amplifiers (essentially determining the site range) contribute the most to the overall energy consumption and respective transmission power can be significantly reduced in the case of additional installations. The increased use of resources for the additional hardware (i.e. of the additional antenna sites) is coupled with additional energy consumption, but this may not offset the savings from the reduction of energy required by the power amplifier. [15] |
| D | **"Technology modernisation"**<br>Technology modernisation describes the replacement of system components (in the RAN and the TCN) with newer modernised ones. Newer hardware increases energy efficiency, mostly through miniaturisation in the semiconductor industry. Beyond improving energy efficiency there are additional gains from energy saving components through reduction of conversion losses in the power supply. A high rate of technology modernisation leads to a slower increase of the energy requirement of the RAN and leads to an almost constant energy requirement of the TCN, since here technology modernisation has a large leverage by increasing the energy efficiency of computing and routing tasks. A high rate of technology modernisation implies a frequent |

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| | replacement of hardware components thus increasing resource demands and energy demands in the production phase. This has to be balanced against the gains in the operation phase. [15] |
| E | **"Energy management"**<br>Load-adaptive energy management including deliberate switching off of selected transceivers and other infrastructure components during specific, known or predicted time intervals with zero load can significantly reduce the energy consumption in the RAN. Energy management potentials are increased through 5G enabled VNF and SDN. [15] |
| F | **"Energy required by RAN"**<br>The radio access network (RAN) consists of antenna units, radio units (including transceivers), baseband units, cables, mounting and racks. The RAN accounts for a substantially larger share of the total energy demand than the TCN (more than 80% in Germany in 2019). The power amplifiers of the radio units (RU) generate particularly high energy losses. These increase at higher frequencies. Conventional power amplifiers are also optimised for fixed operating points and are hardly load-adaptive. Though somewhat lower, the Baseband Units (BU) also account for a substantial share in energy consumption, via the computing effort of the analogue-to-digital conversion and the digital signal processing, as do conversion losses of the AC/DC power supplies. The energy required by the BU increases disproportionately if mmWave technology is used at the RAN segment, because the analogue to digital conversion requires considerably more energy due to the increased data volume. [15] |
| I | **"Campus Networks implementation"**<br>A campus network (NPN) is an exclusive mobile network that provides 5G network services to a clearly defined user group or organisation, such as factory premises, a university or other (temporary) location. Through isolation from other networks, such networks can guarantee high QoS, can fulfil security and privacy requirements and are protected against malfunctions in public mobile networks. There are different categories (1) purely private, isolated campus networks and (2) private networks based on slicing, with control plane provided by public networks. Purely private campus networks (1) function completely separately from the public mobile network: all components of the infrastructure from the antennas to the core network to the network server are located locally on the customer's premises. In the second case (2), some components are shared between public and private network domains, e.g. the RAN, the data plane functions (UPFs) can be private or shared, the control plane functions can belong to the public network etc. |
| J | **"mmWave implementation"**<br>The mm-wave spectrum with frequencies above 24 GHz and bandwidths above 100 MHz (FR2) allows very high data rates, but has an increasingly shorter range (up to a few 100 m). This range depends on antenna design, transmission power and environmental factors such as weather, vegetation or buildings. The high frequency results in correspondingly small dimensions of the antenna elements, which enable the design of active, phase-controlled antenna arrays. Antenna arrays can be constructed from several sub-arrays and these from dozens of antenna elements (Massive MIMO, Beamforming).<br>mmWave is energy efficient, in that it provides greater data rates at lesser energy, i.e. less energy per bit is required. However, considering the incorporation of mmWave at the RAN segment, due to the fact that mmWave enables serving higher total traffic volumes the overall energy demand increases. Considering the additional energy |

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| | demand of the transport network segments and the additional processing requirements of the core network segments. In addition, there is a massively increasing energy demand of digital signal processing in the radio access network segment due to the high realisable data rates and volumes. With higher frequencies, the efficiency of the amplifiers decreases and the power loss increases. A reduction in energy consumption can be achieved through greater modernisation of technology. With new semiconductor technologies based on mostly supply-critical materials such as gallium, germanium, indium, etc., this energetically negative effect is to be compensated. The design and operation of the power amplifiers is a decisive factor for the energy requirement, especially for mmWave technology [15]. |
| K | **“Digital divide / accessibility”**<br>Three types of digital divide can be classified: (i) the access divide, which refers to the unequal distribution of physical access to digital technology and the internet, (ii) the quality divide, which refers to varying levels of technological infrastructure, including internet speed and reliability and (iii) the usage divide, which refers to differences in the extent of technology use, such as disparities in online activities and skills. These three types of digital divide exacerbate existing social inequalities and create new forms of disadvantage for marginalised groups [32]. One important dimension on which there is a digital divide is rural vs. urban. The status of 5G deployment in rural areas varies: Due to the cost and infrastructure requirements of deploying 5G networks, it may be more challenging and take longer to roll out 5G in rural areas compared to more urban areas, requirements and costs may depend on population density, terrain, and existing infrastructure [55]. Rural areas differ in several factors such as population density and terrain and deploying 5G in rural areas may have different requirements, such as using smaller cells or different spectrum bands. It is the EU Commission’s ambition that by 2030 all European households will be covered by a Gigabit network, with all populated areas covered by 5G [32]. Beyond equality of infrastructure, there are 5G services that hold particular potential to increase quality of life in rural areas, some of which are transferable from urban usage, while others need to be geared specifically towards rural usage [56]. |
| L | **“Societal acceptance (radiation / health focused)”**<br>Parts of the EU population as well as international scientists and medical professionals repeatedly express their concerns towards 5G related radiation and health concerns [57] [58]. Health effects of radiation caused by mobile networks are topic of ongoing research activities.<br>Independently of scientific evidence, as with previous cellular network generations, fears and narratives around radiation and 5G are present in parts of the population. In Germany, for example, a third of the population states that there is too much radiation exposure [59]; 43% oppose the installation of further antennae and state that they would protest planned antennae close to their home [60]. Since the onset of the COVID-19 pandemic, despite lacking any scientific evidence, rumours around relations between the virus and 5G have circulated in parts of the population [61]. Accordingly, there is a potential for fears around this affecting societal acceptance. These fears can be addressed through dialog and, where the fears are based on rational concerns, trough further health related research. Several 5G specific factors can be considered, for example the following: Regarding 5G infrastructure expansion, the number of base stations and antennas might rise and increase radiation exposure. On the other hand, the use of beam forming may limit the spread of the radio signal by directing it towards a specific device and so decrease exposure towards humans. It is possible that radiation exposure is more variable depending on the location of the users and their |

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| | network use (because use of multiple beams from 5G antennas). The frequencies used differ in terms of health implications, with higher frequencies penetrating the body tissue less [62]. To gain acceptance for 5G research activities regarding health and transparency and clear communication of the results to a wider public are important. |
| **M** | **"Real time intelligent security"**<br>Real time intelligent security denotes technical equipment, that enables real time automated detection of risks in (a) system in harmful working environments like factory premises, energy plants, rail tracks (including rail signaling) etc. and/or (b) relevant areas of the public sphere, like public transportation (trains, busses and corresponding stations) by using AI. Detected risks are communicated to an actuator/stakeholder, who decides on and executes action to eliminate the risk. Intelligent security systems may consist, for example, of autonomous, mobile, HD camera equipped robots and/or static 360° HD cameras (CCTV) [32] [37] [47] [51]. The most important 5G service categories are eMBB and prioritised URLLC. |
| **N** | **"Real time intelligent utilisation"**<br>Real time intelligent utilisation includes AI driven computing that enables a real time optimised utilisation of technical equipment (including assets for energy production, storage and use) and infrastructures, such as from adaptive communal lightning systems over production facilities up to the whole transport system including parking and traffic lights management etc. Optimised here means reduced energy consumption, increased resource-efficiency and facilitation of efficient sector coupling [32] [38] [41] [45] [51] [43]. Real time intelligent utilisation can also be used to optimize multimodal transport [32] [33] [34]. Real time automated tracking and sensing is complemented by AI-controlled actors. The most important 5G service categories are mMTC and URLLC. |
| **O** | **"Predictive maintenance and digital twins"**<br>Elements of predictive maintenance applications perform real time tracking / sensing of parameters of assets and facilities in order to avoid accidents and damage. Digital twins and AR applications are considered here as tools for simulations of future physical assets and infrastructures. Examples for the latter are spatial planning or designing of future appliances and plants to identify the most relevant and/or efficient version of the system under study. Predictive applications may be equipped with AI for automated (autonomous) control or processing [33] [37] [45] [44]. The most important 5G service category is uRLLC. |
| **P** | **"Real time on-demand services for travellers"**<br>Real time on-demand services for travellers offer a variety of services instantly, such as HD live streaming on board public transport, on demand multimodal solutions for travellers, on demand pop-up stops for public transportation, or on demand AR enabled guidance in public spaces (e.g. instant translations by spatial scanning of train stations and their affiliated stores and further environment for foreigners or AR enabled tourist guidance through cities / memorial sites / museums) [51] [52] [43]. The most important 5G service categories are eMBB and URLLC. |
| **Q** | **"Real time VR/AR enabled training and education"**<br>Applications for real time VR/AR support training and education in two ways. Firstly, real time remote training classes using 360° VR multicamera live streaming create similarity to real class experience and ease access to education, independent from the location of educators and educated, the possibility of individual mobility or matters of individual social anxiety. Furthermore, establishments will be able to exploit their content by making it available to a much wider audience than this is possible with the |

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| | restricted localised delivery of education. Secondly by implementing AR enabled multimedia education an experience of deeper understanding among the educated can be achieved by enhancing the possibilities of digital (remote) education and training. AR also brings the potential for barrier-free access (language etc). The most important 5G service category is eMBB [44] [46] [39] [41]. |

### 4.3.3 Step 3: Analysis of the KFs

After defining the KFs that shape the scenarios, the different values that these factors can plausibly take on in 2030 are determined. The goal is not to have a full description of all possible values, but rather of identifying several plausible and sufficiently different values that span the space of possibilities. This is done using the same sources as for the identification and definition of the KFs themselves. The following values are determined for the KFs:

**Table 4-2 KF values**

| No | KF Title and Value Description |
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| A | **"Demanded data rate and data volume"**<br>**A1 strong increase**: based on the definition of a medium increase, an increase in data volume that significantly exceeds the factor 10 (growth by 2030 compared to 2022) is defined as a strong increase.<br>**A2 medium increase:** using the example of Germany, the growth of the demanded data volume over the past 8 years (2014-2022) has been on average 47% annually, implying an increase by the factor 10 compared to 2022 [15]. Studies looking at data volume increase globally estimate a growth rate of 63% p.a. [63]. We take the value from Germany as our definition of a medium increase in data volume. This is justified because it is lower than the estimated global growth rate (which is made up by heterogeneous countries). Moreover, since it is likely that through more services that are offered via mobile networks the growth rate will increase compared to the past, thus judging by the past 8 years is rather a conservative estimate, thus medium growth.<br>**A3 weak increase:** based on the definition of a medium increase, an increase in data volume that is significantly below the factor 10 (growth by 2030 compared to 2022) is defined as a weak increase, since this constitutes a decrease of the growth rate. |
| B | **"Energy required by CN (TCN)"**<br>**B1 strong increase:** we base our definition of a strong increase on the baseline scenario developed by Stobbe et al. [15]: here the energy required by the CN is expected to rise by 82% in the baseline scenario (between 2019 and 2030 for a scenario without comprehensive measures to increase energy efficiency). This model only includes macro cells. In a separate model for (medium short range outdoor) micro cells the authors estimate an increase of around 330% (from 2026 to 2030, since deployment of micro cells in not underway yet). We take a value of about 150% as threshold, this value and everything above is defined as a strong increase.<br>**B2 weak increase**: based on the definition of a strong increase, a weak increase is everything (significantly) below 150% increase in energy required by the CN. |
| C | **"Number of antenna locations"**<br>**C1 rises:** there is a rise in the number of antenna locations compared to the current number. Note, however, that this does not consider additional antenna locations necessary for mmWave, this is considered in KF J.<br>**C2 does not rise:** there is no rise in the number of antenna locations compared to the current number. |

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| D | **“Technology modernisation”**<br>**D1 fast:** all technical equipment will be replaced by a new and more efficient generation after less than 7 years (short replacement cycle)<br>**D2 slow:** all technical equipment will be replaced after more than 7 years (long replacement cycle) |
| E | **“Energy management”**<br>**E1 low implementation:** energy management measures are only partly optimised towards reduction of energy consumption.<br>**E2 comprehensive implementation:** energy management measures are fully implemented and optimised towards reduction of overall energy consumption-<br>**E3 no energy management** |
| F | **“Energy required by RAN”**<br>**F1 strong increase:** we base our definition of a strong increase on the baseline scenario developed by Stobbe et al. [15]: here the energy required by the CN is expected to rise by 350% in the baseline scenario (between 2019 and 2030, for a scenario without comprehensive measures to increase energy efficiency). This model only includes macro cells. In a separate model for (medium short range outdoor) micro cells the authors estimate an increase of around 380% (from 2026 to 2030, since deployment of micro cells in not underway yet). We take a value of about 360% as threshold, this value and everything above is defined as a strong increase.<br>**F2 weak increase:** based on the definition of a strong increase, a weak increase is everything (significantly) below 360% increase in energy required by the CN. |
| I | **“Campus Networks implementation”**<br>**I1 strong privileged implementation:** Campus Networks are only available for business or private users with high purchasing power. In this case the digital divide between financially unequally equipped businesses/consumers is aggravated, supporting an unequal and less competitive (digital) economy.<br>**I2 strong accessible implementation**: Campus Networks is affordable and available for most business and private users, independent from their purchasing power. In this case a competitive digital economy with equal opportunities is supported.<br>**I3 limited implementation:** campus networks are not utilised to any significant extent. |
| J | **“mmWave implementation”**<br>**J1 limited implementation**: mmWave is not utilised to any significant extent.<br>**J2 strong ecologically sustainable implementation:** sustainable use of hardware including distinct energy management as well as the use of energy- and resource-saving hardware components, by all involved technical providers/owners to actively minimize the negative impact on the environment.<br>**J3 strong ecologically unsustainable implementation**: sustainability aspects are not of importance regarding used hardware and energy management is not addressed, e.g. since costs resulting from energy use can be allocated to the customers/consumers. |
| K | **“Digital divide / accessibility”**<br>**K1 equalizing infrastructure** expansion focusses on closing the urban rural digital divide and equal accessibility in general, while expanding and renewing of the telecommunication infrastructure to 5G standard. |

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| | **K2 unequal infrastructure** expansion and renewal pays little or no attention to closing the urban rural digital divide and equal accessibility in general. |
| L | **“Societal acceptance (radiation / health focused)”**<br>**L1 infrastructure expansion with focus on societal acceptance** takes concerns by the public seriously, actively considers scientific researched proven, predicted and potential health effects of 5G related radiation of equipment and infrastructures during the process of the infrastructure expansion to minimize health issues, supports research and communicates transparently with concerned individuals, associations and institutions.<br>**L2 infrastructure expansion without focus on societal acceptance** follows the paradigm of market first and considerations second and by doing so does not give the principle of precaution utmost priority. On the contrary, it actively searches for loopholes in applicable regulations to maximize financial outcomes. |
| M | **“Real time intelligent security”**<br>**M1 implementation in line with privacy** always actively prioritizes the issue of an individual's privacy when developing, marketing and operating a real time intelligent security system especially if third parties are surveilled, who are intentionally not suspected being security relevant. Security relevant data are always handled in a way, which precludes the possibility of a misuse of these data.<br>**M2 implementation not in line with privacy** follows the paradigm of market first and considerations second and so does not give the principle of precaution utmost priority. On the opposite it actively searches for loopholes in applicable regulations to maximize financial outcomes.<br>**M3 limited implementation:** real time intelligent security is not utilised to any significant extent. |
| N | **“Real time intelligent utilisation”**<br>**N1 sustainability-focused implementation** means that the motivation of implementing real-time intelligent utilisation is always “sustainability first” to reduce energy and resource use by the facility/produced good/provided service. By doing so, all activities regarding sustainability potentials are realised as much as possible, independent of related investment needs.<br>**N2 cost reduction focused implementation** means, that the motivation of implementing is cost and revenue driven. As far as sustainability potentials can be achieved by this strategy, they have to be seen as windfall profits.<br>**N3 limited implementation:** real time intelligent utilisation is not utilised to any significant extent. |
| O | **“Predictive maintenance and digital twins”**<br>**O1 widespread implementation:** the use of predictive maintenance and digital twins is used to the utmost extend by all possible users to enable most energy and resource efficient infrastructures, machineries etc. Moreover, relevant potentials of predictive maintenance regarding safety for workers or third parties who are directly affected by infrastructures, machineries etc. are enabled. Furthermore, the wide use of digital twin applications for planning can create transparency and potential for participatory decision making, which minimizes unsustainable effects of infrastructures, machineries etc. that derive from contestable decisions in questions of public interest (like construction delays due to lawsuits). |

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| | **O2 limited usage of predictive maintenance:** limited use mostly by financially strong major industries, who use these technologies with the overarching goal of maximizing financial benefits. |
| P | **"Real time on-demand services for travellers"**<br>**P1 sustainability-focused implementation:** A sustainability focused implementation of these services enables energy and resource efficient mobility by making multi-modal transport more appealing and making public transport more attractive. Public transport is more sustainable since energy and resource consumption per capita and distance is reduced compared to private transport and it leads to reduced infrastructural demands for mobility. These effects also enable noise and pollution reductions in urban, suburban and rural environments and a more efficient operation of vehicles, since, e.g., private cars are parked 23h/d while public vehicles are in operation more often. This sustainability implementation of real time on-demand services for travelers also enables social potentials, since pricing effect resulting from an efficient operated public transport may make travelling more e.g. affordable for low income groups and lead to a social equalisation in this sphere of life. A sustainable public implementation can also focus on including disadvantaged people, like people with disabilities to better participate in mobility and of course also extending mobility services in rural areas, to meet the mobility possibilities of urban areas. Sustainable on demand services for travelers may also include streaming, but with solutions that reduce the energy required significantly.<br>**P2 comfort and growth focused implementation:** A focus on growth in mobility services, especially when this contains or increases the share of individual mobility, always results in higher external costs for society and environment compared to public transport alternatives. This includes the exclusion of disadvantaged groups from mobility services, since the group of people with special needs and the group of people with low income are often correlated. Further, a comfort and growth focused implementation is expected to lead to a bigger divide between travel/mobility options for rural and urban inhabitants, since higher revenues for services are expected to be generated in dense urban areas. Real-time on demand services for travelers for comfort and growth may also include ultra HD streaming, which requires substantial amounts of energy.<br>**P3 limited implementation:** real time on-demand services for travellers are not utilised to any significant extent |
| Q | **"Real time VR/AR enabled training and education"**<br>**Q1 inclusivity/accessibility focused implementation**: The inclusivity and accessibility focused implementation of real time VR/AR enabled training and education creates either equal benefits for all or benefits particularly for people who are currently disadvantaged, e.g., with special training needs: real time translation services in case of language barriers, virtualised/augmented training for working in dangerous environments to avoid unsafe situations for the respective persons, augmented support structures for people with higher support needs during work etc. It also works towards closing the digital divide between urban and rural populations.<br>**Q2 limited usage of VR/AR enabled T&E:** limited usage implies that not all potentials (e.g. enabling inclusion) will be fully addressed on the one side and that it will only be implemented by few actors, e.g. financially strong companies (first runners) with the goal to generate as much financial revenue as possible out of these technologies. |

After determining the values that the KFs can take, the next step consists of applying Cross-Impact Balance (CIB) analysis, i.e. examining how the KFs interact with each other. CIB is a type of cross-impact analysis, which operates with expected degrees of influence. Specifically, this entails considering each value of each KF and analysing whether, in what direction (positive or negative) and to what degree it is likely to affect each value of each other KF. Analyzing the relationships and dependencies between the different KFs that shape the scenarios is important to ensure the robustness and credibility of the scenarios selected.

KFs do not necessarily interact with one another, scenarios can also consist of KFs that are quite independent. However, often the way one KF develops will affect the value of another KF and vice versa. This also means that there are KF values that are inconsistent, meaning they will not plausibly occur in one scenario together.

The relations of KFs among each other is not limited to direct effects, but also is made up of indirect effects: if KF 1 influences KF 2, which in turn influences KF 3, then there is an indirect relation between KF 1 and KF 3, even if there may not be a direct influence.

With multiple KFs considering consistencies between scenarios becomes highly complex. For this reason, we use the tool scenario wizard for conducting CIB. In a first step the degree and direction of impact between pairs of KF values are entered based on research and expert judgement. Positive, negative, and neutral influence is possible and entered as numeric values. In our case we defined a scale from -3 to 3, with -3 capturing very strong negative/hindering influence, 3 capturing very strong positive influence and 0 being defined as no influence or ambivalent influence which could equally go in both directions. This results in the CIB matrix representing the interrelationships among factors (see Appendix 7.4.1).

The matrix is then balanced by the scenario wizard to achieve logical consistency, addressing any contradictions or circular causations between KF values. This iterative process results in a rating of which scenarios are how coherent and internally consistent, which leads to the subsequent step, the generation and selection of scenarios (see Appendix 7.4.2, 7.4.1).

### 4.3.4 Step 4: Generation of the scenarios

Using the scenario wizard, a set of consistent scenarios is identified. From these scenarios we select two scenarios, one baseline scenario (scenario I) and one SDG advancing scenario (scenario II). These scenarios are presented below first in a table displaying the active KF values in both scenarios (Table 4-3). Column four in this table displays the differential impact these two scenarios have on the SDGs: this means that where Scenario I and Scenario II differ, Scenario II contributes to advancing the SDGs listed in the last column, while Scenario I, the baseline scenario, does not. Note that the baseline scenario is termed baseline scenario because there is no specific advancement of SDGs – the deployment of 5G infrastructures and services is expanded in both scenarios. In Table 4-4, the SDGs with their sub-targets that are referenced in the previous table are listed. Subsequently, there is also a text describing each scenario.

**Table 4-3 Scenarios for 5G Implementation**

| Scenarios for 5G Implementation | | | |
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| | Scenario I: Baseline Values of KFs | Scenario II: SDG advancing Values of KFs | Differential Direct Impact on SDG sub target* |
| A Data volume and demanded data rate | A1 strong increase | A2 Medium increase | |
| B Energy required by CN (TCN) | B1 strong increase | B2 weak increase | SDG 7.3, SDG 12.2 |
| C Number of antenna locations | C1 rises | C1 rises | |
| D Technology modernisation | D2 slow (>7 years) | D1 fast (<= 7 years) | SDG 7.3, SDG 9.4, SDG 12.2 |
| E Energy management | E1 low implementation | E2 comprehensive implementation | SDG 7.3, SDG 12.2 |
| F Energy required by RAN | F1 strong increase | F2 weak increase | SDG 7.3 |
| I Campus networks | I1 strong privileged implementation | I3 strong accessible implementation | SDG 9.1 |
| J mm-Wave infrastructure | J3 strong ecologically unsustainable infrastructure deployment | J1 limited infrastructure deployment | SDG7.3, SDG 12.2 |
| K Digital divide / accessibility | K2 unequal infrastructure expansion | K1 equalizing infrastructure expansion | SDG 10.2, SDG 11.A, SDG 9.3 |
| L Societal acceptance (radiation / health focused) | L2 infrastructure expansion without focus on societal acceptance | L1 infrastructure expansion with focus on societal acceptance | SDG 16.7 |
| M Real time intelligent security | M2 smart security not in line with privacy | M1 implementation in line with privacy | SDG 3.6, SDG 8.8, SDG 12.2, 16.1 |
| N Real time intelligent utilisation | N2 cost reduction focused implementation | N1 sustainability-focused implementation | SDG 7.2, SDG 8.4, SDG 12.2, SDG 9.4 |
| O Predictive maintenance and digital twins | O1 widespread implementation | O1 widespread implementation | SDG 8.8, SDG 11.3, SDG 12.2, SDG 9.1, SDG 9.4, SDG 16.7 |
| P Real time on-demand services for travelers | P2 comfort and growth focused implementation | P1 sustainability focused implementation | SDG 3.6, SDG 8.9, SDG 10.2, SDG 11.2, SDG 13.2 |
| Q Real time VR/AR enabled training and education | Q1 inclusivity / accessibility focused implementation | Q1 inclusivity / accessibility focused implementation | SDG 4.4, SDG 4.5, SDG 4.A, SDG 4.C, SDG 8.5, SDG 8.8, SDG 10.2 |

** For the name and definition of the SDG sub target see Table 4-4 below*

**Table 4-4 Relevant SDGs and their sub targets**

| SDG sub targets | |
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| **SDG** | **Sub targets** |
| 3 GOOD HEALTH AND WELL-BEING | 3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents. |
| 4 QUALITY EDUCATION | 4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship. |
| | 4.5 By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations. |
| | 4.A Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, nonviolent, inclusive and effective learning environments for all. |
| | 4.C By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing states. |
| 7 AFFORDABLE AND CLEAN ENERGY | 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix. |
| | 7.3 By 2030, double the global rate of improvement in energy efficiency. |
| 8 DECENT WORK AND ECONOMIC GROWTH | 8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead. |
| | 8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value. |
| | 8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment. |
| | 8.9 By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products. |
| 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE | 9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all. |
| | 9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets. |
| | 9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities. |

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| 10 REDUCED INEQUALITIES | 10.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status. |
| 11 SUSTAINABLE CITIES AND COMMUNITIES | 11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons. |
| | 11.3 By 2030, enhance inclusive and sustainable urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management in all countries. |
| | 11.A Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning. |
| 12 RESPONSIBLE CONSUMPTION AND PRODUCTION | 12.2 By 2030, achieve the sustainable management and efficient use of natural resources. |
| | 12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse. |
| 13 CLIMATE ACTION | 13.2 Integrate climate change measures into national policies, strategies and planning. |
| 16 PEACE, JUSTICE AND STRONG INSTITUTIONS | 16.1 Significantly reduce all forms of violence and related death rates everywhere. |
| | 16.7 Ensure responsive, inclusive, participatory and representative decision-making at all levels. |

To analyse the impact of 5G in general and 5G-VICTORI in particular, two consistent scenarios were selected from the number of consistent scenarios - which were determined on the basis of the relationships between the KFs using the Scenario Wizard - that differ substantially in terms of their contribution to the SDGs. This is to illustrate the potential breadth of impact of 5G deployment by 2030. As stated above, a scenario depicts a possible future, but does not represent a forecast or prediction of the development. While the two selected scenarios differ in many parameters, there are some factors that have the same or similar values in both scenarios and some basic relations regarding, e.g., energy consumption that underlay both. The following briefly introduces these points before describing scenario I and scenario II.

#### 4.3.4.1 Scenario-independent aspects

- An increase in data volume and data rate: experts studying telecommunications developments as well as technology providers and telecommunications companies see this trend clearly until 2030 and beyond (e.g. see [15] [64] [65] [66] [67] [68]). In the scenarios selected there are two different values, but they both assume an increase: medium and strong increase.

- A substantial increase in internet data traffic in the recent years stems from video-streaming [69]: streaming of videos with higher quality, video streaming for gaming, augmented reality (AR), artificial intelligence (AI) training, and autonomous vehicles with streaming cameras, holography. This trend will continue through 2030.
- The relative energy consumption of the RAN and TCN cmWave macrocells (for the case of Germany) corresponds approximately to the ratio RAN:TCN = 5:1 (baseline scenario 2019, [15]). Corresponding future scenarios regarding the energy consumption of these infrastructure areas assume that these will separate even more, by reaching a ration RAN:TCN = 10:1 in 2030 (see baseline scenario; combined scenario (scenario 5) with the same tendency) in [15]). In mobile telecommunication networks radio units, which include the power amplifiers and analog-to-digital converters account for the largest share of the total energy requirement (accounting to over 60 % in 5G infrastructure; see [15]). The main reasons for these increases are [15]:
  - Conventional, less load-adaptive power amplifiers with fixed operating points generate high energy losses. This effect is amplified at higher frequencies.
  - 5G realizes higher data volumes and data rates with, among other things, larger channel bandwidths (up to 150MHz bandwidth), multiplication of antenna paths (Massive MIMO) and new modulation methods (e.g., 256 QAM). These higher network capacities in turn increase the computational effort and thus the energy requirements of analog-to-digital conversion and, in particular, digital signal processing in the baseband module.
  - Particularly in urban areas, the energy requirement for the necessary transmitting power of the 3.5 MHz systems increases due to the specific stronger attenuation of higher-frequency signals and the additional ambient attenuation caused by dense building.
  - In addition to the radio modules (RU), the baseband modules (BU) and the conversion losses of the AC/DC power supplies also make a notable contribution to the increase in total energy requirements. Although the volume of data to be processed by the BU increases sharply by 2030, this can be partially offset by increasing computing efficiency of the new hardware generations.
  - Moreover, the number of antenna locations will rise until 2030 to increase the area covered by 5G [15] [68] (also stated by the project partners). The construction of additional antenna locations reduces cell sizes while increasing data capacity. A reduction in cell size results in a reduction of transmit power per radio module. This effect is not expected to compensate the additional number of antenna locations for 5G bands, which results in an increasing energy demand of the RAN [15].
- Higher data rates require more processing power and data handling in the core network. Processing the increased traffic volume puts additional strain on the network infrastructure, resulting in higher energy demand by the upgraded and/or added equipment like optical network units, radio network controllers, routers and core network servers itself. This leads to a rising energy demand to cool the TCN equipment [15]. But since the technology modernisation of the TCN is coupled with strong positive impact on energy efficiency, the energy demand of the TCN is expected to increase much less than the energy demand of the RAN (in the case of cmWave macrocells; see baseline scenario and scenario with accelerated technology modernisation (scenario 2) in [15]).

- The higher energy consumption in the 5G mobile network enables a disproportionately higher data rate, both today and in 2030, i.e., the amount of data transmitted increases significantly more than the amount of energy required for it.
- The mmWave technology to be adopted by 5G networks also enables large data volumes and high data rates and thus makes new use cases possible. It is particularly well-suited for high-speed fixed wireless access (FWA) in urban areas, ultra-fast broadband connections for businesses and homes, and short-range communications for IoT devices. It can also enable applications industrial automation, and augmented reality experiences that require high data rates and low latency. VR and AR applications are sensitive to latency, as any delay between user actions and corresponding system responses can lead to motion sickness and a degraded experience. MmWave-Technologiy is associated with additional, specifically high energy consumption in the mobile network. Stobbe et al. [15] assume that by the year 2030 the RAN:TCN ratio regarding energy consumption of the mmWave microcell infrastructure differs notably from the RAN:TCN ratio of cmWave macrocells. While by 2030 the RAN:TCN ratio for cmWave macrocells is expected to be 10:1, this ratio is estimated by 5:1 for indoor mmWave microcells and by 2:1 for outdoor mmWave (e.g. given the assumed individual patterns of use and infrastructure utilisation). Due to the significantly higher data transport volume in outdoor mmWave microcells, the energy requirement of the optical network technology and, in the data and signal processing effort and thus the energy requirement of the switching and network control technology increases. However, the rollout of mmWave (e.g. via campus networks) by 2030 is estimated to be low ([15], interviews with 5G-VICTORI partners), but given the exponential increase in data rate requirements set for cellular networks, mm-wave technology could have a noteworthy share of wireless access by 2050 (interviews with 5G-VICTORI partners).
- 5G and especially 5G SA is based on SDN and VNF, since 5G is a “softwarised by default” technology. SDN and VNF technologies are expected to enhance energy efficiency, through enabling more efficient resource allocation and utilisation in network infrastructure (in real time). The decoupling of control and data planes allows for centralised management and optimisation of network resources, enabling more efficient routing, load balancing, and traffic management and thus reducing energy consumption. Network softwarisations allows network upgrades and maintenance to be done through software updates rather than physical equipment replacements, reducing the disposal of hardware components. VNFs, being software-based implementations, enable dynamic scaling and allocation of network functions, avoiding the previous need for dedicated hardware appliances. This flexibility is expected to improve energy efficiency by allowing operators to allocate resources based on demand, thereby reducing energy consumption. VNF therefore is expected to lead to optimised use of hardware resources, reduced space requirements, and lower overall resource consumption. SDN and VNFs can contribute to better resource utilisation, reducing the need for overprovisioning and wastage and so to optimizing the use of network infrastructure. On the other side, since built-for-purpose hardware is more power (and processing) efficient than SDN/VNFs running on generic computing hardware, for very small-scale networks without high data rate requirements, legacy equipment could result in lower power consumption and deployment complexity. Energy efficiency analyses regarding implementations of VNF (RU, gNBs) and SDN, that were carried out as part of the use case assessment of 5G-VICTORI (for more details see chapters 3.2.2, 4.4.2 and deliverable **D3.7** [1]) showed a significantly lower energy consumption of around 20-30% by the implemented VN and SDN functions for dynamic routed data opposed to a static legacy routing solution.

The above-mentioned interrelationships are effective in both the scenarios described below, but their values may differ in strength. This is explained in more detail in the scenarios and taken into account later in section 4.4 when comparing the scenarios in terms of their impact.

Both selected consistent scenarios implement services of predictive maintenance and digital twins to a comprehensive extent to enable energy and resource efficient infrastructures, machineries etc. This further increases safety for workers or third parties who are directly affected by them. The widespread implementation of digital twins also fosters transparency and procedural efficiency if used for participatory decision making (e.g. virtually supported district planning enabled by 3D-spatial scanning). Note that, while both scenarios share the same value here, this does not mean that this is the only possible or even the most likely development.

In both the chosen, consistent scenarios, the use cases in the area of VR/AR enabled training and education are offered with a low threshold access. This means, they are especially offered to target groups with special needs and therefor serve social sustainability. This covers a very wide field of uses cases, like the support of people with learning disabilities through audiovisual and, if necessary, AI-assisted AR applications in the execution of professional activities and thus their integration into the primary labor market or the AR- or VR-supported practical learning of working in typically hazardous work environments for job entrants and thus the reduction of situations with potential physical or psychological harmful effects. Many other examples are conceivable, but these two already show potential for counteracting the imminent shortage of skilled workers in a wide variety of industries [71] and thus developing ecological, social and economic (and macroeconomic) potential for businesses on the one side and the society as a whole on the other side. As for predictive maintenance, while both scenarios share the same value that advances SDGS, this does not mean that this is the only possible or even the most likely development.

#### 4.3.4.2 **Scenario I: Baseline scenario**

The scenario describes the business as usual respectively purely market driven implementation of 5G mobile communications, where efforts in generating sustainability effects are realised by all actors of the 5G ecosystems mainly as windfall profits. This means for example that the target of energy or resource efficiency is only addressed as long as it realizes financial benefits for the particular actor and markets are created focused only on conventional business concerns. Therefore, not only environmental but also social sustainability issues like inclusivity or equality are only addressed, if they provide immediate financial profit. The consumer’s wish for a constant increase in enjoyment, entertainment and convenience is addressed by all actors along the 5G ecosystem. This entails a strong increase in demanded data volume and rate.

To comply with this demand, with the aim of obtaining the highest possible profit from it, the infrastructure is extended and modernised as follows:

- Technology modernisation is slow which means that new equipment will only be installed to cover existing gaps, e.g. additional base stations on additional antenna sites given the increasing data rate. Old and therefore inefficient equipment is utilised until it is no longer functioning and will only be replaced if financial gains due to lower costs for energy overweigh investment costs.
- Since, in this scenario, decisions from actors in the 5G ecosystem are primarily driven by (directly financial) business considerations, not all potentials regarding energy efficiency will be realised and only a low degree of energy management is implemented. Due to this in combination with the strong increase in demanded data

volume and rate, as well as other factors, the increase in energy required by RAN and TCN is strong.

- 5G telecommunication infrastructure will be extended in areas with the highest expected profits, e.g. highly populous or industrialised areas. This leads to an unequal infrastructure expansion, which results in a remaining digital divide (e.g. between rural and urban areas) and so an unequal access to the benefits of this technology.

Since the concerns in the population regarding the not (conclusively) proven health-damaging potential of radiation from 5G infrastructures and equipment are not addressed in an open dialog, the (unfounded) skepticism toward the technology continues to increase. This leads to increased acts of sabotage [72] [73], resulting in technical failures and an increased resource demand.

In a “market first” scenario, all services for (a) commercial customers, from industries to SMEs and NGOs, (b) public customers like municipalities or universities and (c) private end users that promise profit are offered, regardless of whether they create or reinforce a distortion of competition or unequal access resulting from the different financial possibilities of the economic participants and by this increase the digital divide between them and/or negative impacts on other social or environmental sustainability. This results in the following:

- A strong privileged implementation of campus networks makes them available only for customers with high purchasing power.
- Service providers of mmWave technology make at best a low effort to optimize energy and resource demands, since costs resulting from these are allocated to customers with high purchasing power. mmWave is used widely (if affordable) even if the full capacity is seldom used and constitutes over-dimensioning.
- Providers for real time on demand services for travelers focus on a financially strong user group by offering services that prioritize convenience for this group. Convenience in traveling like a short flight instead of a more time-intensive railway trip for the same distance or taking a private car instead of combining public transport and bicycle is (as in any other field of consumption) linked to a higher use of energy and resources. A more convenient and comfortable travel option is often (but not necessarily) linked with higher financial expenditures. If both parameters are linked, travelers with low purchasing power do not benefit in this scenario, on the contrary: since low income households are more affected by air or noise pollution, e.g. exhaust gases from private cars, but use them less, they are negatively impacted by this scenario [74] [75] [76]. In addition, a bigger divide between travel/mobility options for rural and urban inhabitants exists in this scenario, since higher revenues for services are expected to be generated in dense urban areas.
- Since the implementation of real time intelligent security follows the paradigm of market first and considerations second, it does not give the principle of precaution utmost priority. On the contrary, it actively searches for loopholes in applicable regulations to maximize financial outcomes or generates unintended or unforeseeable risks (like threats to the personal integrity of individuals or to the democracy see e.g. [77] [78]).
- The motivation of implementing real time intelligent utilisation by commercial customers is cost and revenue driven, which results in not leveraging the highest degree in possible energy efficiency.

#### 4.3.4.3 Scenario II: SDG advancing scenario

This scenario describes a sustainable implementation of 5G mobile communications including infrastructure and services and all actors of the 5G ecosystem: telecommunication operators, business users, service providers for end users and also manufacturers of the technical equipment as well as cloud and data center operators.

On the infrastructure side, all the potential of an energy- and resource-saving 5G deployment is realised:

- Technology modernisation which means the replacement of system components in the RAN (antenna units, radio units including transceivers, baseband units etc.) and the TCN (optical network unit, switches, radio network controllers, router/gateways and core network server units etc.) with newer modernised versions is driven by sustainability issues as the first priority and economic issues as the second priority, since energy efficiency is hardware related, due mostly to miniaturisation progresses in the semiconductor industry. By a fast pace of technology modernisation, the increase in energy consumption of the TCN until 2030 can be negligibly small, while the energy consumption of the RAN is supposed to increase strongly (see [15], Scenario 2). Rapid technology modernisation also has a positive effect on cooling and conversion losses, which can be additionally reduced. But a fast technology modernisation is coupled to a rising demand in resources like gold and high pure silicon. In the SDG advancing scenario the gains in the operation phase are balanced against the resource and energy demands in the production phase and the rate of technology modernisation is optimised to reduce overall energy and resource consumption.
- Load-adaptive energy management including deliberate switching off of selected transceivers and other infrastructure components during the time intervals with low load is implemented to the utmost extent with the goal of maximizing energy efficiency and reducing energy consumption. Further, all possible energy management potentials through 5G enabled VNF and SDN are realised.

Social sustainability aspects relevant to the 5G infrastructure are taken into account and part of an integrative perspective that considers ecological and social sustainability simultaneously:

- Despite higher costs and specific infrastructure requirements of deploying 5G networks in individual rural sites, telecommunication operators have addressed the issue of equalised infrastructure expansion to the extent possible. By doing so, the digital divide between rural and urban areas is reduced.
- Worries regarding 5G expansion are taken into account through addressing health concerns related to (high frequent) radiation of telecommunication technologies by conducting research and through clear, transparent and barrier-free communication and dissemination of research result. 5G expansion is therefore accepted by almost all parts of the population.

Industries and commercial companies (e.g. transport operators and mobility providers) and large public users of 5G mobile networks (e.g. universities, municipalities) are creating 5G services with the highest degree of sustainability orientation:

- The services used are guided by the principle of data economy: data collection, processing and storage take place to the lowest possible extent and not to the highest possible extent.
- Through sustainable business models, infrastructure providers are able to offer affordable campus networks, which are available for most commercial and public costumers, independent from their purchasing power, supporting a competitive digital economy with equal opportunities.
- Where mm-Wave technology is crucial due to the requirements of the given use case, it is optimised in terms of energy efficiency, e.g. by using of massive MIMO and

beamforming. Aligning individual antenna arrays separately can reduce the required transmit power because less energy is lost in the area [79] [80] [15].
- The 5G services (a) real time intelligent utilisation and (b) real time intelligent security, aim at environmental, social and economic (also macroeconomically) sustainability simultaneously. This means for example reducing the energy and resource requirements by the facility and the produced goods as well as to reduce the risk for the workers in their working environments or from potential havaries and sabotages of, e.g., facilities or infrastructural equipment.

Services for private end users and SME's are also created with principle of sustainability as a priority. This means:

- Every effort is made to limit the growing data demand itself and to reduce the energy demand associated with it (acting in accordance with the principle of thrift and implementing all former mentioned efficiency measures as far as applicable). This means, e.g., to restrict ultra-high resolution (3D) streams for areas of particular relevance, e.g. security instead of pure entertainment.
- Service providers have developed business models that break down the digital divide between (a) major industries and SMEs and (b) advantaged and disadvantaged groups in society (e.g. urban/rural, financial strong/weak, abled/disabled, etc.).
- Use cases in the area of mobility are focused on the highest possible degree of energy and resource efficiency and on the goal of promoting a reduction of $CO_2$ emissions in transport, furthering an increase in attractiveness of multi-modal transport with a high share of public transportation. By this energy and resource consumption per capita and distance are reduced compared to private transportation. Further social benefits are advanced: an efficient operated public transport system has a very strong potential for a social equalisation of mobility [81].

## 4.4 Transfer of scenario insights/Impact assessment in light of the scenarios

### 4.4.1 Scenario assessment in light of the SDGs

Examining the SDG advancing scenario (scenario II) and the baseline scenario (scenario I), which KF values are realised where and how they are likely to affect the SDGs can give an idea of how to assess different developments and how to work towards realizing a scenario that furthers the SDGs to the extent possible.

The scenarios include both the infrastructure as well as some service types. We included both to also examine how, i.e. through which KFs, the two aspects of sustainability in a 5G context, sustainable 5G and 5G for sustainability, are related.

Comparing infrastructure and services, it is noteworthy though not surprising that the impact on the infrastructure side is focused on environmental sustainability and here on SDG 7 (energy, in particular energy efficiency) and on the sustainable use of resources. Regarding energy efficiency, even in scenario I, the baseline scenario, energy efficiency is likely to increase somewhat, due to 5G technologies and VNF and SDN leading to somewhat more energy efficiency in terms of required energy per amount of data, even if there are no targeted efforts towards this. However, the full potential of energy efficiency is not realised. Covering aspects of social, environmental and economic sustainability SDG 9, resilient infrastructure and inclusive industrialisation is also likely to be impacted by infrastructure KFs.

For services, on the other hand, the potential to further SDGs is distributed across all three sustainability dimensions, concerning environmental, social and economic SDGs. In the service areas we examine, there is a concentration on social and economic sustainability (see Figure 4-5). Yet several service areas in the scenarios have a clear direct potential for furthering environmental SDGs: a sustainability focused implementation of real time on-demand services for travelers has the potential to further SDG 13 (combating climate change) by aiding the shift to climate-friendly multi modal transport. A sustainability-focused implementation of real time intelligent utilisation can contribute to energy efficiency SDG 7), if used for energy management in different sectors and to increasing the share of renewable energy through enabling decentralised power networks. It may also contribute to resource efficient consumption (SDG 12) and production (SDG 9). In terms of social and economic sustainability, the service areas we examine affect SDG 3 (health and safety), SDG 4 (quality education), SDG 8 (decent work and economic growth), SDG 10 (reduced inequalities), SDG 11 (sustainable cities and communities) and SDG 16 (strong institutions/participation).

Some KF values, in particular those belonging to the service areas, have the identified potential to affect multiple SDGs. These potentials may enhance or interfere with each other, in gauging the impact of and designing particular services such target conflicts need to be kept in mind. This is also the case for some infrastructure KFs, for example technology modernisation. In the SDG advancing scenario the active value is fast technology modernisation: this can positively affect energy efficiency, through hardware improvements [15]. However, a fast technology modernisation requires more frequent replacement, which can negatively affect sustainable resource use and energy consumption in hardware production. According to estimations by Stobbe et al. [15] a rate of technology modernisation, which replaces all relevant hardware after every third year (compared to a base scenario with a replacement every seventh year) leads to 36 % less energy consumption but a doubled increase in the demand for gold and silicon. Accordingly, there is a conflict of goals between the demands of the production phase and the gains in the operation phase, which needs to be considered and alleviated through recycling and circular economy approaches.

Besides considering impacts of the infrastructure and impacts of the services the intersection of these two types of impacts also needs to be considered. This is relevant for example for KF K, which in our SDG promoting scenario has the value equalizing infrastructure expansion. The importance of equal infrastructure rises with the amount and importance of services that are enabled by this infrastructure: if many beneficial 5G services are created but only are geared towards and available for people living in urban environments the digital divide is increased. Similarly, if beneficial industrial services are enabled by 5G, but are only available for large industrial companies and not accessible to SMEs this interferes with progress on SDG 9 (resilient infrastructure and inclusive industrialisation).

Rebound effects are also situated at the intersection of service and infrastructure impact. Rebound effects describe the effect that frequently enhanced efficiency of resource (in this case energy) consumption do not lead to an overall decrease in consumption but instead to a higher consumption in absolute term [68]. This is very likely with respect to 5G: the overall consumption of energy through 5G is expected to rise despite increases in energy efficiency, because the amount of data that is transmitted is expected to increase immensely. This is particularly the case in scenarios where energy efficiency is not substantially increased. However, even in scenarios with high energy efficiency the rise in absolute required energy will not be compensated [15] [68].

The difference between the scenarios regarding overall energy consumption is hard to estimate, especially given the tentative nature of the scenarios that focus on future potentials however existing research can provide a rough idea: the share of electricity consumption by the ICT sector in the total electricity consumption of the EU is estimated to be around 4 - 10 %, resulting in 1.4 % - 4 % of the EU-wide GHG emissions [68] [82]. According to the gross electricity generation in the EU-27 totaling 2,910 TWh in 2021 [83], the ICT sector within the EU consumed an average of just over 200 TWh (min 116 TWh, max 290 TWh). According to the studies, the ICT sector in the EU-27 thus caused an average of 95 million t $CO_2$ eq (min 49 million t $CO_2$ eq, max 140 million t Cos eq) of the total 3.5 billion t $CO_2$ eq of the EU-27 in 2021 [84]. Based on the previous annual increase in mobile data demand and the estimated future development, a tenfold increase is assumed for the year 2030 compared to the mobile data demand of 2022 (Stobbe Tabelle 28). The share of mobile networks and data centers in the overall ICT sector's energy consumption is difficult to determine. For Germany, with 487 data centers [85], the energy consumption of mobile networks and data centers is approximately 2.3 TWh in 2019 [15]. Linear scaling up to the approximately 2,000 data centers and connected mobile networks in the entire EU-27 [85] results in an electricity demand of 9.5 TWh; a tenfold increase in energy demand by 2030 consequently 95 TWh.

From a technical point of view, the rising energy consumption due to the increase in the demand for (mobile) data volumes can only be counteracted by increasing efficiency. The following interrelationships are elementary here:

- The computing power per kilowatt hour consumed has doubled every 18 months in the past, mainly as a result of the ongoing miniaturisation of computing components [86].
- There is a minimum amount of energy required to move an electron and thus trigger a switching operation (Landau's principle). The approach to this minimum value takes place in smaller and smaller steps.

Overall, studies assume that efficiency in the ICT sector can still be increased significantly in the future, but that (mobile) data demand will increase disproportionately [15] [87] [68]. With 5G, countless new (and therefore additional) applications are possible that entail additional energy requirements, so that the lower energy consumption of 5G per transmitted data volume is offset again by multiplication of the applications. The extent to which efficiency gains will be overcompensated by increased (mobile) data demand is not currently foreseeable. However, the trend is clear: both scientific analyses, including that of technology provider Huawei, see a clear absolute increase in energy consumption as a result of the switch from 4G to 5G (min +70 %, max +170 %) [68] [88] [89]. This trend is also seen by 99 of 105 telecommunications operators surveyed in an international study [89].

In the study Environmental impact Assessment of Mobile Communication Networks in Germany [15] specific future scenarios for the German mobile communications sector in the year 2030 are determined against the backdrop of the current mobile infrastructure and environmental conclusions are drawn from these scenarios. Besides the baseline scenario, the so-called combined scenario (Scenario 5) is particularly relevant. In both scenarios, 3G is being deactivated starting from the year 2022, and until the year 2030, 2G will remain active for basic coverage while 5G is rapidly implemented. However, the expansion of mm-Wave is not included in this scenario, due to limited data and assumed slow expansion rates.

While both mobile communication scenarios feature equal antenna site expansion (+33%), they differ significantly in several aspects:

- The pace of technology modernisation (Baseline: slow, Combined: accelerated).
- Nationwide roaming (Baseline: no roaming, Combined: roaming can potentially reduce overall required transmission power considering the total area traffic density regardless the service or the serving network operators).
- Energy management (Baseline: no load-adaptive operation; Combined: load-adaptive operation and if plausible, selective transceiver shutdown during predicted or defined zero usage periods).
- Redundancy in TCN (Baseline: redundancies in metro and aggregation rings, Combined: no redundancies).

In the baseline scenario, the energy consumption of mobile networks and data centres in Germany increases from 2.3 GWh in 2019 to 7.5 GWh in 2030. However, the energy-saving options in the combined scenario (Scenario 5) only lead to a consumption of 3.6 GWh. The energy-efficient expansion of mobile communications, including 5G, thus has significant environmentally beneficial effects compared to an expansion that is not focused on energy efficiency.

Extrapolating these study results linearly to the EU, based on the assumed 9.5 GWh consumption in 2019, yields the following results for 2030: In the baseline scenario, the power consumption of mobile networks, including 5G implementations and data centres, rises to over 30 GWh, while in the combined scenario, it reaches only 14.6 GWh, which is less than half, but still a rise by 50%.

While these estimations constitute only a rough ballpark, they do show that at the overall rise in energy consumption is not trivial and the share of mobile network infrastructures in energy consumption will become increasingly less negligible even though it may make up a smaller share than other sectors. A target of SDG 7 is to decarbonize energy by increasing the share of renewable energy. As overall energy consumption rises this becomes more difficult – the amount of (rapidly) accessible renewable energy has limits, not least because it requires space and often faces acceptance issues by the public. Moreover, since we are likely to face electrification in many areas [90] it is important to be as energy efficient as possible in all areas, even increasingly clean energy is used. In addition, raw materials are needed in the energy sector as well as in the ICT sector (e.g. germanium, boron and rare earth elements like dysprosium, neodymium). There are scarcity overlaps between those sectors and the e-mobility sector, regarding these materials and/or others [90]. It is therefore of utmost importance to stress recycling activities for numerous elements and materials and transition into a circular economy. Nowadays, only about 1% of rare earth elements are recycled on a global scale, despite recycling's enormous benefits: The recycling of neodymium from end-of-life magnets, for example, takes only around one third of the energy that is needed to extract it from ores, while releasing fewer toxins [91].

While the potential of positive environmental impacts through services can offset this, this development is not a given, however, as demonstrated by the differential impact on SDGs the service areas examined have in the two scenarios and the likely occurrence of rebound effects. In order to compensate or overcompensate the energy consumption increase in the infrastructure, the services thus have to be actively shaped in order to realize their sustainability advancing potential.

Given that higher frequencies such as made possible by mmWave technologies enable even higher network capacities and data rates, the absolute increase in energy consumption is likely to be particularly high if mmWave is deployed in more than a very limited number of areas [15]. This is also visible in our scenarios: in the SDG promoting scenario mmWave deployment is limited – if it is switched to stronger deployment, even if in a sustainable way (including extensive energy management etc.), this leads to inconsistency with weak increase in the energy consumption of the RAN and the TCN.

Delving a bit deeper in to mmWave deployment, for the case of Germany [15] estimate for the use of 26/28 GHz bands covering 1% of the area of Germany a total of 3.1 TWh of electricity (with roughly 1/3 being accounted for by the TCN and 2/3 by the RAN). In interviews with our partners a higher percentage of deployment is expected, <10% by 2030, but potentially much more by 2050. It is clear that such scenarios would lead to an immense increase in power consumption, despite the higher energy efficiency (a roughly 16 times higher mobile data transport capacity compared to macrocells [15]).

### 4.4.2 5G-VICTORI contributions in light of the scenario results

The goal of the impact assessment in Task 5.3 was to examine the future potentials of the upscaled impact of the project. Therefore, we went beyond the work done in the project and identified KFs relevant for a hypothetical scenario of 5G infrastructure and services at a national and EU level. In this section we look at the scenarios from the perspective of the concrete work done in 5G-VICTORI and discuss which aspects can be seen as promoting one or the other scenario.

Regarding the infrastructure, virtualised network infrastructure is expected to be significantly more energy efficient than legacy implementations [15] (interview with 5G-VICTORI partners). In T3.4, experiments were made to evaluate the virtualised RAN and 5G core network components (including virtualised resources and functions) in terms of energy consumption and energy efficiency. To realistically evaluate the energy performance of the 5G-VICTORI solution a city scale analysis was carried out, which adopts the 5G-VICTORI architecture and its technical capabilities to support real traffic requests recorded for the city of Milano (available online [27]). The performance of the 5G network that supports these requests is captured through an experimental infrastructure (lab scale) that was purposely set up for this evaluation including both 5G RAN and 5G core solutions. The results for the lab setup show the following distribution of energy demand in the case of dynamic routing enabled by the 5G-VICTORI approach: 48% energy demand in the RAN (virtualised RUs and virtualised gNBs), 30% energy demand in the core and 21% energy demand in network (including access, aggregation and core network). As a result, compared to conventional solutions (supporting static routing), the 5G-VICTORI solution was able to achieve significantly lower energy consumption, in the order of 20-30%, due to its ability to dynamically reconfigure computational and network resources of the end-to-end 5G system to better meet input traffic requirements. This is practically achieved by optimally configuring:

- The RAN segment by assigning the appropriate configuration setting (i.e. RBs) to match traffic requirements in a specific region.
- Network resources taking optimal routing decisions for the interconnection of the gNBs with the CN.

More detail can be found in section 3.2.2 and in the deliverable on UC assessment (**D3.7** [1]). These insights support the KF energy management as well as the KFs energy required by the RAN and TCN, creating tools that further the KF value comprehensive implementation in scenario II and working towards realizing **SDG 7.3** (energy efficiency). The model set-up should be transferred and extended to other settings to further investigate its potential (all details see deliverable **D3.7**).

The cross-domain service orchestration platform at the core of 5G-VICTORI (5G-VIOS) enables different vertical actors to use a common infrastructure and offers flexible architectures, which can be easily tailored to different requirements. While no measurements regarding energy efficiency beyond what is discussed in the previous paragraph were made, enabling common orchestration and thus energy management and sharing of infrastructure resources holds the potential of both supporting a comprehensive energy management (furthering SDG 7.3) and possibly also furthering SDG 12.2, efficient use of resource.

The work done in all use cases of 5G-VICTORI contributes to technology modernisation, since new hardware and software is used and tested. This is a step towards increasing the rate of technology modernisation and will often, though not necessarily, coincide with using more efficient hardware. As such can contribute to SDG 7. A survey on the acquisition of infrastructure components conducted among 5G-VICTORI partners in the early stages of the project indicated that energy efficiency was not a main factor in the decision what to acquire.

This likely due to the specific nature of (partly custom made) components required. In building on the technologies developed, however, explicit focus should be put on ensuring that the new hardware utilised is as energy efficient as possible. In future this should also be realised as far as possible in early stages of the R&D process, since the longer-term overall energy requirements of a system can be better estimated. While new hardware can be beneficial in terms of energy requirements, as stated in scenario II, resource use has to be balanced against potential energy efficiency increases and measures have to be taken to ensure sustainability in resource use, both up- and downstream.

5G-VICTORI contributed in all testbeds to research on campus networks, thus providing insights on the feasibility of campus networks that may support strong implementation. However, strong implementation can either be privileged or accessible.

mmWave technology was utilised in several use cases in 5G-VICTORI. Among these is for example **UC #3** CDN services in Berlin where mmWave connectivity is used for a data shower functionality, transferring large amounts of media data between caches within a very short time period, from the station to a train while it is in the station. In **UC #2** and **UC #3** Digitisation of Power Plants a mmWave link was used as an extension of the 5G-VINNI infrastructure from the cloud to the facility (of **ADMIE** and of **TRA** respectively). Considering the SDG advancing scenario, the deployment of mmWave should take into account the energy consumption factors as a criterion where alternative network deployments are available (e.g. optical for the transport segment, or 5G at lower bands for the RAN segments, or sparce site deployment for the data shower application).

Regarding service areas, there are potentials to pave the way towards scenario II, furthering both environmental as well as social and economic sustainability goals. Depending on the service requirements there are also risks, however, for example regarding privacy concerns or the data capacity and the corresponding 5G infrastructure required by particular services. These aspects will be briefly presented in the following for each service area. The social sustainability potentials of the UCs and services created in 5G-VICTORI were recorded in more detail in Task 3.4 (see deliverable **D3.7** [1]), here are only briefly discussed.

As described in section 4.3.2, real time intelligent security here captures, firstly, detection of risks in working environments and secondly in public spaces. The 5G-VICTORI UCs: **UC #1.1**, **UC #1.3** and parts of **UC #2** contribute to the former, in the rail sector. The functionalities here are signaling, rail monitoring and critical services, such as emergency communication. There are no immediate privacy concerns, thus this contributes to scenario II, with positive potential for SDG 3.6 (reduction of traffic accidents) and 8.8. (protect labor rights) **UCs #1.2** and **#3** contribute to safety in public spaces, specifically onboard buses and in train stations. While this can contribute to SDG 16.1 and 3 (strong institutions and reduction of violence), there are substantial concerns regarding privacy and human rights, particularly if camera surveillance is used in conjunction with AI, which may also allow for facial recognition and similar functionalities [68]. Moreover, for such functionalities, very high data rates and a high volume of data is necessary (which is of course why 5G technologies are enablers for such UCs), which contributes to the absolute increase of energy consumption. Accordingly, several services within this service area may lead towards scenario I, to a use of intelligent security that may not be sufficiently focused on privacy and yield an overall high consumption of energy.

Real time intelligent utilisation captures optimised utilisation of technical equipment, processes and infrastructures, both in companies as well as in cities and communities (see section 4.3.2). **UC #4** contributes to this service area: it comprises firstly a service providing energy metering in a smart city context (public buildings and street lighting), including telemetry analytic tools for consumption monitoring. Secondly, it comprises real-time power consumption measuring in a rail context, allowing operators to apply smart energy management techniques. These services promise to contribute to a sustainability-focused use of real time intelligent utilisation thus contributing to SDG 7.3 (energy efficiency) and 8.4 (resource efficiency in production and consumption). While there are concerns regarding privacy in smart city applications [68], these do likely not primarily concern the main types of data relevant here (power consumption).

Regarding predictive maintenance, **UC #1.3** and **UC #2** demonstrate the use of predictive maintenance both in a rail infrastructure as well as a factory and power plant setting. This contributes to SDG 8.4 (resource efficiency in production and consumption, 8.8 (decent work and full employment), 9.1 (sustainable and resilient infrastructure), 9.4 (upgrading infrastructures), 11.3 (inclusive and sustainable industrialisation) and 12.2 (resource efficiency).

The service area real time on-demand services for travellers consists of a variety of different services, such as streaming on board public transportation, multimodal travel planning solutions and guidance in transport and public spaces. UC 1.2 contributes to multimodal travel planning and guidance, improving the travel experience and the comfort of travellers. Through making public transport more attractive it also may contribute to shifting to more environmentally friendly modes of transport, contributing to SDG 8.9 (sustainable tourism/job creation), 11.2 (sustainable transport systems) and 13.2 (climate change measures). Depending on the data capacity required, which may be high if VR/AR technologies are used, this can also contribute to increasing the overall energy consumption of the infrastructure, especially if mmWave is required. These potentials need to be further examined and balanced against each other. **UCs 1.1**, **1.2** and **3** focus on providing streaming access on board public transport. On the one hand, this can substantially improve the comfort of travellers and beyond this it can also contribute to accessibility of information and media (furthering SDG 10.2, inclusion). On the other hand, a rise in streaming, in particular mobile streaming with high resolution, significantly increase the rise of energy consumption [68]. Thus, streaming services can contribute to steering towards scenario II, by means of a comfort and growth focused implementation of real time on-demand services for travellers that neglects sustainability aspects. Research and development regarding more sustainable streaming technologies can alleviate this to some extent. A step in this direction is the 5G enabled data shower service developed in 5G-VICTORI, making high quality streaming on trains possible without making it necessary to implement a massive data transfer capacity all along the train route. Data on the overall impact of this concept on energy efficiency are not available yet. In sum, the benefits of services offering high resolution streaming need to be weighed against the substantial impact on energy consumption.

The final service area considered in the scenarios is Real time VR/AR enabled training and education. One service within **UC #1.2** focuses on providing a remote training class using 360° VR multi-camera live streaming. This has the potential to provide high quality or specialist education and training in areas where this is difficult until now and to provide such content to large numbers of students. A further extension is training and safety instruction in companies. This service can contribute to SDG 4.4 (skill creation), 8.5 (full employment and decent work), 8.8 (labour rights and safe work environments) and 10.2 (inclusion). At the same time, since VR/AR require large data capacity and may require mmWave, it is likely to contribute to high absolute energy consumption.

### 4.4.3 General insights and policy recommendations

A first point that emerges from the expert interviews conducted in the process of identifying KFs as well as from the existing literature is that services have the larger potentials regarding positive contributions to SDGs, as compared to the infrastructure. Regarding the infrastructure there is also a notable difference in the possible contribution to SDGs, but the impact is likely to be smaller [91] [93] (expert interviews). Nevertheless, even though the size of the impact of designing the infrastructure in a more sustainable vs. a less sustainable way may be smaller, it is of high importance to realize all the potential that there is. Main reasons for this are not only the goal of energy efficiency and saving, but also the necessity of decarbonizing energy sources and the time it will take to fully do so as well as the current limits of the expansion of renewable energies as discussed in section 4.4.1.

Examining and comparing the sustainability potentials of 5G services and infrastructures and the fact that there may be a conflict of goals between the two makes it particularly important to look at the intersection of both, as has been done in the previous sections focusing on the scenarios for more general and on 5G-VICTORI for more concrete conclusions. In the next few paragraphs insights concerning the 5G infrastructure will be discussed first, followed by insights focusing on services and finally by insights and policy recommendations focusing on the intersection of service and infrastructure impact.

Concerning the infrastructure, energy management and technology modernisation are two factors that can contribute to reducing the energy consumption of 5G infrastructures and are part of an SDG advancing scenario. All efforts should be made to support the first factor. With regard to the second, it is important to also take into account resource concerns. In-depth analyses examining energy consumption patterns and focusing on simultaneous minimisation of energy consumption and efficient utilisation of resources need to be conducted. Projects focusing on these issues should be tendered. When considering expansion plans of mobile network operators, decisions should be based on plans for optimizing energy efficiency and generally the plans for aligning the expansion with sustainable resource utilisation and energy minimisation. This should also be taken into account regarding the number of antenna sites (see also section 4.4.1). The number of antenna sites also has implications for energy consumption. Because the amplifiers needed to strengthen the signal consume a considerable amount of energy, it can be efficient to increase the number of antenna sites though this depends on a number of factors including geographic topology [15], antenna technical specifications and configuration options. Decisions regarding the number of antennas should be also informed by the implications for energy consumption and resource usage, and shall come hand in hand with the antenna technical specifications and configuration, as well as with the intended service/ traffic coverage. Similarly, under energy efficiency considerations fiber is preferable to wireless transport -only considering some aspects of the infrastructure-, because of lower energy consumption by signal transmission [94].

A further aspect that has potential to impact energy efficiency but was not considered in the scenarios is national roaming. Depending on the distribution of antenna sites by operator and the distribution of customers national roaming and sharing of antenna sites can lead to increases in energy efficiency if the distribution is sufficiently uneven [15]. The aim of national roaming is to eliminate coverage outages and connectivity bottlenecks (e.g. in rural areas and in cases of interruption), to enable load balancing, to reduce unnecessary redundancy of RAN and TCN infrastructures by different network operators and to secure investments. The potential of national roaming should be considered with potentials for energy efficiency in mind, although the energy saving potential during operation is expected to be rather small in some country contexts (e.g. expectable around 6% in Germany due to topology and settlement characteristics.

While the main sustainability implications of the 5G infrastructure concern environmental sustainability, an important social sustainability aspect is captured by KF K, digital divide and accessibility. In particular, the equality of infrastructures between urban and rural areas becomes all the more essential the more services are based on 5G. As discussed before, 5G wide coverage is not necessarily compatible with the goal of limiting the overall energy consumption. There is, accordingly, a conflict of goals between a strong accessible implementation and the mitigation of the energy consumption increase.

A further related aspect concerns accessibility for business actors and competitiveness: The more (industrial) service types are enabled by 5G, partly by private campus networks, the more important it is that such infrastructures are also accessible for medium and small industrial actors, including non-profit organisations or communal and other public actors.

Concerning services, in the previous two sections we focused on specific service areas (KFs M – Q). Examining the broader scope of services enabled by 5G, in our expert interviews the services that were ranked highest in terms of impact on sustainability, in particular environmental sustainability were the following: 1. Transport, with the main potential identified lies in reducing the km travelled, especially by motorised individual transport; 2. The power grid, with intelligent management enabling better use of renewable energies; 3. Heating of buildings, including all smart city or smart home measures leading to heating efficiency. Flexible work and agriculture were also named, although, with respect to flexible work in particular, the reliance on 5G was not seen as necessarily very strong (expert interviews).

Turning to the intersection of service and infrastructure impact and examining this ranking and the potentials for the service areas included in the scenarios, it stands out that those service areas that require especially high data rates and a large network capacity (eMBB) are rarely those that promise positive impacts on environmental sustainability goals. Consider high resolution streaming: while this benefits customer comfort and market growth to some extent, in general it does not have any positive impact on environmental sustainability. Studies indicate that mobile streaming causes 2.5 times as many greenhouse gas emissions as streaming via fixed network, at the same resolution. Streaming with 5G compared to 4G is 2.5 times more efficient considering GHG-emissions. The highest impact is caused by a higher resolution (from HD to Ultra HD), as one hour streaming in HD needs 700 MB compared to 7.000 MB for one hour Ultra HD [95] [68]. This example shows that - despite energy efficiency gains - overall energy consumption is likely to increase. This is a classic example of a rebound effect (as discussed above), which has been demonstrated in many other cases. Since 5G primarily entails new services, high rebound effects can also be expected here [68]. While some studies appear to have overestimated the importance of streaming, even studies with lower estimates stress the importance of rebound effects and doubt that the efficiency gains can keep pace with the growing demand [96][95]. An exception could be the application cases for public transport as discussed above, here there is the potential that high quality/interruption free streaming increases the attractiveness of public transport and reducing the kilometers travelled by car. Concerning energy metering applications, these have a substantial potential for furthering energy efficiency and renewable energy infrastructures and, depending on the number of sensors and data transmission required, do not belong to the high contributors to the energy consumption of 5G-infrastructures (expert interviews). Regarding 5G services utilizing AI, depending on the service area there are potentials for environmental sustainability, as seen, for example, in the ranking above. The use of AI can also lead to substantial energy consumption [68] [97]– 5G enabled services relying on AI thus constitute a case were the potential for energy reduction and the required energy for providing services and training models can be balanced directly. The net impact here depends mainly on the energy reduction potential of the service, but also on how the model is trained, e.g. the extent to which audio and video data, which is requires considerable energy, are used for training [68].

Accordingly, 5G enabled services are likely to differ greatly in terms of their net impact on all three sustainability dimensions: environmental, social and economic sustainability. The set of 5G enabled services realised should comprise those that have higher overall potential. Each service idea should be examined with regards to its potential and should accordingly be modified either to lead to lower energy consumption increase in the 5G infrastructure or to rely not on mobile networks but on other types of connectivity (such as fixed broadband or Wi-Fi) in the cases where this is more energy efficient.

On the infrastructure side, the potentials for energy efficiency through, for example, energy management need to be fully realised. Besides fostering more research in this area, optimal energy management can be brought about by introducing obligations for actors such as network operators to demonstrate the implementation of the best possible energy management practices and requiring energy-optimised routing or evidence of demand-optimised power control. Yet with an expansion of the types and numbers of services relying on the mobile network some aspects of energy management possibilities face limits: for example, the time periods in which parts of the infrastructure can be turned off will become fewer, because different services will be required at different times (expert interview).

Looking at energy efficiency more generally it is likely that there are still substantial energy gains possible, but in the future the possible gains will become smaller, as the gains through miniaturisation face technical limits [68].

Beyond energy efficiency, the sustainable use of materials used for production should be taken into focus as well. In mobile network infrastructures shorter innovation cycles can contribute to energy consumption/efficiency, but taking into account the full life cycle implications and considering recycling, both up and down stream becomes of utmost importance. In sum, technology modernisation can have efficiency effects in the short run, but only if the recycling of the required materials, especially rare materials, is made possible, as demand will increase by 2030. Moreover, extracting these materials requires significant effort, often under questionable conditions (e.g. military dictatorship in Myanmar). The process produces toxic and radioactive waste and also toxic waste water. In the short term, the European Commission's proposal from the 16th of March 2023 for a recycling quota of 15% for strategic materials should be approved by the European Parliament and the Council of the European Union and implemented in the EU countries as soon as possible. A long-term target of 50% should be set. To achieve this, the collection of electrical appliances - especially those with high proportions of these materials such as loudspeakers, wind turbine motors and computer hard drives - should be made mandatory. Mandatory quotas for a certain share of secondary materials should be imposed on producers. In addition, the circulation of these materials should be recorded, e.g. in cooperation with the Rare Earth Industry Association. In design guidelines, such as the eco-design directive, the possibility of simple recovery of these materials should also be introduced as an obligation [91] [98]. Partnering with international companies should further be in accordance with the Corporate Sustainability Due Diligence directive and national Supply Chain Acts. This applies not only to the mobile network infrastructure, but importantly also to end user devices.

Overall, it is the promise and the potential of 5G (and 6G) to enable new types of services in mobile networks. Examining this from a sustainability perspective, it becomes clear that some such services can have a positive impact while others are likely to increase the energy consumption of the mobile infrastructure to a non-trivial degree without providing sustainability benefits. To reach an SDG advancing scenario, a subset of services that are on balance net-positive in their sustainability impact should be realised and not all potential services that may be marketable among end users should be implemented. Incentives should be set accordingly. This makes clear how important sustainability-oriented business modelling by companies becomes – integrating sustainability values by those actors that significantly shape the demand of the end users contributes to reaching an SDG advancing scenario.

Recommendations:

- Sustainability oriented business modelling should be promoted, already in early stages of technology and especially service development.
- Identify the 5G enabled services with the highest positive sustainability potential (our experts name transport and the power grid – promote and invest in these services.
- Examine the net sustainability potential of 5G enabled services, including the expected impact of the service as well as the infrastructure requirements - a system of sustainability reporting mandating an impact assessment of specific services that gauges environmental, social and economic potentials and consequences can help identify services with a net positive impact.
- Real time on-demand services for travelers: focus on those services that are most likely to reduce individual motorised kilometers travelled – focus on services that have a net positive sustainability potential and are likely to contribute to making climate friendly transport more attractive.
- Intelligent security: those services involving CCTV and video data need to be evaluated particularly carefully with respect to energy requirements but also privacy concerns.
- The net sustainability potential of predictive maintenance and real time intelligent utilisation is likely to be positive – such services should be promoted, though there is a potential of privacy issues, which needs to be taken into account.
- More research on energy consumption in 5G infrastructures is needed and necessary data should be made available.
- Research on energy consumption patterns and possibilities of energy management should be fostered.
- Incentives to maximise energy efficiency need to be implemented (for example, if energy costs can be passed on to end users this can reduce incentives).
- A normative framework providing guidance for the deployment of mmWave infrastructure should be formulated: mmWave deployments shall be evaluated considering energy consumption minimisation aspects, as well as ensuring that the services enabled have a clear, positive sustainability impact.
- Network expansion plans should require alignment with sustainability plans, focusing on resource utilisation and energy minimization.
- Decisions regarding the number of antenna sites need to be informed by the antenna configurations considering also energy consumption and resource usage aspects.
- Campus networks offer the possibility to utilize the functionalities enabled by 5G, also including those requiring very high frequencies realised by mmWave, while limiting the scope of the role out of very high frequencies.
- To the extent possible, hardware utilised in technology modernisation should also be obtained from sources that use renewable energy in the production process.
- The European Commission's proposal from the 16$^{th}$ of March 2023 for a recycling quota of 15% for strategic materials should be approved and implemented in the EU countries as soon as possible, a long-term target of 50% should be set.

# 5 Conclusion and final remarks

This deliverable documents the work done in 5G-VICTORI Task 5.3 “Business Plans, Impact Assessment and Exploitation strategies”, focusing on different aspects of the impact of the 5G-VICTORI project. While business plans capture the economic impact in the sense of developing new business models, exploitation captures the technological, scientific and commercial takeaways, thus creating the basis for all further impact. The impact assessment in this deliverable focuses on the expected impact with respect to social and environmental sustainability.

The deliverable first presented the business modelling activities and results, with a focus on sustainability-oriented business modelling. The awareness of sustainability-orientation of the consortium as a whole, within the business modelling process and formulated business plans is noticeable. Several business models have been promoted by some of the 5G-VICTORI partners that are being validated through (additional) user testing and other measures to then be finalised.

In the second part, exploitation activities and outcomes were documented. As a large project covering multiple verticals, testbeds and types of partner, the exploitation activities by partners are very diverse and cover a wide area of different outcomes. Besides documenting exploitation by partner, we also presented the main assets created through 5G-VICTORI. This includes the testbeds, the operating system and the mobility management function. Beyond this, it is notable that there are a range of other assets with broad use for other actors and the community. This includes a start-up and a competence centre, as well as the creation of tools for sustainability assessment, energy metering and techno-economic analysis.

In the third part the expected impact on sustainability (environmental and social) was analysed. For this the focus was broadened, looking at the expected impact of 5G infrastructure and service scenarios more generally. In a second step this perspective was applied to 5G-VICTORI, examining how it contributes to which scenario. One takeaway here is that 5G-enabled services have large sustainability potentials, including net potentials (taking infrastructure aspects such as energy consumption into account). Yet to realize these potentials it is necessary to actively shape the developments. One important way to do so is integrating sustainability-oriented business modelling as the standard approach to creating new services.

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# 7 Appendix

### 7.1 Generic process model for sustainability-oriented business modelling

## Generic Process for Sustainable Business Modelling

created by Henning Breuer & Kiril Ivanov of UXBerlin in November 2021

Horizon2020 European Union Funding for Research & Innovation

izt Institute for Futures Studies and Technology Assessment

UXBerlin Innovation Consulting

## I. Introduction

This generic process model should enable you to create and consolidate sustainable business models for your 5GVictori service ideas. It describes five overarching steps (see fig. 1 below) and is complemented by a number of resources and templates that contain further support and instructions (make sure you have these available in a folder with this document). One person within your organisation should volunteer to go through these materials and to facilitate the process. She or he will need at least one week to prepare and facilitate this process, and another to analyse and refine the workshop results, but will also learn a lot about sustainable business modelling. In the end you should have one or serval business models to communicate and proceed with, and a profound shared understanding also about its / their maturity respectively the need for further experimentation and investigation.

### II. Background

The 5G-VICTORI project (funded as part of EU's H2020 program) supports the development of new business models that spur the transition from 'network as an asset' towards 'network as a service' model visions. To achieve this objective, and to ensure integration of 5G network services on the European market, the 5G-VICTORI consortium conducts business modelling workshops. Business modelling has become essential to innovation management, especially for establishing new service offerings and advancing the development of emerging industries, such as 5G. Moreover, well-defined business models help to recognize business opportunities, attract investors and avoid uncertainties and risks.

There are numerous tools and conceptual approaches that support business modelling but only a few aim at developing sustainable business models (SBMs). Recognising that sustainability is a top priority for both public and private actors in the EU, 5G-VICTORI adopts the Business Innovation Kit (BIK; Breuer, 2014; resource 1 - paper introducing the toolkit: Breuer & Lüdeke-Freund 2018). The BIK is a toolkit specifically designed to facilitate business model innovations that integrate and cater to stakeholder values, such as sustainability, security or privacy. This values-based approach does not simply address sustainability as a constraining factor that requires a reactionary response to comply with regulation. Instead, it focuses on utilizing stakeholder values as enablers and drivers of sustainable business model innovation. Taking stakeholder values into account will allow you to clarify and establish overarching directives as a basis for (sustainability-oriented) purpose, mission and vision statements that will direct your future business. Values will also provide you with a heuristic for ideation and for evaluating the strengths and weaknesses of your business model at an early stage of the innovation process. The BIK is there to help you and your team to take advantage of these potentials and model new values-based businesses or advance your existing business ideas while keeping different stakeholders in mind. Using the BIK, you will be able to gather ideas relevant to all key components of your business model (such as value proposition, revenue model, capabilities, partners, cost structure etc.), to develop a shared understanding of your future business, and to identify key potentials and challenges for its implementation.

Besides the BIK, a collection of 45 sustainable business model design patterns will provide you with a set of proven and reusable solutions to reoccurring sustainability challenges (Lüdeke-Freund et al., 2021). Each SBM pattern exemplifies business design options within and across business model components. It contains problem and solution statements, an outlook statement as well as references and examples of various sustainable businesses and the essential components of their business models. The patterns will enable you to identify which priorities and potentials for sustainable business modelling are most relevant to your business idea.

Now, let us take a closer look at how to prepare a business modelling workshop, how to facilitate it using the BIK and what to consider when analysing the results and proceeding to the next steps.

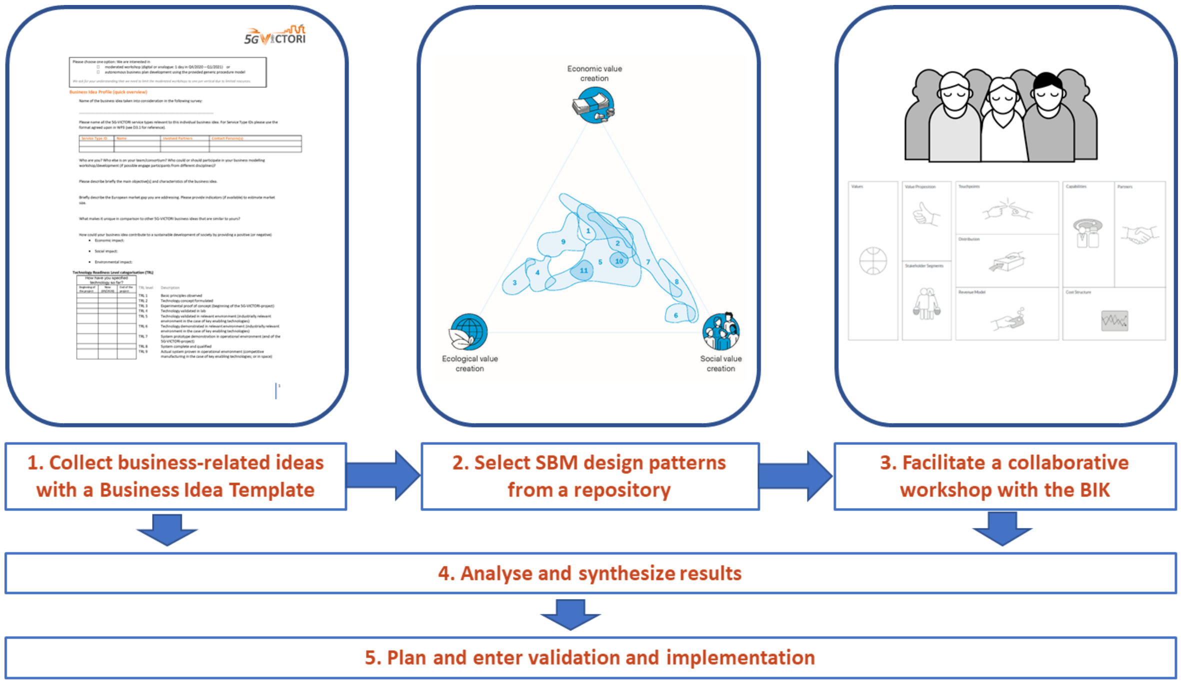


**Figure 7-1 Overview of overarching steps in the generic workshop process model**

# III. Generic process model

## 1. Collect business-related ideas

Before the workshop, some basic information should be collected to prefill the business model template. Send out a survey (resource 2 - Business Idea Profile Template (see below); resource 3 - refinement sheet for business modelling, available here[4]) to the providers of the business idea to collect initial assumptions and set the scene for values-based business modelling. Determine the name of the BI, its main objective[s] and characteristics, its uniqueness and the market gap it addresses, how it can lead to positive (or negative) economic, social or environmental impact, and who are the key partners and associates involved. Also note down which are the 5G-VICTORI service types relevant to the business idea and what is the categorisation of the Technology Readiness Level (TRL).

## 2. Select SBM design patterns

Afterwards, browse through the collection of SBM design patterns (resource 4 - SBM Design Pattern Collection, see Appendix to Lüdeke-Freund et al., 2018; a more comprehensive collection in Lüdeke-Freund et al. 2022) to select suitable patterns that can advance the sustainability aspects of the business idea. You can search for those patterns that address sustainability challenges, which are commonly experienced by relevant stakeholders. Start by looking deeper into the underlying causes of these challenges. Are they primarily environmental, social or economic? Then look into the respective corner of the SBM triangle to discover relevant solutions and pathways for business modelling. Alternatively, you can search the patterns without having a particular problem in mind but rather seeing them as sources of inspiration to advance individual business model components or their interrelations. For instance, you can look into the "Pricing & Revenue Patterns" to find alternative revenue models that can increase the accessibility of an offering or into the "Eco-Design Patterns" to find new ways for optimizing capabilities and offering more ecological value propositions. Whatever strategy you choose, remember that a pattern is not a ready-made solution but a template that needs to be adapted to the particular business idea and its potentials for sustainable value creation. Therefore, it is essential to derive questions from the selected design pattern(s) that will guide the participants' ideation during the workshop.

For example, in the case of *vCDN (virtual content delivery network) services for railways*, the *Resource Efficiency and Productivity* pattern (resource 5 - Design Pattern from Lüdeke-Freund at al. 2022. examples available here) suggested to enhance the business model through system thinking and technological solutions that can reduce energy consumption. Based on these considerations the following guiding questions were derived and presented to the participants at the beginning of the workshop:

I. How can we increase resource efficiency and productivity?
II. if we think about the whole vCDN system rather than isolated parts?
III. Which new value propositions can we formulate? Which benefits can we promise?
IV. How can we improve supply and procurement, or internal processes?
V. How can we make the most efficient use of technology?
VI. How can we design for easy, maintenance, repair and recycling?

In the case of **UHA** with their *Multimodal Mobility Services*, the same SBM design pattern can be used to generate a different set of questions:

- What new value propositions can be formulated for travellers sharing your pro-environmental values?

[4] https://www.uxberlin.com/wp-content/uploads/2018/02/Values-Based_Business_Modelling_UXBerlin.pdf

- Which new stakeholders can be engaged to improve the regional passenger transport system rather than just isolated parts?
- How can you improve supply and procurement or internal processes?
- Can you introduce new revenue streams from add-on services?

### 3. Facilitate collaborative stakeholder workshop

Before preparing the workshop, consider which **participants** should contribute and invite them several weeks before, also sending an agenda. For best results, engage diverse stakeholders – including business professionals, colleagues from other departments, representatives of potential partner companies or customer groups, engineers and other experts. Get 4 to 12 participants on board and plan for a 3 to 4 hours session. Make sure that all participants are familiarised with the background of the business idea, the business model concept, the objectives of the workshop and the selected SBM pattern(s). You can send out a written summary of these details (including the resources mentioned above) before the workshop and then briefly present them at the start of the event. Since the workshop is facilitated using the virtual whiteboard **MURAL**, you should also share basic instructions on how to use the platform (e.g. a short video). Advise the participants to use a laptop with mouse instead of a phone or a tablet (since the latter will hinder fluent writing and moving on the whiteboard). Alternatively, you can use a BIK composed of tangible cards in a face-to-face environment.

Also make sure to **warm up** the participants before the actual business modelling starts. One good approach is to ask them to bring an object that they associate with the business idea. (For instance, in the case of *vCDN*, a showerhead might illustrate the 'data shower' metaphor, a train ticket might refer to the open issue of pricing such a service, a mobile phone can depict the concern that downloading the app might become a bottleneck for adoption.) When the participants introduce themselves, they can also introduce the object and explain its significance. This allows participants to highlight an important aspect that they would like to stress during the workshop and that can contribute to the ideation and discussions later on.

**Preparing the workshop session**, create a few slides with the warmup-exercise, agenda, and introduction to the business ideas and the **concept** for the workshop. You also need to adapt the MURAL board. A public version of the MURAL board can be found here (resource 6: Mural Board Image, see figure 2 below). Please request a private link to an editable board for each new session that you are going to moderate. Prepare the board by prefilling all information concerning the various business model components, which you collected through the (resource 2 & 3) Business Idea Template and Refinement sheet from the idea providers. Use one colour of sticky notes (e.g. light blue) to add these details to the respective field (i.e. business model component). Underneath the triangle on the left side of the workspace, you can paste further relevant information, e.g. screenshots and explanations of the SBM pattern(s) that you selected for the workshop. Add the guiding questions that you derived from the SBM pattern(s) in the designated field above the business model canvas. Assign a colour code for the main customer groups and also indicate that in the sticky notes on top. Participants should try to use sticky notes with a corresponding colour when they add ideas referring to these customer groups.

Depending on the domain and focus of the business idea additional frameworks can be integrated to structure the discussion. For instance, for modelling "*On Demand Private Network for Industry 4.0 capabilities*" we drew from an energy hierarchy framework (Wolfe 2013) to prompt reflection on how the technology can be used to improve usage of renewable energy sources, make energy usage more efficient and/or realize energy savings.

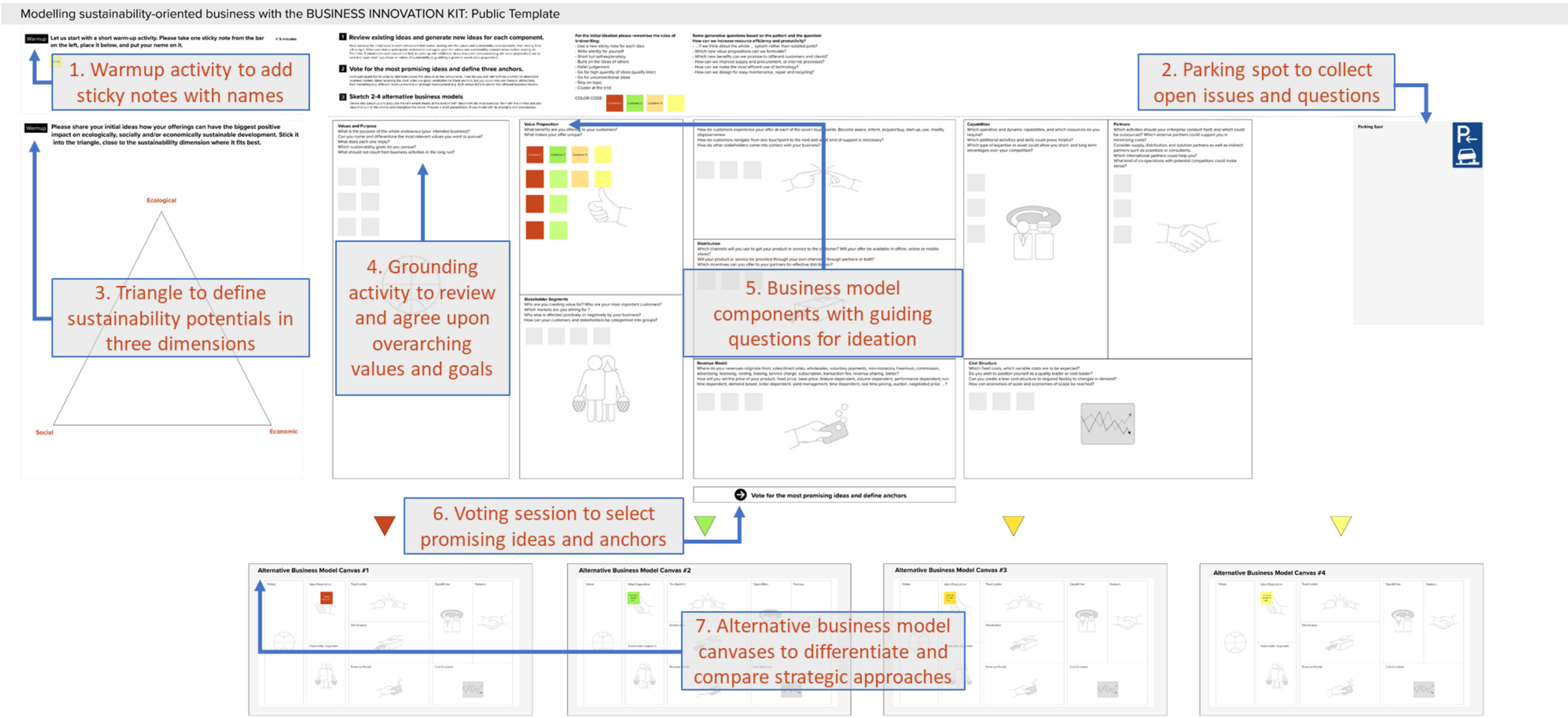


**Figure 7-2 Overview of the MURAL board and facilitation steps**

1. The MURAL board contains all necessary instructions for moderating the workshop. Start by asking the participants to add a **sticky note with their name** in the first box on the top left. This will allow you to find out if everyone is comfortable with using the platform – or to provide further instructions for those who need help.

2. At this point, you can also introduce the **"parking spot"**, on the very right of the MURAL board. There participants can "park" their sticky notes with critical questions that crop up during the workshop but cannot be sufficiently discussed within its timeframe. Dealing with these questions is one of a series of further steps.

3. Then you can introduce the rules for brainwriting which are listed on the top of the board. In the second warmup activity, ask the participants to generate initial ideas about how their business can bring about the biggest positive impact on ecologically, socially and/or economically sustainable development. They should place these ideas close to the corresponding sustainability dimension in the **triangle**. This initial activity generates a set of sustainability potentials, which can be considered and elaborated upon during the subsequent business modelling.

Each field of the business model canvas comes with a set of questions that stimulate creative discussions and idea generation among the participants. It is not necessary to address all those questions or to answer them from top to bottom. Just introduce some of them before a brainwriting round begins.

4. The BIK process starts with a **grounding** exercise to review and agree upon overarching values and goals. This determines the „common ground" of fundamental values that the business model should be based on. "Like in the case of a search engine provider claiming to reorganize the world's knowledge, these ideal values reach beyond profit-oriented economic goals" (Breuer, 2014, 16). For example, they can be derived from a consideration of what is important to customers or other key stakeholders. Participants should define a set of (for instance 3 to 7) core values. It may be helpful to arrange these values in a hierarchical order, placing the most important priorities for the business on top. At a later stage in your business development project, participants may also come up with a purpose, mission and vision statement based on the core values.

5. The next step is to generate ideas for the individual **business model components**, moving from left to right through the workspace. This will require the most time for deliberation and discussions. Depending on the business idea and the number of participants, time may be short to address each one of the components, one by one. In that case, you can focus on those components that are most crucial for the business development and that can contribute the most for realizing the previously defined values and sustainability potentials. However, it is essential to address at least one component from each of the three component clusters, representing demand (the value proposition and the stakeholders being addressed or affected by the model), customer interaction (the touchpoints between stakeholders and the company, including the customer journey, distribution and revenue model) and business performance aspects (the capabilities of the venture, its key partners and cost structure).

6. Thirty minutes before the end of the workshop, start a **voting session** in MURAL and invite participants to vote for those ideas that they find most promising. Then discuss and define two to four anchors for alternative business models. Ideas receiving the most votes are good candidates for these anchors, but you can refer to the other approaches for selecting anchors suggested in the task description on MURAL or simply use the main customer groups that you colour coded before the workshop.

7. Copy the selected anchors to the **alternative business model canvases** on the bottom and divide the workshop participants into groups that will work on them. The groups should

look into the previously generated ideas and copy those that fit to the anchor that they work on onto the same alternative canvas. The same ideas can be copied to different canvases as long as they fit to the anchor therein. In the end, you are likely to have 2 to 4 distinctive business model sketches, each illustrating consistent strategic alternatives for your intended business, each depicting unique relations between values, sustainability potentials and business model components. Before closing the session, ask each group to present their canvas. Then invite all participants to share final words and reflect on the biggest challenges and risks for implementing each business model in the market and realizing its sustainability potentials.

Don't forget to **record** the session in order to be able to focus on the flow of the session and postpone its documentation and analysis. Inform participants that the recording will not be shared with anyone outside the consortium and will be used only for analysis purposes.

At the end, allow some discussion among the main idea providers, which ones of the strategic alternatives they would start with if they had to select one, and for their reasoning behind this decision. In some cases, this will be evident since one model sticks out as the most promising or comprehensive one, whereas others require further research or development with respect to business model components. You can also force a decision for one preliminary top candidate through voting.

## 4. Document, analyse and synthesize results and implications

After the workshop, you should compare and synthesise the generated ideas and considerations for sustainable business modelling and describe them in a comprehensive document. Start by gathering, sorting and evaluating all previously generated ideas as well as any further relevant information about the intended business. Extract quotes from the recording of the workshop that explain the ideas in more detail. In some cases, further desk research might be required to spell out and qualify contributions from the workshop. Collect statements about the main challenges and success-critical issues to implementing the business model and contributing to sustainable impact. Then take a deeper look into the results with the consideration of different stakeholder perspectives (e.g. customer groups, partners, network providers, public organisations, etc.) and sustainability potentials (economic, social, environmental). Think about the advantages and disadvantages of alternative ideas for how to design the business model components and their interrelations. The outlook statements in the collection of SBM design patterns can give you hints to describing some of these aspects. Other publications about business modelling can also help you to weigh ideas and elaborate on the potential gains and risks that they imply.

The next step is to integrate the contributions from the workshop participants and your notes into a coherent structure as follows:

1. The workshop synthesis starts with the part you write last: A short summary of the **key takeaways**, including the core values, potential contributions to sustainable development, key value propositions and other essential aspects of the business model design, critical success factors and challenges. Summarize how the values and sustainability potentials contribute to differentiating the business model design and bring benefits to different stakeholder groups. Present the most promising 1-2 models and explain the relations between values, sustainability potentials and business model components.
2. Provide further details about the **objectives, values and sustainability potentials** of the intended business. Start with the main objective[s] and characteristics, the market gap that the 5G service addresses and its TRL. Then describe the core values (and if available any normative – purpose, mission or vision-related – statements) defined by

the participants. You can present the values in a hierarchical order and in relation to different stakeholder groups (see example from the *Multimodal Mobility Services* case). Highlight alignments between stakeholder values. These can provide a basis for establishing mutually beneficial relationships with business partners or customers based on shared values. Describe the used SBM patterns and how they contributed to the ideation process (e.g.: What questions were derived from the patterns?). Describe the sustainability potentials (economic, environmental, social), how they can be realised and which stakeholders would benefit from them.

3. Continue with a description of the business model design, i.e. the ideas for **each individual business model component.** Describe what are alternative designs depending on which stakeholder group is prioritised within the business model rationale. For example, considering the demand side, a value proposition can be provided B2C (e.g. selling a travel guidance app directly to passengers) as opposed to B2B (offering digital brokerage for insurance providers) or B2B2C (providing travel guidance for free and selling the collected passenger data to insurance providers; see case of *Multimodal Mobility Services*). Depending on which stakeholder group is primarily addressed by a certain value proposition, the other business model components are modified accordingly.

   For example, a B2B model will differ from a B2B2C model in terms of the marketing strategies, partner relationships or revenue models that it uses. Sometimes, alternative business model designs are differentiated only with respect to a single business model component. For example, in the case of *vCDN services for railways*, three alternative revenue flows are described depending on which stakeholder is responsible for deploying the network infrastructure. Such distinctions should be complemented with a visualisation to enhance comprehensiveness.

4. Enrich and expand your discussion by taking **scientific insights and literature** (e.g. on sustainability and impact management) into account to reflect upon key aspects of you envisioned business model and review its implications. For instance, consider unintended consequences of innovation and rebound effects that diminish gains in resource or energy efficiency by behavioural or systemic responses. For example, energy saving though *vCDN services for railways* can be levelled out up by increased demand for high quality video (while still increased attractiveness of carbon neutral electric trains might lead to an overall positive impact in the long run). If the business model is already well defined, you can also prepare a result chain matrix (e.g. based on DECD 2017) in order to describe how flows of business activities should lead to business outputs, associated outcomes and pre-defined intended impact. In most cases, however, it will be too early for such a structured assessment of environmental, social and economic impact.

## 5. Plan and enter validation and implementation

Next come the first steps for putting your ideas into practise. Now you need to communicate the workshop results, evaluate the different assumptions and gain traction within a (test) market environment. By reflecting upon the workshop results you will gain understanding of strengths and potential weaknesses for each component and the interaction between them. You will also be able to define what further capabilities are required to realize the sustainability potentials of the intended business (e.g. collecting user data, complying with environmental standards, using tools for footprint monitoring). Create a few slides based on the synthesis documentation to trigger further discussion and clarification of the business model design. Bring forth the open issues, which could not be sufficiently addressed and clarified during the workshop. Your team has already gained a shared view on the basic components of the business model but those initial assumptions still need to be further specified, validated, adjusted or even pivoted during the upcoming steps of (test) market introduction.

## References

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DCED (2017). Guidelines to the DCED Standard for Results Measurement: Articulating the Results Chain. Online, 3.9.2018: https://www.enterprise-development.org/wp-content/uploads/1_Implementation_Guidelines_Results_Chains.pdf

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# Business Idea Profile Template

**Goals in T5.3**

"This task focuses on the commercial exploitation and impact assessment of project results. This cover (1) business models & plans, (2) commercial exploitation strategies and (3) assessment of overall project impact. Business models and plans will be defined within the first half of the project and further refined and matured in the second half. The iterative process integrating stakeholders from early stages is based on a thorough strategic and commercial analysis of exploitable assets. Exploitation strategies developed per partner and product will be integrated in order to use synergies, optimize market potential and maximise impact. The impact assessment will be performed on the basis of high-level KPIs and by upscaling the project results to national and EC level. Input is provided by T3.4 use case assessment and T4.5 cross-site integration. It covers economic, environmental, social dimensions and innovation aspects. It also identifies contributions to Sustainable Development Goals and includes assessment of the sustainability performance of 5G infrastructures" *(Source: 5G-VICTORI Grand Agreement).*

Empowering vertical industries requires **appropriate business models** for each use case. Iterative business modelling **from the early stages of the project** allows to:

- clarify and review assumptions among the participants
- leverage diverse stakeholder knowledge to create innovative business models
- ensure efficient collaboration based on shared values (e.g. prioritizing privacy or security, affordability or efficiency, or a specific understanding of sustainability goals)
- ensure that viable and sustainable business models are developed that can be implemented in each city.

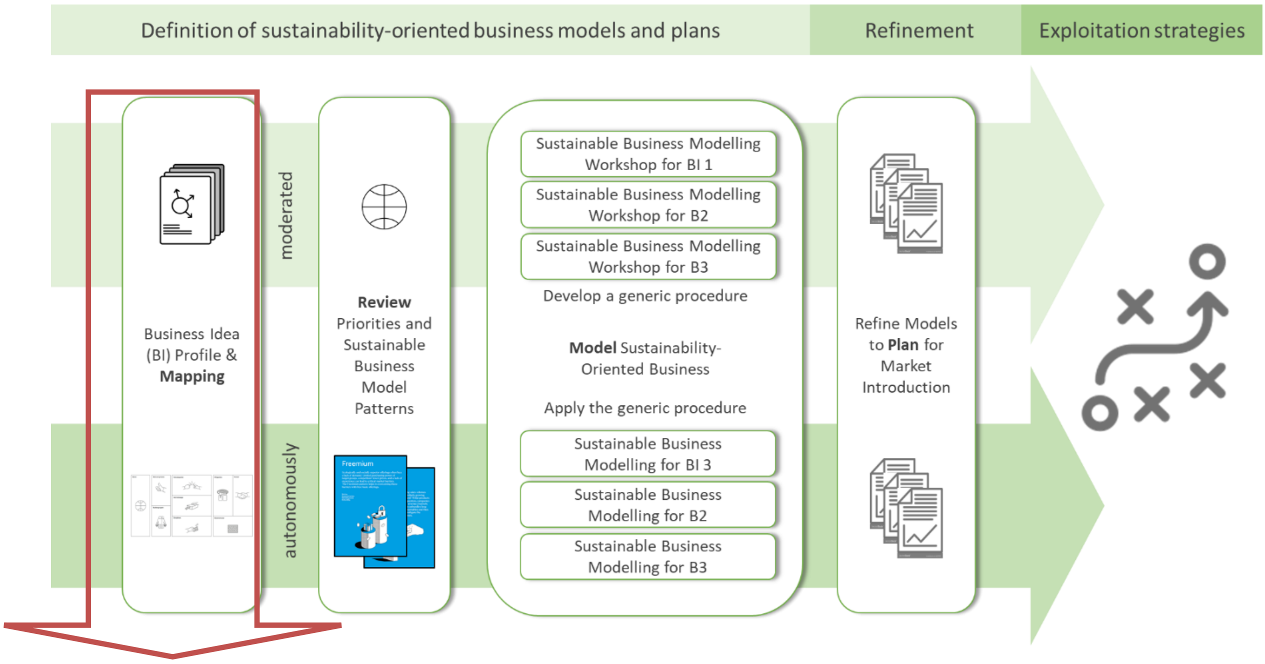
Exploitation activities will focus on the formulation of novel business models and plans towards ensuring commercial exploitation of the project work and results providing benefits beyond the project end.

**Process**

1. Identify business ideas (BI) either at UC or service type level; business idea profiles and business model canvas (BMC) need to be filled in within 2 weeks.

2. Conduct 3 workshops (one per vertical per cluster) with stakeholders to specify and prioritize potential business models for each business idea. Preparation of the moderated workshops includes a review of potentially applicable sustainable business model patterns.

3. Document the methodology and develop a generic procedure model as a blueprint for other business ideas that autonomously develop their business models.
4. Elaborate upon exploitation strategies and activities




**To do:**
Please fill in the Business Idea Profile including the business model canvas for your Business Idea (BI) since they are fundamental for the development of the business models.

Please choose one option: We are interested in

- ☐ moderated workshop (digital or analogue: 1 day in Q4/2020 – Q1/2021) or
- ☐ autonomous business plan development using the provided generic procedure model

*We ask for your understanding that we need to limit the moderated workshops to one per vertical due to limited resources.*

## Business Idea Profile (quick overview)

Name of the business idea taken into consideration in the following survey:

______________________________________________________________

Please name all the 5G-VICTORI service types relevant to this individual business idea. For Service Type IDs please use the format agreed upon in WP3 (see D3.1 for reference).

| Service Type ID | Name | Involved Partners | Contact Persons(s) |
|---|---|---|---|
| | | | |

| | | | |
|---|---|---|---|
| | | | |
| | | | |

Who are you? Who else is on your team/consortium? Who could or should participate in your business modelling workshop/development (if possible engage participants from different disciplines)?

Please describe briefly the main objective[s] and characteristics of the business idea.

Briefly describe the European market gap you are addressing. Please provide indicators (if available) to estimate market size.

What makes it unique in comparison to other 5G-VICTORI business ideas that are similar to yours?

How could your business idea contribute to a sustainable development of society by providing a positive (or negative)

- Economic impact:
- Social impact:
- Environmental impact:

**Technology Readiness Level categorisation (TRL)**

How have you specified technology so far?

| *Please select* | | | | |
|---|---|---|---|---|
| Beginning of the project | Now (09/2020) | End of the project | TRL level | Description |
| | | | TRL 1 | Basic principles observed |
| | | | TRL 2 | Technology concept formulated |
| | | | TRL 3 | Experimental proof of concept (beginning of the 5G-VICTORI-project) |
| | | | TRL 4 | Technology validated in lab |
| | | | TRL 5 | Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies) |
| | | | TRL 6 | Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies) |

| | | | | |
|---|---|---|---|---|
| | | | TRL 7 | System prototype demonstration in operational environment (end of the 5G-VICTORI-project) |
| | | | TRL 8 | System complete and qualified |
| | | | TRL 9 | Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space) |

## Business Model Canvas (detailed information)

Please answer the following questions to share your first ideas about different business model components. Your answers will help us to select the three moderated workshops and provide a necessary input for all business modelling workshops. Please answer at least one of the questions in each component (i.e. values, value proposition, stakeholders …) – select one or two of the questions that you can easily answer with respect to your business idea. You can either enter them here in the Word file, or use this interactive PDF (just download, enter your text into the boxes and save the file). The review of project-related values at the beginning of the modelling process facilitates cooperation and improves your prospects for effective implementation of ideas into viable business models. Therefore, we start with your business-related values in order to understand what is important for you and your founding partners.

**1) Values: The most important priorities for your business.**

What is the purpose of the whole endeavour? What mission or vision do you pursue?

Can you name and differentiate the most relevant values you want to pursue? What does each one imply?

Which sustainability goals do you pursue? What should not result from business activities in the long run?

**2) Value proposition: The benefits you are promising to customers and stakeholders.**

What benefits are you offering to your customers?

What makes your offer unique?

**3) Stakeholder Segments: Anyone being affected and / or contributing to your business idea.**

Who are you creating value for? Who are your most important customers?

Which markets are you aiming for?

Who else is affected positively or negatively by your business?

How can your customers and stakeholders be categorised into groups?

**4) Touchpoints: Where you get in contact with your customers and other key stakeholders.**

How do customers experience your offer at each of the seven touchpoints: Become aware, inform, acquire/buy, start up, use, modify, dispose/renew.

How do customers navigate from one touchpoint to the next and what kind of support is necessary?

How do other stakeholders come into contact with your business?

**5) Distribution: How do you acquire and supply your customers?**

Which channels will you use to get your product or service to the customer?

Will your offer be available in offline, online or mobile stores?

Will your product or service be provided through your own channels, through partners or both?

Which incentives can you offer to your partners for effective distribution?

**6) Revenue Model: How do you generate revenues and determine prices?**

Where do your revenues originate from? Consider for instance: sales/direct sales, wholesales, voluntary payments, non-monetary, freemium, commission, advertising, licensing, renting, leasing, service charge, subscription, transaction fee, revenue sharing, barter.

How will you set the price of your product? Consider for instance: fixed price, base price, feature dependent, volume dependent, performance dependent, run-time dependent, demand based, order dependent, yield management, time dependent, real time pricing, auction, negotiated price.

**7) Capabilities: Which skills and resources do you need in order to fulfil your value proposition?**

Which operative and dynamic capabilities, and which resources do you require?

Which additional activities and skills could prove helpful?

Which type of expertise or asset could allow you short- and long-term advantages over your competition?

**8) Partners: Your most important business partners with complementary capabilities.**

Which activities should your enterprise conduct itself, and which could be outsourced?

Which external partners could support you in minimizing costs?

Consider supply, distribution, and solution partners as well as indirect partners such as scientists or consultants.

Which international partners could help you?

What kind of co-operations with potential competitors could make sense?

**9) Cost structure: Cost drivers including fixed investments and variable costs.**

Which fixed costs, which variable costs are to be expected?

Do you wish to position yourself as a quality leader or cost leader?

Can you create a lean cost structure to respond flexibly to changes in demand?

How can economies of scale and economies of scope be reached?

## 7.2 Reports from business modelling workshops

### 7.2.1 5G-VICTORI Business Modelling Workshop – Pervasive vCDN services adaptive to network resources for railway environments

***5G-VICTORI Business Modelling Workshop - Pervasive vCDN services adaptive to network resources for railway environments***

Synthesis of ideas and considerations for sustainable business modelling
(Draft of May 3rd, 2021 by UXBerlin)

This document synthesizes of ideas and considerations derived from a co-creation workshop conducted on the 23.04.2021 with the aim to explore potential sustainable business models for provisioning of "pervasive vCDN services adaptive to network resources for railway environments". We present the main objectives, values and potentials that motivate the venture and its sustainability orientation. Then we proceed with a comparative analysis and synthesis of the ideas generated in the workshop from the perspective of a vCDN service provider and with regards to different business model components (i.e. value proposition, stakeholder segments, touchpoints, distribution, revenue model, capabilities, partners and cost structure) and generic stakeholder groups involved in the business model rationale (passengers, railway operators, network operators and content providers). Finally, we discuss the main challenges and success-critical issues to implementing the business model and contributing to sustainable impact through vCDN services.

**Key takeaways:**

- Monitoring, assessment and optimisation of environmental benefits of infrastructure and energy efficiency should be integrated in the further development of the technical solution and the business case. However, rebound effects need to be considered.
- Increasing attractiveness of electric public transport (e.g. no need to collect content upfront) through provision of uninterrupted quality video can lead to relevant environmental benefits.
- Railway operators can benefit from the vCDN service as a new and unique asset to bundle into special offerings. User acceptance of the app, and pricing scheme (fixed, subscription, pay-per-view, and / or premium) are critical for widespread adoption.
- Key stakeholders are vCDN service provider, railway passengers, railway operators, network operators and content providers. Contractual agreements among the business partners are essential to ensure effective cooperation.

- Alternative revenue models depending on whether the end customer is considered to be the end customer of the network provider or the railway operator.
- Organisational capabilities with respect to technology, partnering and legal competencies, marketing and sustainability management are essential to deliver the value propositions in an energy efficient manner.

**Essential specification of business model components**

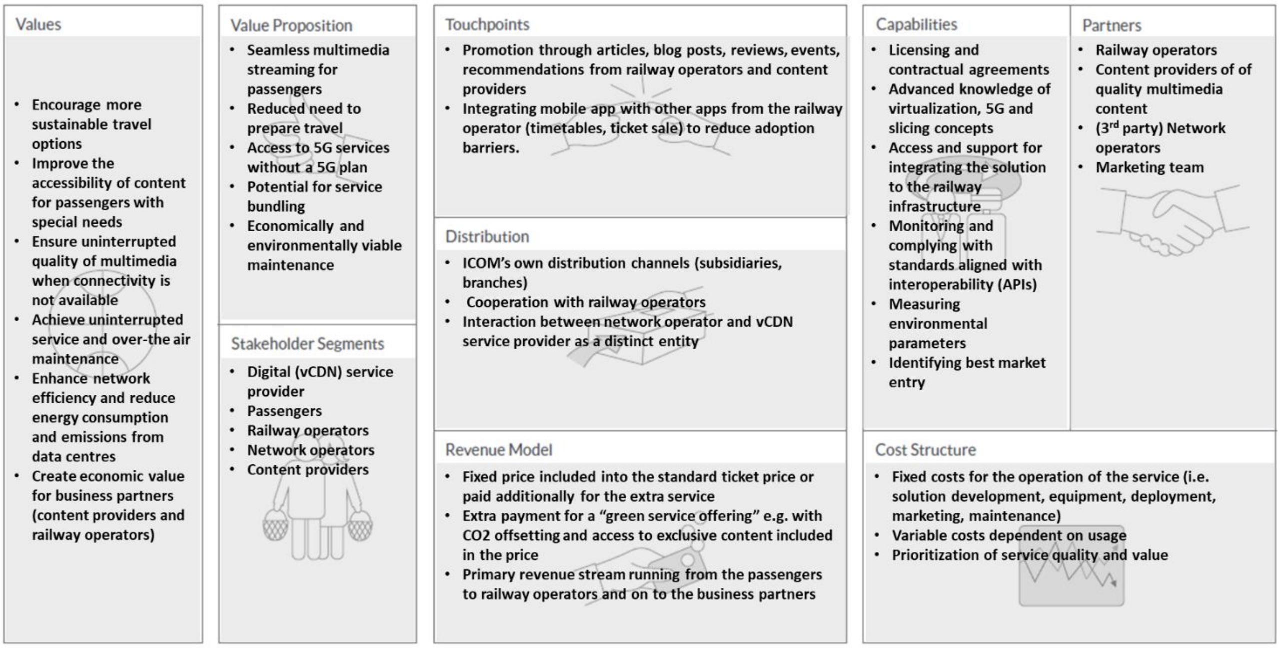



**Figure 7-3 Business model component overview of vCDN services for railways**

**Main objectives and values**

**Objectives/characteristics:**

The main objectives and characteristics of the business idea can be summarised as follows:

- Train passengers select their content of preference through a CDN application installed on their devices (smart phones, tablets, laptops) which has access to the content caches through trains local network (e.g. Wi-Fi).
- The content caches of the train are automatically updated with new ultra-high-quality video content through 5G connections when a high-speed train arrives at train stations (data shower). The vCDN proactively brings large volumes of high-quality target content on-board during short-time stops. Video continuity and high-quality maintenance are achieved during the whole journey on the train, even in areas where there is no network coverage.
- The virtualised CDN solution for multimedia content in railway environments is based on existing ICOM fs|cdn® Anywhere solution. The end-to-end fs|cdn® Anywhere platform enables service providers to deliver high-quality video to any television, computer, smartphone or tablet. It smoothly bundles middleware & conditional access offering live TV, video on demand, restart TV, network DVR and TV anywhere over any managed or unmanaged network.
- A similar usage scenario can be also applied in other cases like the case of ships (cruise ships, passenger ships, etc.) whose content servers can be automatically updated with new content via 5G connections when they arrive at a port. This is an indication of the perspectives of the BI.

**Market gap and uniqueness**

This idea addresses a considerable gap in the European market which results from the increasing demand for integrating media industry offerings within the transportation sector. More and more transport organisations have started to provide multimedia content to their passengers for their trip duration for infotainment purposes. Up to now however, the available content is locally prefetched beforehand and remains static during the trip without being periodically updated. The business idea not only provides passengers with updated content during connectivity periods but also suggests - if appropriate 5G technologies are available - to bring enough content on the train so that the passengers can watch without interruption until the next update. The uniqueness of the business idea lies in the fact that it addresses the case where there is no network connectivity available on-board. Without such offering, passengers would face interruptions and quality fluctuations in the content during train movement or cannot receive any content at all.

**Technology Readiness Level (TRL)**

The solution proposed is currently TRL4 (Technology validated in lab). The prototype that will be created will be demonstrated in the operational railway environment of TRAINOSE in the 5G-VINNI Patras testbed and will reach up to TRL7 (System prototype demonstration in operational environment) by the end of 5G-VICTORI.

**Initially identified sustainability potentials**

Initial sustainability potentials of the business idea with respect to economic, social and environmental impact were discussed prior to the workshop:

- Economic impact: The business idea will bring more revenues to Media Industry, network, service and solution providers and railway operators who offer the final service.
- Social impact: Infotainment continuously available to transportation passengers.
- Environmental impact: Since the vCDN service will make adaptive usage of the available network resources, it can optimize resource efficiency leading to reduced energy consumption. Moreover, it will help make the railways a more attractive means of transport, resulting in less use of private transports and thus positive effects on the environment.

**Values-based and sustainability-oriented priorities of vCDN services for railways**

To provide a directive and initial framing of the sustainable business modelling activities in the workshop, participants started with reviewing and agreeing upon sustainability-related priorities, values and goals that motivate the new business. To do that they elaborated upon two preformulated statements that specify the business's priorities in a conventional sense:

- "The main priority for our business is to provide a valuable and reliable solution for customers and stakeholders, and specifically achieve uninterrupted service and quality maintenance."
- "The purpose of our business idea is to overcome in practice the interruptions and quality fluctuations in multimedia content on a moving train when connectivity is not available."

Furthermore, the participants could put their business idea into a sustainability perspective with reference to the "***Resource Efficiency and Productivity***" design pattern for sustainable business modelling. This pattern was selected from a collection of 45 proven and reusable solutions to reoccurring sustainability challenges (Lüdeke-Freund et al., 2021) and helped participants to identify which priorities and potentials for sustainable business modelling are most relevant with respect to their idea. The main principle behind the Resource Efficiency and Productivity pattern is to meet customer needs while optimizing the efficiency and productivity of the capabilities within the business model. There are two distinct and complementary ways through which this can be achieved. First, whole-system thinking can be used to optimize the use of key resources and activities throughout the whole system, rather than tinkering its isolated parts. In the case of vCDN services, where service provision relies on the interaction between multiple actors engaged in fulfilling various complementary functions, such an approach reveals opportunities to increase efficiency of content delivery through the whole 5G ecosystem. Second, the Resource Efficiency and Productivity pattern focuses on "adopting or developing technological solutions wherever they reduce the use of material or energy" (ibid, 2). Again, in the case of vCDN services, virtualisation of conventional networks allows for optimisation of resource efficiency leading to reduced energy consumption. Following these considerations, we provided the following guiding questions to reflect upon potentials to increase resource efficiency and productivity when modelling individual business model components as well as their interrelations:

- How can we increase resource efficiency and productivity?
- …if we think about the whole vCDN system rather than isolated parts?
- Which new value propositions can we formulate? Which benefits can we promise?
- How can we improve supply and procurement, or internal processes?
- How can we make the most efficient use of technology?
- How can we design for easy, maintenance, repair and recycling?

Taking into consideration the potentials for creating sustainable value-add that the provision of vCDN services implies, we identified several sustainability-oriented priorities to cater to with respect to the main stakeholder groups targeted by the business idea.

*End users* of vCDN services can respond to their environmental concerns by encouraging more sustainable travel options that reduce their CO2 footprint. In addition, social benefits for passengers can also be realised through vCDN services. The technology can contribute to the accessibility of content for customer segments with special needs, such as kids, elders, people with disabilities, etc. For example, passengers can be connected to private vCDNs that offer access to TV subscription services with tailored content for kids, such as educational movies or environmental documentaries, which create positive impact on social knowledge.

While vCDN services can reduce the environmental footprint of public transport by making it more attractive to *railway* passengers, the adoption of this new technology as well as its continuous maintenance and optimisation does not come at the price of reduced environmental performance for the railway operators. Since system updates are implemented over-the-air they do not depend on on-sight *operations*, which eliminates costs and environmental impact from physical mobility of maintenance staff and from service interruptions. Moreover, the vCDN service can utilize the functionality of servers that are already available at the train stations, which allows railway operators to upgrade their infrastructure more efficiently, i.e. without the need to install new hardware.

Depending on which stakeholder undertakes the network *deployment* (either the railway operator or the network operator) economic value-add can be realised through the utilisation of existing network infrastructure and the resulting returns on investment. Besides enabling the exploitation of investments from existing network resources, vCDN services can also contribute to enhanced environmental and economic performance of the network deployment itself. Because the virtualised service is delivered over the cloud rather than through physical hardware.

With respect to the *content providers*, vCDN services can enhance the accessibility of content, leading to more revenues from maximised viewing time and/or new subscriptions. For example, some content providers (like Cosmote TV) offer subscription contracts that combine traditional (over fixed line or satellite dish) and mobile TV services. However, in many cases customers are reluctant towards such kind of offerings because they often find themselves unable to watch mobile TV through the common public network, due to latency and other network quality issues. However, data showers that deliver high-quality TV content at train stations can incentivise customers and trigger increased subscriptions.

These *environmental benefits* of increased energy efficiency of content provision (e.g. in comparison to a pre-fetched content solution, or individual content storage by each passenger), over-the-air updates and utilisation of existing network infrastructure have to be estimated, quantified and monitored during (test) operations – according *data* is currently missing. In addition, potential rebound effects must be considered – for instance improvements in energy efficiency can easily be levelled out by increased quality video consumption on trains. Increased attractiveness of carbon neutral electric trains might lead to higher positive impact in the long run.

In any case, the outlined potentials for sustainable value creation (including increased attractiveness for passengers) provide a directive for the following specification of business model components and a later development of the business case, as well as for the technical development and operations design.

**Demand**

**Value Proposition:**
The business modelling of value propositions distinguished between different potentials for value delivery with respect to the four generic stakeholder groups.

For *passengers* the provision of vCDN services enable them to enjoy multimedia services during their train journey without interruptions or quality fluctuations. Frequently updated content (automatically updated through data showers in each train station) allows streaming near-live infotainment like news, movies and sports. In addition, there is a possibility for content providers to offer access to exclusive content for end-users that take advantage of the vCDN service and purchase an associated subscription plan. Even passengers who do not have access to stable high bandwidth streaming through their device plan or do not have a 5G-capable device can benefit from the seamless multimedia streaming enabled by the vCDN service. Simply using the Wi-Fi network already available on board of the train they can access high-quality content suited to their needs. Instead of preparing the multimedia content for their travel in advance, for instance downloading their favourite movies or appropriate content for kids, the users of the vCDN service can benefit from a reduced need to prepare their journey as this content will be readily available on board.

The above-mentioned passenger benefits serve as a value proposition that the *railway operators* can also capitalize upon since the available onboard media will make their travelling offerings more attractive. In addition, the railway operators can benefit from the vCDN service as a new and unique asset to bundle into special offerings from their portfolio. For example, agreements with the content providers can enable provision of exclusive content as a compensation or indemnity for train delays. This can help to minimize customer complaints and churn rates.

Another value proposition for the railway operators is the minimum interference for service maintenance. Since the service offers a software-based solution coupled with advanced management and orchestration mechanisms, updates can be processed over-the-air, with minimum disruption of services at railway sites. Moreover, railway operators do not need to install dedicated devices for the particular vCDN service and can utilize the existing servers available on their trains, which again should create economic and environmental benefits.

Here it is important to mention that there are two different and mutually exclusive alternatives of designing the business model and defining the value propositions that it will offer to the stakeholders operating the network deployment.

In one case (A) the network deployment is realised by a *railway operator*, who already operates a private FRMCS (Future Railway Mobile Communication System) network and therefore has the capability to support and operate the new generation of 5G networks. In that case the network infrastructure is updated and fully deployed by the railway operator itself, either as a private network or as an extension of the public network. In this first case, railway operators can increase their revenues through offering infrastructure (slice provisioning) for the vCDN service deployment and through final service consumption by the passengers (as example of "Business" services in FRMCS categorisation (FRMCS Functional Working Group, 2016). This will also enable them to achieve differentiation on the market and thus increase customer (passenger) acquisition.

In an alternative case (B), the network infrastructure is owned and operated by a *communications service provider*, i.e. network provider. In this case, where the network deployment is undertaken by network operators, these can increase revenues through providing connectivity to the railway operator's infrastructure as well as through offering virtual infrastructure slices of their deployed network to the vCDN service provider. Here the value proposition for the network operators is the unveiling of a new market, which will allow them to exploit their network infrastructure in a better way (through virtualisation and slice provisioning), and which will also generate new revenue streams for them.

The value proposition offered to the *content providers* is also related to the unravelling of new market opportunities. Through the adoption of vCDN services in railway environments content providers that have previously not been able to offer their services on trains will now get access to a new customer segment – the passengers.

**Stakeholder Segments:**

There are various (provisioning) actor roles in the 5G ecosystem which can be assumed or shared by single or multiple business stakeholders simultaneously, depending on the specific business environment, stakeholders' interests and capabilities, etc. Hallingby et al. (2019) identify 23 key actor roles for 5G ecosystems that can be grouped in 9 role clusters. According to the authors these role clusters are "sufficient for describing most of the business models in the future 5G ecosystem" (ibid, 36). Using their classification, we can generalize the provider of the vCDN service in the business model as a *digital service provider*, i.e. a service provider which offers online application services to vertical service providers, which are in turn facilitating the service provision to end-customer or are the end-customers themselves (ibid, 33f). However, it should be noted that the role of the digital service provider can be realised by different mapping of business stakeholders to it. vCDN software can be operated by a digital service provider whose functions are fulfilled either by a network operator as a single actor or in collaboration with vCDN service provider (owning the images and operating the software) who interfaces the customer and the network operator and shares revenues in the value chain. In the business modelling workshop participants assumed the latter, more generic scenario, which describes how vCDN services can be introduced to any market as opposed to only ICOM's market.

Furthermore, as discussed in the previous section, the potential split of actor roles, which can be undertaken (or shared) by various stakeholders can also take place if the vCDN service provisioning is realised over network infrastructure deployed by the railway operator. This scenario can be compared to two previously described business models within the 5G-PICTURE project (Theodoropoulou et al., 2020), where:

- The railway industry (driven by FRMCS) undertakes the role of network deployment and operation, and leases resources to 3rd parties, and interacts with public telecom operators.
- Venue owners undertake the role of network deployment and operation, and lease resources to 3rd parties, such as content providers and public telecom operators for various business purposes.

Synthesizing the above discussion, the stakeholder segments of a generic business model of vCDN services for railways can be described as follows:

- ***Digital service provider*** (or ***vCDN service provider***) who offers the described vCDN solution for railway environments.
- Railway ***passengers*** who are affected as the end users consuming the service offered on board.
- ***Railway operators*** who contribute to the business idea by offering their railway (and network) infrastructure to get the service deployed.
- (5G) ***Network operators*** who are offering the required network infrastructure.
- ***Content providers*** who provide the multimedia content which is offered to the passengers.

**Interaction**

**Touchpoints:**

Customers and other stakeholders can get informed about the vCDN services through articles, blog posts, reviews and events. The railway operator will acquire the service through direct installation of the components on their premises. The service will be started up by the vCDN service provider on-site. For any modifications or disposal/renewal the railway operator will be in contact with the vCDN service provider. Since the service needs to run on top of a railway operator's infrastructure, it can be recommended to passengers through the railway operator. Content providers can also raise awareness about the service.

The train passenger will be able to acquire the vCDN application by downloading it on his/her mobile device or laptop (e.g. from Google Play Store / from on-board network). Then, he/she will be able to start up the service through the installed app on his/her device and navigate to use the service by selecting his/her content of preference. Any modifications will be made directly through the UI of the vCDN app. However, the need for users to download, approve and update yet another app on their mobile phones may act as a major *barrier to service adoption*. Therefore, it was stressed that the vCDN service provider should make downloading and running the app as easy as possible. Potentially, the app may be integrated with other apps from the railway operator that offer timetables, ticket purchase, etc.

**Distribution:**

ICOM's distribution channels and its network of subsidiaries and offices around the world (indicatively: Russia, Saudi Arabia, South Africa, USA) offer the potential to effectively introduce and promote vCDN services in markets where the company is already active. Another route to the market can be realised through cooperation with railway operators. In the scenario in which the vCDN service provider assumes a distinct role (interfacing the customer and the network operator through slice provisioning) the distribution channels will depend on the interaction between these two entities.

**Revenue model:**

The pricing scheme that was considered as most relevant for the business model is based on a *fixed price* paid by passengers for the use of the vCDN service. This fixed price can be either included into the standard train ticket price or paid additionally for the service, offered as an extra. The latter approach will allow railway operators to reach price sensitive customers while offering other customers the possibility to get access to high-quality multimedia content as needed. This approach is considered relevant because railway travel offerings require a pricing scheme that can appeal to a variety of customers.

Other alternatives were also considered by the workshop participants. For example, *subscription* pricing can allow for more predictable cash inflows, help to establish longer-term relationships with customers and lower cost-barriers for them. However, subscription pricing also creates a barrier that might make the offering interesting only to frequent travellers once they are already convinced of the service. This challenge can be addressed by offering a *free trial* period, however this will also limit the potential to generate revenues from occasional travellers. Another pricing scheme that can be used in the business model is *pay-per-view*. It can be based on the time the service is used, the amount of downloaded data or the type of content (e.g. standard content is offered at a fixed price while exclusive content is payed per view). This strategy can similarly lower cost-barriers for customers, but it can also create a negative impact on customer retention rates, make revenues difficult to predict and discourage users who view a lot of content.

Ideas on how to make the business model more sustainable via the pricing strategy were also proposed. For example, in a *green premium* model, users may pay extra for using a green alternative of the offering (e.g. with CO2 offsetting included in the price) and receive access to exclusive content or other perks as opposed to users who pay for the standard offering only.

The revenue model and the distribution of cash flows among the involved stakeholders can be designed differently depending on whether the end customer is considered to be the end customer of the network provider, the vCDN service provider or the railway operator. In the case where the passengers pay directly to the railway operator, this primary revenue stream can be distributed among the business partners as follows (also see fig. 2):

- The railway operator pays a fixed price to the vCDN service provider for the provision, licencing and operation of the service. Alternatively, the railway operator can pay a commission rate based on their revenues from vCDN service users.
- If the network infrastructure is deployed by the network operator (B / see purple arrows in fig. 2) then the railway operator pays to the network operator for the connectivity established on the railway infrastructure. In that case the railway operator will not only pay for utilizing the network infrastructure for vCDN services but also for the utilisation of the FRMCS provided by the network operator. However, since the network operator has to deploy equipment to the railway operator's premises they would also need to pay leasing costs for the site.
- If the network infrastructure is deployed by the railway operator (A / see red arrows in fig. 1) then the railway operator is paid for deploying the vCDN service by both the end customer and the vCDN service provider (whose role can be undertaken either by the network operator or by a distinct stakeholder). In that case the vCDN service provider generates revenues from the content provider.
- If the vCDN service provider is a distinct stakeholder who interfaces the customer (passenger) and the network operator, then the vCDN service provider pays to the network operator for the virtual infrastructure resources provided (see pink arrow in fig. 2).

- In both alternative, the railway operator and/or the vCDN service provider pays the content providers.

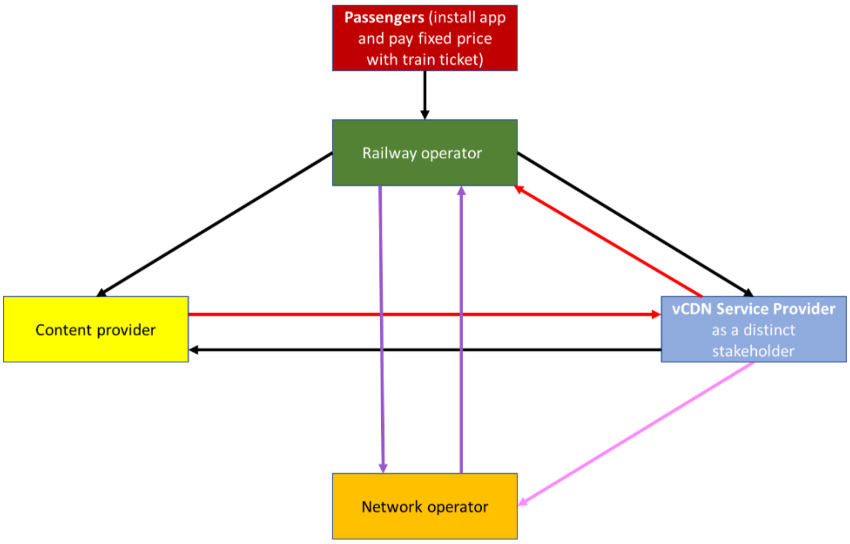



**Figure 7-4 Visualisation of the revenue model if passengers pay to the railway operators, considering the cases where the network operator deploys the network infrastructure (purple arrows), the railway operator deploys the network infrastructure (red arrows) or the vCDN service provider is a distinct stakeholder (pink arrow)**

In an alternative revenue model (not depicted in fig. 2) the passenger pays directly to the network operator to receive the vCDN service, then the network operator pays the content providers, the vCDN service providers, and also potentially to the railway operators in order to compose all the necessary operations so as to offer the final service to the end customer.

**Performance**

**Capabilities:**

Organisational capabilities with respect to technology, partnering and legal competencies, marketing and sustainability management are essential to deliver the value propositions in an energy efficient manner.

The inherent capacities of the vCDN platform include its potential to be deployed over versatile networks, customised and optimised. However, the actual deployment of the service depends on 5G access (5G protocol) backed with advanced knowledge of virtualisation technologies, 5G and slicing concepts. Thus, the business model relies not only on the capabilities that can be developed by the vCDN service provider internally (e.g. software development, trialling, implementation and maintenance) but also on *partnering* to include the capabilities of the other stakeholders involved. The railway operators have to provide the railway environment and support regarding the integration details of the solution on the infrastructure. Corresponding *contractual agreements* with the railway and network operators need to be established. Network operators would also need to monitor and comply with standardisation activities and evolvement of standards aligned with interoperability aspects (e.g. APIs). Content providers need to provide high-quality multimedia content to be offered to the end users as well as support regarding the definition of the technical interface between the vCDN solution and the content. Corresponding licensing and contractual agreements will be required.

The vCDN solution implementation also depends on identifying best *market entry* with respect to partnership agreements, target customer segments and types of multimedia content to be offered. An appropriate pricing strategy should be developed and adjusted to the market needs.

In order to improve the *sustainability* of the business model, to attract a larger user base through market differentiation and to increase passengers' awareness about their environmental footprint it is necessary to *monitor* and communicate environmental parameters such as energy consumption and savings. This will require the development of appropriate *indicators and tools* for measuring them.

**Partners:**

Partnership agreements need to be established in order to support the capabilities mentioned above. These include:

- Agreements with railway operators to provide infrastructure where the network components will be deployed.
- Agreements with content provider to provide the content for distribution to end users, and definition of the interface between the vCDN solution and the content.
- Agreements with (3$^{rd}$ party) network operators.

Additional agreements need to be established with a marketing team for dissemination of the solution online and in media and for reaching directly those consumers who are most interested in purchasing the service.

**Cost Structure:**

Fixed costs include the operation of the service (i.e. solution development, equipment, deployment, marketing, maintenance) whereas variable costs include any cost that depends on the volume of dta transmissions (e.g. usage on-board). While cost efficiency is an important priority for the service provision, it should not come at the price of reduced service quality and use value.

**Challenges and success critical issues**

Figure 7-4 summarizes the key aspects of the proposed business model with respect to the individual business model components and the values-based and sustainability-oriented priorities of the endeavor. During the workshop key challenges and success criteria issues to implementing the business model were identified:

- **Integrating** the – previously missing – **sustainability impact assessment** and optimisation in the further development of the technical solution and the business model.
- **Communicating environmental parameters**, such as energy consumption and savings.
- **Motivating passengers** to download the new mobile application and **reducing other potential barriers to adoption** (costs, lack of awareness about the service, lack of awareness about environmental impact.
- **Integrating the mobile application** with apps from the railways.
- **Identifying best market entry** with respect to partnership agreements, target customer segments and types of multimedia content to be offered.
- The need to **get the different parties on board** (**in legal terms** and with respect to **technical interoperability**).
- **Aligning the interests of all business partners** for cooperation in mutually beneficial ways.
- **Refining the revenue model** with convincing value propositions and revenues for all parties.

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### 7.2.2 5G-VICTORI Business Modelling Workshop – On Demand Private Network for Industry 4.0 capabilities

*5G-VICTORI Business Modelling Workshop -*
*On Demand Private Network for Industry 4.0 capabilities*

**Synthesis of ideas and considerations for sustainable business modelling**
**(June 11th, 2021 by UXBerlin / Henning Breuer & Kiril Ivanov)**

This document synthesizes the ideas and considerations derived from a co-creation workshop conducted on the 31.05.2021 with participants of ADMIE, Patras, IZT and UXBerlin. The aim of the workshop was to explore **potential sustainable business models for market introduction of “On Demand Private Network for Industry 4.0 capabilities”** with the Patras SG Autonomous Edge mobile box. The Patras SG Autonomous Edge solution is provided by a joint venture, consisting of **ADMIE** S.A. (Research, Technology and Development Department, Information Technology & Telecommunications Department, Transmission System Maintenance Department), which facilitates the integration of industrial protocols and sensors, and the University of Patras (NAM Research Group), which provides the networking and computational resources and orchestration. We present the main values that motivate the venture and its sustainability potentials. Then we compare and synthesize the ideas generated in the workshop with regards to different business model components (i.e. value proposition, stakeholder segments, touchpoints, distribution, revenue model, capabilities, partners and cost structure). Two alternative business model sketches resulted, one focussing on customised solutions for fixed plants of industrial clients or utilities with a negotiated pricing, another focussing on temporary standard implementations with run-time pricing and / or a pay-for-success business model especially for pilot clients. Finally, we discuss the main challenges and success-critical issues to introducing a business model with environmental and social benefits through the Patras SG Autonomous Edge solution.

**Key takeaways**

- Efficiency, security and safety are core values of the project. Potential contributions to a sustainable development can be achieved in three domains:
  - **Enhancement of process and energy efficiency** in industrial sites (e.g. through on demand private network deployment, integration of low-energy sensors, predictive and condition-based maintenance): Enhanced industrial efficiency reduces CO2 emissions, results in cost savings and contributes to the affordability of several manufactured products’ and (utility) services. It can also improve the safety of personnel, e.g. during maintenance procedures.
  - **Facilitating a seamless transition to more sustainable Industry 4.0**: The integration of both legacy and state-of-the-art equipment contributes to a seamless and economically viable transition towards more sustainable Industry 4.0.
  - **Enabling 5G connectivity in isolated areas**: Extended 5G connectivity to elsewise off-grid locations contributes to improved safety and well-being of remote communities and ecosystems (e.g. through prevention or recovery in disaster areas management).
- Data **security** is an important value for industrial clients that can harm the marketability of the solution if not adequately adopted and communicated.
- Key **value propositions** of the business model are linked to the sustainability potentials of the solution, i.e. to enhance energy efficiency of industrial plants or utilities through: 1) on demand private network deployment; 2) integration of state-of-the-art, low energy sensors; 3) enabling third-party optimisation of power consumption and 4) prediction of spikes in energy demand; as well as to optimize the utilisation of equipment through 5) predictive maintenance and 6) virtualisation.
- The business idea is **transferable** to a variety of different use cases even beyond the industrial domain (e.g. firefighting, rescue, research, transportation, festivals, leisure events, tours). This poses the challenge of recognizing and addressing the specific requirements of many different client segments.

- Some success **critical aspects** still need to be evaluated and defined:
    - The primary contact for clients: A client facing unit, with one representative from each of the three partners, may be formed especially for this purpose.
    - Indicators and methods for monitoring and proving the environmental benefits.
    - A revenue model that specifies how value is captured and redistributed among the three project partners and how it may be expanded to other application domains (i.e. beyond industry 4.0).

**Essential specification of business model components**

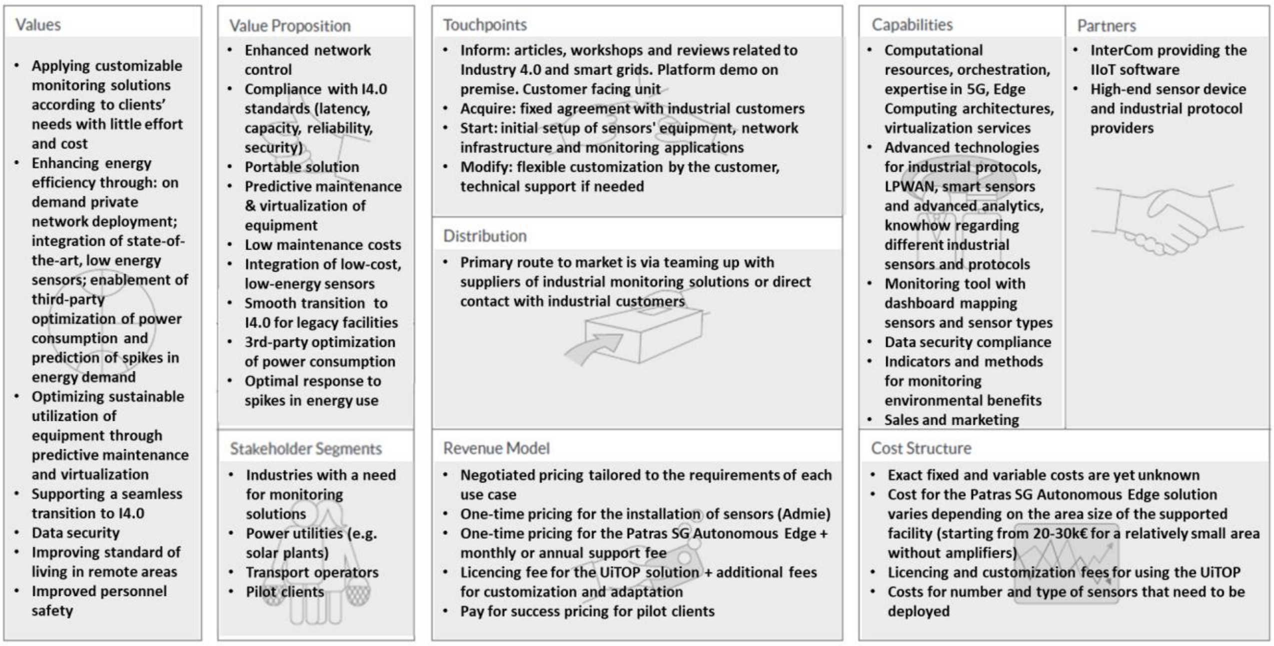


**Figure 7-5 Business model component overview of On Demand Private Network for Industry 4.0 capabilities**

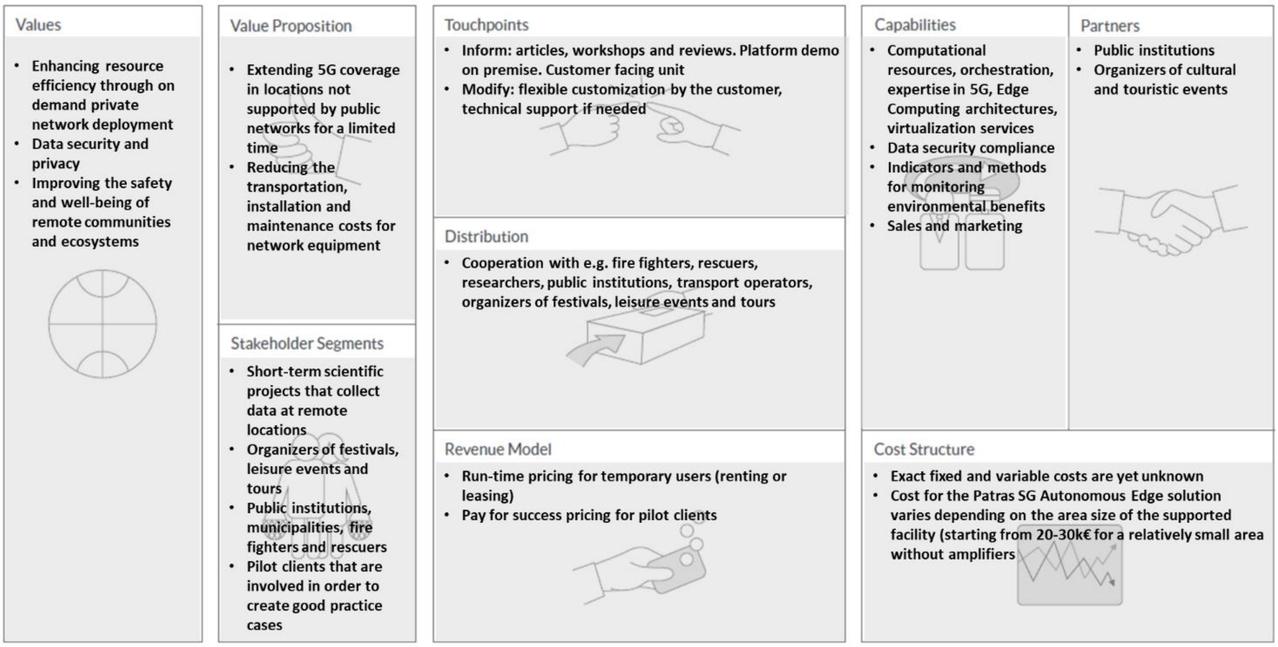


**Figure 7-6 Business model component overview of temporary On Demand 5G Coverage in Remote Areas**

**Objectives and values**

**Objectives/characteristics:**

"**Patras SG Autonomous Edge**", is a portable **box**, containing everything from the SG New Radio and SG Core, Network and Service Orchestrations including a Virtualised environment based on openstack technology (Patras 5G Wiki, 2021). It has the capacity to deploy a 5G network on demand as well as to host cloud-based applications, thus enabling end-to-end 5G private connectivity on-premise (e.g. in remote locations). Implementation and testing of the Patras SG Autonomous Edge is foreseen with respect to two 5G-VICTORI service types, EDHv (within the use case of "Energy and factories Digitisation of power plants for real-time monitoring of HV power cable Patras") and EDSv (within the use case of "Energy and factories Digitisation of power plants for Sensor data collection Patras"). The services that will be demonstrated in these use cases are divided into operation, maintenance and security related applications. The real time monitoring of a submarine HV cable between the ADMIE sites in Rio and Antirio, in Greece, is one application example.

The objective of this application is to **identify possible abnormal operation conditions in real-time**, inform the operator and provide input to future local controllers. This implies strict timing requirements, including sensing time, transmission, and processing time as well as zero-perceived downtime (availability), reliability, security. Furthermore, the applications for enabling preventive maintenance require support of different type of low power sensors and protocols and a monitoring system and network able to transmit, process and store massive data. Lastly, the security application requires streaming of high-quality video and high availability and security of data transmission.

Responding to these requirements and client needs, the on demand 5G private network solution provided through the Patras SG Autonomous Edge aims to fulfil the following **objectives**:

- Provision of end-to-end portable platform for the support of Industry 4.0 applications.
- On-premise 5G private network deployment compliant with Industry 4.0 standards (latency, capacity, reliability, security).
- Support of different IIoT (Industrial Internet of Things) protocols and backwards compatibility with legacy industrial protocols and equipment.
- Support of edge computing capabilities for time critical applications.
- Offer flexible and expandable solution with the integration of low-cost wireless sensors, enabling the transition of legacy facilities to smart factories.
- Provide customisable real-time monitoring and advanced analytics, according to client needs.

**Market gap and uniqueness**

Industrial needs for higher efficiency, effectiveness and sustainability stimulate the transition to Industry 4.0 and the widespread adoption of 5G connectivity to support it. They are also key motivators for the future evolvement towards 6G network ecosystems (5G Infrastructure Association, 2021). Manufacturing companies push these developments, e.g. within the 5G Alliance for Connected Industries and Automation, which aims to ensure that the requirements of the industrial domain are considered in 5G standardisation (5G-ACIA, 2019). While other business ideas from the 5G-VICTORI project are centred around multimedia applications, the herein described deployment of 5G private network on demand focuses on utilizing the potential of 5G applications in the industrial domain.

Furthermore, the ever-increasing number of connected devices, combined with the evolution of connectivity technologies, necessitates **flexible IoT platforms that allow control and management of this diverse and complex infrastructure** (Intracom, 2021). "Most IIoT platforms provide simple functionalities such as basic data collection and filtering services. However, when addressing multiple sensor scenarios and even considering use cases where an abundance of 5G sensors are present, management issues arise as the IoT platforms have to transmit high-volume messages to the cloud, which not only stresses the communication network but also hinders the overall operation of the vertical applications. In that respect, smart data analysis and filtering services or otherwise called data fusion services, are necessary for reducing the network traffic by sending data to the cloud only when it is necessary" (Tzanis & Mylonas 2021). The Patras SG Autonomous Edge responds to this need by enabling on demand 5G private network deployment coupled with simultaneous hosting of cloud-based applications at the edge. In addition, while existing solutions that offer industrial IoT platforms rely on existing network infrastructure, the Patras SG Autonomous Edge provides network coverage, computational resources and applications in a portable box, which can support 5G connectivity in isolated areas. At the same time the solution allows backward compatibility, meaning that it can work with already existing infrastructure (e.g. with legacy sensors). In this way the Patras SG Autonomous Edge offers a promising potential to support a seamless, cost-efficient and widespread transition to Industry 4.0.

**Initially identified sustainability potentials**

Initial sustainability potentials of the business idea with respect to economic, social and environmental impact were discussed prior to the workshop:

- **Economic** impact: Reduction in operational and maintenance costs through predictive maintenance and on demand network deployment.
- **Social** impact: Cost reduction in operation and maintenance can lead to substantial reduction in the costs of industrially manufactured products, making them accessible to the general public.
- **Environmental** impact: 1) Low-cost and low-energy sensors and 2) Preventive maintenance activities stemming from advanced analytics help reduce CO2 emissions.

**Technology Readiness Level (TRL)**

On-demand private network for industry 4.0 capabilities is currently TRL4 (was 3 at the beginning of the 5GVictori project, and will reach up to 7 when it is finished).

**Values and potentials for sustainable business impact**

Prior to the workshop, the purpose of their business idea was conceived in a conventional sense, without much emphasis on the sustainability potential of the solution:

*"The purpose behind the project is to provide an end-to-end portable platform for the support of Industry 4.0 applications. The platform will support on-premise 5G Private Network deployment, compliant with Industry 4.0 standards (latency, capacity, reliability, security), Edge Computing capabilities and a set of different applications for real-time infrastructure analytics and monitoring."*

During the workshop participants further specified this purpose statement and differentiated it into three purposes that underlie the resulting business model sketches:

- **Apply customizable monitoring solutions** according to clients' needs with low effort and costs.

- Allow industries or clients to deploy cost-effective monitoring solutions for remote locations.
- Support both legacy sensors and industrial protocols as well as new types of services and sensors.

In addition, they highlighted **data security** as an important value of high concern for potential clients that needs to be integrated in the business model. While 5G connectivity will significantly improve the security of wirelessly transmitted data, stakeholders may remain averse to the adoption of wireless as opposed to wired network solutions, considering them more vulnerable to attacks. Although the on-demand platform will offer compliance with high data security standards, biased perceptions can harm the marketability of the solution. Therefore, privacy should be deliberately considered especially when shaping the marketing aspects of the business model.

Furthermore, the participants elaborated upon the potential of the solution to contribute to sustainable business impact and agreed upon sustainability-related priorities and goals that motivate the new business and provide a directive and initial framing for the development of the business model design. As in the "Pervasive vCDN services for railways" workshop, here too the "***Resource Efficiency and Productivity***" design pattern (Lüdeke-Freund et al., 2021) served as a benchmark to support the identification of the most relevant priorities and potentials for sustainable business modelling. The pattern prompted the participants to adopt whole-system thinking in order to reflect on the potential of the solution to enhance resource efficiency throughout the whole IIoT infrastructure as well as with respect to different stakeholder groups (e.g. industry operators, network operators, power utilities, maintenance personnel, end-users, etc.). Some guiding questions were formulated in advance to support the ideation process:

- How can we increase resource efficiency and productivity if we think about the whole Smart Factory as a system rather than about its isolated parts?
- Which new value propositions can we formulate? Which benefits can we promise?
- How can we improve supply and procurement, or internal processes?
- How can we make the most efficient use of technology?
- How can we design for easy predictive maintenance?
- How can we integrate environmental sustainability within the revenue and pricing model?

In addition, the energy hierarchy framework (Wolfe, 2017, see fig. 3) was introduced to prompt reflection on how the Patras SG Autonomous Edge can be used to improve usage of renewable energy sources, make energy usage more efficient and/or realize energy savings. Elaborating upon these considerations, the participants further specified the **solution's potential to optimize resource efficiency** through: 1) on demand private network deployment; 2) integration of state-of-the-art, low energy sensors; 3) enablement of third-party optimisation of power consumption and 4) prediction of spikes in energy demand; as well as by **optimizing the utilisation of equipment** through 5) predictive maintenance and 6) virtualisation. Below we review these and further potentials for realizing sustainable business impact, which were identified by the participants and guided the subsequent business modelling activities.

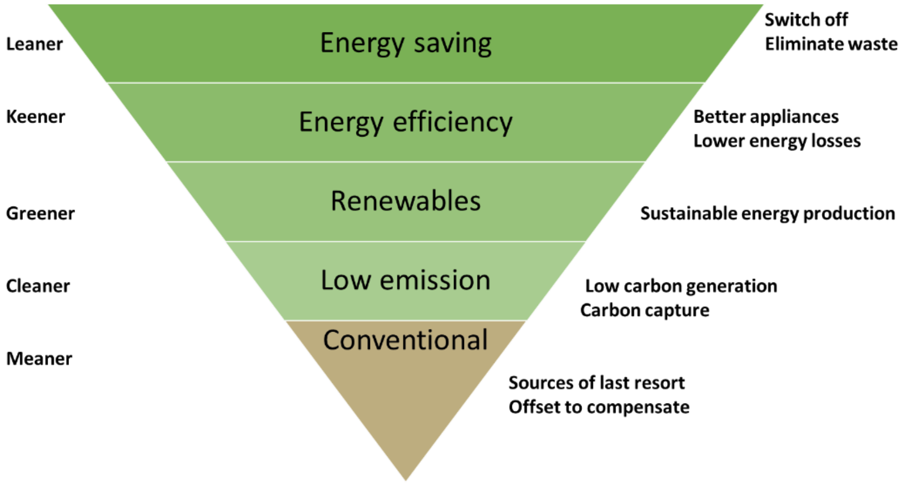


**Figure 7-7 Energy hierarchy framework adapted from Wolfe, 2017**

The Patras SG Autonomous Edge platform allows services to be deployed without reliance on the full backbone connectivity provided by commercial 4G or 5G networks. It enables the assembly of "on-demand islands" of connectivity which can deploy a private network that is limited in location, has specific lanes, specific clients and can be deployed for a limited time. This enhances network control and allows services to be deployed when needed and set down when no longer required, resulting in energy savings. For example, in industrial settings surveillance cameras are used for continuous streaming of high definition videos, a resource intensive task that is rarely necessary. In practice the streaming service is required only when an alarm indicates a fault or an intrusion that calls for attention. During the rest of the time, the same energy and network resources can be utilised to support other necessary services. In addition, the portability of the on-demand solution allows industries (e.g. power utilities) to deploy cost-effective monitoring solutions to remote locations. This eliminates the need of using additional resources to install permanent, wired infrastructure on site. The improved network coverage can enable flexible integration of new industrial sites and thus contribute to positive economic and environmental impacts (e.g. by enabling more solar and wind power plants to be deployed in remote areas).

The Patras SG Autonomous Edge also facilitates the integration of state-of-the-art, low-cost and low-energy sensors. For example, new NB-IoT sensors come at a module price below $5 and can last for over 10 years without requiring a battery replacement (Lee & Lee, 2017). Industrial actors will increasingly adopt such sensors in order to reduce emissions and ensure compliance with new sustainability goals and regulations, such as the European Green Deal (COM 2019; Szum & Nazarko, 2020).

Currently available solutions that can offer private network connectivity and support of state-of-the-art sensors are usually incompatible with legacy sensors. This poses a major challenge for industrial sites where operations rely on a diversity of sensors as well as applications and protocols. In contrast, the on demand private network solution presented here enables backward compatibility of already existing infrastructure. Thus, clients can take advantage of the solution to extend the capabilities of already existing equipment as well as to retrofit their infrastructure with new energy efficient equipment. This contributes to a **seamless and economically viable transition of legacy facilities towards more sustainable smart factories (Industry 4.0)**.

Furthermore, the Patras SG Autonomous Edge can be integrated with IoT platforms, such as the UiTOP platform provided by IntraCom, to enable integration of third-party optimisation of power consumption and selection. The UiTOP platform provides northbound API as node to already existing higher-level infrastructure which allows real-time monitoring data to be sent for processing by a third-party optimisation algorithm. This enables facilities to reduce their power consumption or flexibly switch to renewable or low emission energy sources without spending additional costs for vertical application development.

Utilities can improve operations through powerplant monitoring and low latency transmission of measurements to act on spikes in energy usage. Continuous real-time monitoring and communication of measurements from numerous devices can be used to predict the proper power supply configuration for the networks, for example, by enabling less or more bandwidth depending on the predicted needs.

Another positive sustainability impact that industrial actors can realize by adopting the Patras SG Autonomous Edge is the extension of equipment lifetime through intelligent predictive maintenance. Predictive (and condition-based) maintenance increases resource efficiency and saves costs (for spare parts, time for maintenance and system downtime) over routine or time-based preventive maintenance, because corrective tasks are performed only when and where necessary. A major challenge associated with predictive maintenance is that it requires the transmission of high volume and largely redundant data. The smart data analysis and filtering services (i.e. data fusion services) enabled by the Patras SG Autonomous Edge help to reduce such excessive network traffic, thus minimizing both operational and maintenance costs. The solution also helps to reduce costs and resources used for the mobility of personnel, which are necessary for conventional maintenance. This is especially valuable when it comes to inspecting equipment in remote locations (e.g. along the power grid). During the workshop it was also proposed that the on demand private network solution can be used to produce an augmented reality in which maintenance personnel can inspect and repair industrial equipment remotely (see also “Digital Twin”; Kaloxylos et al., 2020, 48). Through such applications the solution can contribute to **improving personnel safety at industrial sites**.

Through NFV (network function virtualisation) the Patras SG Autonomous Edge can also allow **virtualisation** of services without the need of buying, transporting and installing specialised hardware. Functionalities of both network devices and industrial devices can be emulated and provisioned on demand, in accordance with the specific use case requirements. When the services are no longer required or need to be scaled down, the network resources can be utilised for a different task. This results in significant cost savings, reduced complexity and risk, and enhanced productivity of industrial processes.

Beyond industrial settings the capabilities of the Patras SG Autonomous Edge solution can be used to flexibly deploy 5G-based public warning systems that improve the safety of remote communities and ecosystems. For example, the solution can be adapted to enable on demand climate monitoring, security surveillance, traffic light control or disaster (e.g. forest fire) prevention and management. Both local communities and industrial actors can also benefit from low downtimes of utility service provision since real time monitoring systems will support prompt detection of faults along the supply infrastructure. Lastly, cost reduction in operation and maintenance can lead to substantial **reduction of several manufactured products’ and (utility) service costs**, making them accessible to the general public.

**Demand**

**Value Proposition:**

Most value propositions specified within the business modelling workshop stem from the above discussed functionalities and associated potentials for sustainable value creation enabled by the Patras SG Autonomous Edge solution. They can be summarised as follows:

- Providing a **portable solution** that enables network coverage, computational resources and applications in a box.
- Supporting on-premise 5G private network deployment, **compliant with Industry 4.0 standards (latency, capacity, reliability, security)**, edge computing capabilities and a set of different applications for real-time infrastructure analytics and monitoring.
- Enabling **smooth transition** of legacy facilities to smart factories (Industry 4.0), whereas existing solutions offer industrial IoT platforms relying on existing network infrastructure.
- Enabling **third-party optimisation of power consumption** and selection.
- Enabling powerplants to benefit from **low latency in transmission of measurements** to better act on spikes of energy usage.
- Optimizing the utilisation of industrial equipment through **predictive maintenance and virtualisation**.
- Supporting the integration of low-cost, **low-energy industrial sensors**.
- **Reducing maintenance costs** for power utilities and thus contributing to lower energy prices for industries and households.

Another key value proposition described in the business model is the **enhanced network control** that the on demand 5G private network solution offers compared to public network solutions. Since network resources are dedicated to and remain under the control of the industrial operator, the platform allows flexible reconfiguration of the network according to the specific use case or service needs. Moreover, communication is performed through private channels which ensures high levels of data security. This is another important value proposition especially for industry operators, processing sensitive measurement data.

A key feature of the on demand private network solution is its potential to extend 5G coverage in locations not supported by public networks, without the need to install expensive fibre-optic connectivity. Various stakeholders that require **5G coverage in a remote area for a limited time** (e.g. fire fighters or rescuers in disaster areas, researchers, public institutions, transport operators, organizers of festivals, leisure events and tours) can benefit from such functionality. This reveals the potential to design an alternative business model that caters to the specific needs of these client groups. Such a business model can apply a different logic of how value is created and delivered to the clients, and in what way revenues are being captured.

**Stakeholder Segments:**

A key stakeholder for realising the business idea is ICOM, which may offer their IIoT software for collection, storage and processing of measurements. Further stakeholders that are regarded as potential clients of the solution include:

- Industries with a need for monitoring solutions (e.g. to manage manufacturing processes).
- Power utilities (e.g. solar plants) that can use the solution to perform local control or to collect measurements and transmit them.
- Transport operators, which may use the solution to deploy an isolated private network (e.g. at remote ports, airports, train stations, etc.) or support cost-effective maintenance of carriers (e.g. cargo ships) through wireless sensors.
- Short-term scientific projects that collect data at remote locations.
- Organisers of festivals, cultural and touristic events and tours.
- Public institutions, municipalities, fire fighters and rescuers that require 5G coverage in a remote area for a limited time.
- Pilot clients that are involved in order to create good practice cases.

**Interaction**

**Touchpoints:**

Stakeholders from the industrial domain can get *informed* about the Patras SG Autonomous Edge solution through workshops and reviews related to Industry 4.0 and smart grids. On-premise platform demonstrations can also be used for marketing the solution. Providing the end-to-end solution of the Patras SG Autonomous Edge mobile box will depend on the combined capabilities of the three project partners: the IPTO (Admie), contributing with sensor technology and know-how regarding different industrial sensors and protocols; the University of Patras (NAM Research Group), providing the autonomous platform as well as expertise in 5G networks and virtualisation services; and IntraCom providing its IIoT platform to support the collection, storage and processing of measurements. An important aspect of the touchpoints component, which still needs to be defined, is who of these three project partners will be the primary contact for the client. It was suggested that a client facing team, with one representative from each partner, may be formed especially for this purpose.

To *acquire* the solution, industrial clients would sign a fixed agreement. To *start* it up, they will require an initial setup of sensors' equipment, network infrastructure and monitoring applications installed. The platform allows flexible customisation by the client, but in some cases additional technical support may be needed to *modify* the initial setup.

**Distribution:**

Primary routes to market can be established via teaming up with suppliers of industrial monitoring solutions or through direct contact with industrial clients.

**Revenue model:**

As already discussed, the deployment of the on demand private network solution is intended to be realised through the collaboration of the three project partners: Admie, University of Patras and IntraCom. Since each partner provides different aspects of the solution, there are different capabilities and corresponding revenue streams and pricing models that need to be considered. For industrial plants and utilities as clients, a negotiated pricing strategy is envisioned, i.e. the end price will be tailored with regard to the requirements of each use case (e.g. area size of the facility, network and computational resources, sensors' equipment, software customisation). The negotiated pricing strategy is typically used for complex projects or when offerings have to be tailored to the needs of individual clients. Several factors can influence the outcome of negotiations, as for example the availability of information, the participants' negotiation skills or different psychological effects (e.g. anchoring effect), and therefore need to be considered in advance (Breuer, 2014).

The IPTO (Admie) will provide know-how about industrial sensors and protocols and support the installation of equipment. The Patras SG Autonomous Edge platform will be provided by the University of Patras and be sold at a one-off purchasing price coupled with annual or monthly support fee. IntraCom will provide its basic UiTOP solution with a basic licensing fee. Further fees will be charged for customisation and adaption of the IoT platform depending on the clients' needs (e.g. for adjusting the platform to specific sensors, protocols and applications used by the client, setting up different IoT adapters).

An alternative revenue model can be designed for other target client groups outside the industrial sector. For industries, the integration of the solution requires sometimes substantial customisation to the specific sensors and industrial protocols used at their sites. This also implies that industrial clients will seek prolonged use of the solution rather that leasing or renting it for a limited time. In contrast, other potential clients, such as fire fighters, researchers, public institutions and festival organizers, may use the mobile box for a limited time and for standardised purposes that do not require customised installation. A potential revenue model to address those clients is **run-time pricing**, which allows paying only for the time the product is actually used, without purchasing the product itself (cf. use-oriented services in Lüdeke-Freund et al., 2021 and the case of Rolls Royce and its 'Power by the Hour' model for aircraft engines in Lüdeke-Freund et al, 2018; Breuer 2014). This pricing model can be offered for one time uses of the product as well as for using the product during a longer time period. Different end users can benefit from a cost-effective and more resource-efficient provision of the network capabilities. On the other side, the solution provider(s) benefit from the servitisation of the offering, which makes it more easily integrable with other offerings (e.g. technical support, client training, after-sales) that can generate new service-oriented revenue streams. Keeping ownership of the physical instalment of the box, they are also immediately rewarded for pro-environmental optimisations of the hardware for reduced energy consumption, and reuse, repair and recycling of its component parts.

Another alternative pricing model that was suggested to be employed with pilot clients of the solution. The '**pay for success**' sustainable business model pattern (Lüdeke-Freund et al., 2021) makes payments and pricing of the on demand private network solution dependant on predefined levels of success. It reduces the risks to adopting the new technology perceived by potential clients, thereby lowers adoption barriers and facilitates market entry. Predefined performance criteria for success may also include target levels with respect to enhancing energy efficiency or other sustainability indicators. Since success-based contracting is often preferred by public institutions, who seek to enhance their accountability by investing in projects with demonstrable outcomes, this pricing model may reveal opportunities of gaining access to public funds (ibid). However, implementing the Pay for Success pattern requires the definition and continues measurement of the predefined criteria for success.

**Performance**

**Capabilities:**

The key capabilities of the business model are provided by the three project partners and can be summarised as follows:

- **UoP** (NAM Research Group) provides the autonomous platform, computational resources and orchestration as well as expertise in 5G networks, Edge Computing architectures and virtualisation technologies.
- **ADMIE** contributes with advanced technologies for industrial protocols, LPWAN, smart sensors and advanced analytics as well as know-how regarding different industrial sensors and protocols. Therefore, the IPTO assumes a leading role in customizing the on demand private network solution to the existing industrial protocols of the client. The customisation need may vary from 20% to 80% depending on the specific use case.
- **ICOM** provides its UiTOP solution as a monitoring tool with dashboard for mapping sensors and sensor types.

Further capabilities required to support the value creation potential of the business model include:

- Compliance with data security standards.
- Indicators and methods for monitoring and proving the environmental benefits of the solution.
- Sales and marketing team and/or a client facing unit.

**Partners:**

Partnership with InterCom who can provide an IIoT software for collection, storage and processing of measurement data is essential for supporting the business idea. Further partnerships with high-end sensor device and industrial protocol providers are also critical.

**Cost Structure:**

The exact fixed and variable costs for implementing the business model are yet unknown. The cost for the Patras SG Autonomous Edge solution varies depending on the area size of the supported facility (starting from 20-30k€ for a relatively small area without amplifiers). Further expected costs are related to the licencing and customisation fees for using the UiTOP soluition (provided by IntraCom) as well as to the number and type of sensors that need to be deployed (by Admie).

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### 7.2.3 5G-VICTORI Business Modelling Workshop – Future Mobility / InsurTech for multi-modal mobility

***5G-VICTORI Business Modelling Workshop –***

***Future Mobility / InsurTech for multi-modal mobility***

Synthesis of ideas for a sustainability-oriented business modelling
(July 6th, 2021 by UXBerlin – Innovation Consulting)

This document introduces a sustainability-oriented business model for a new mobile application. The app facilitates multi-modal transportation, provides users with assistance in customised journey planning as well as automated recommendations based on 3D spatial data rendering. It also allows claim validation insurances. The current business model sketch is based on discussions and a refined synthesis of a results from co-creation workshop conducted on the 17.06.2021 with participants of Urban Hawk, IZT and UXBerlin – the model needs to be further refined following an assessment of its assumptions and an increasing involvement of different stakeholders such as early clients.

First, we summarize the key takeaways from the workshop, including the main challenges and success-critical issues to implementing the envisioned business model and realizing its environmental and social benefits. Two alternative business model sketches resulted, one (B2B) focusing on partner relationships with insurance providers in order to rapidly gain market traction and to realize commission-based revenues from offering insurances as a premium service (fig. 1). The second business model (B2B2C) focuses on the passengers as users of the services in order to ensure the (market) viability of the solution and develop customer relationships with the end-users of the app (fig. 2). Following this introductory summary, we present the main values that motivate the venture and discuss its sustainability potentials. We also describe, compare and synthesize the ideas generated in the workshop with regards to critical business model components: the value proposition, stakeholder segments, touchpoints, distribution, revenue model, capabilities, partners and cost structure.

**Key takeaways**

- The **purpose** of the project is to make multi-modal travel journeys more efficient and safer (e.g. safeguarding journeys and avoiding congestion in Covid-19 times) by utilizing real time passenger data.
- The technological solution can enable numerous applications and corresponding use cases. The range of ideas to be considered creates the challenge of finding the right focalisation and a sense of direction for the venture from the early stages of its development. The prioritisation of the venture's values and the benefits that it can provide to clients helps to establish and strengthen this sense of direction.
- Core **values** of the venture are efficiency, safety, affordable mobility, passengers' peace of mind and health, ecological justice and inclusion. Insurers' (clients) concerns for data reliability and accuracy need to be integrated as essential stakeholder values.
- **Positive impact** on sustainability can be realised by:
    - Making multi-modal (and potentially low-emission) travel more attractive and convenient, and easily and affordably insured through automated insurance services.
    - Incentivizing users to choose the healthiest or most environmentally friendly modalities and routes on their journeys (through recommendations, differentiated pricing or gamification).
    - Reducing the risk of overcrowding during pandemics or major events.
- A (social and / or green) **freemium** revenue model (Lüdeke-Freund et al., 2021) can align social value creation (e.g. through free 3D indoor navigation for passengers with disabilities and special needs), ecological value creation (e.g. cross-subsidizing low-emission mobility choices), and economic value creation (e.g. through automated and more accurate validation of insurance claims for premium users and business

clients). The freemium model will facilitate fast rollout of the service and allow to quickly reach a critical mass of end-users that the company can capitalize upon

- A key challenge and success factor for implementing the freemium strategy is to balance the number of paying and non-paying customers so that the former can fully subsidize the latter. This requires the involvement of **established distribution channels** as well as the provision of exceptional value through the premium offerings. The use of established distribution channels is also required to foster scalability.
- Substantial effort will be required to design and facilitate a rewarding **customer journey** that mainly relies on external on partners, and to devise and manage all touchpoints to please customers. Integrating the customer journey into these partner's journeys will be essential to ensure a frictionless experience.
- One important challenge that has to be considered with respect to brokering insurances for multi-modal travel is how to make sure that **liabilities** are clarified between the different providers in cases of delays, i.e. how liabilities can be transferred when switching from one provider to another.
- Options on the mobility market are evolving fast and this development increases the relevance of multi-modal travel through new mobility-as-a-service options and means of transportation (e.g. car and bike hire fleets, e-scooters, autonomous vehicles). Urban Hawk's solution is particularly relevant and valuable for customer and clients running these new transport modes.

**Essential specification of business model components**

Figure 1. Business model component overview of InsurTech-focused rationale (B2B)

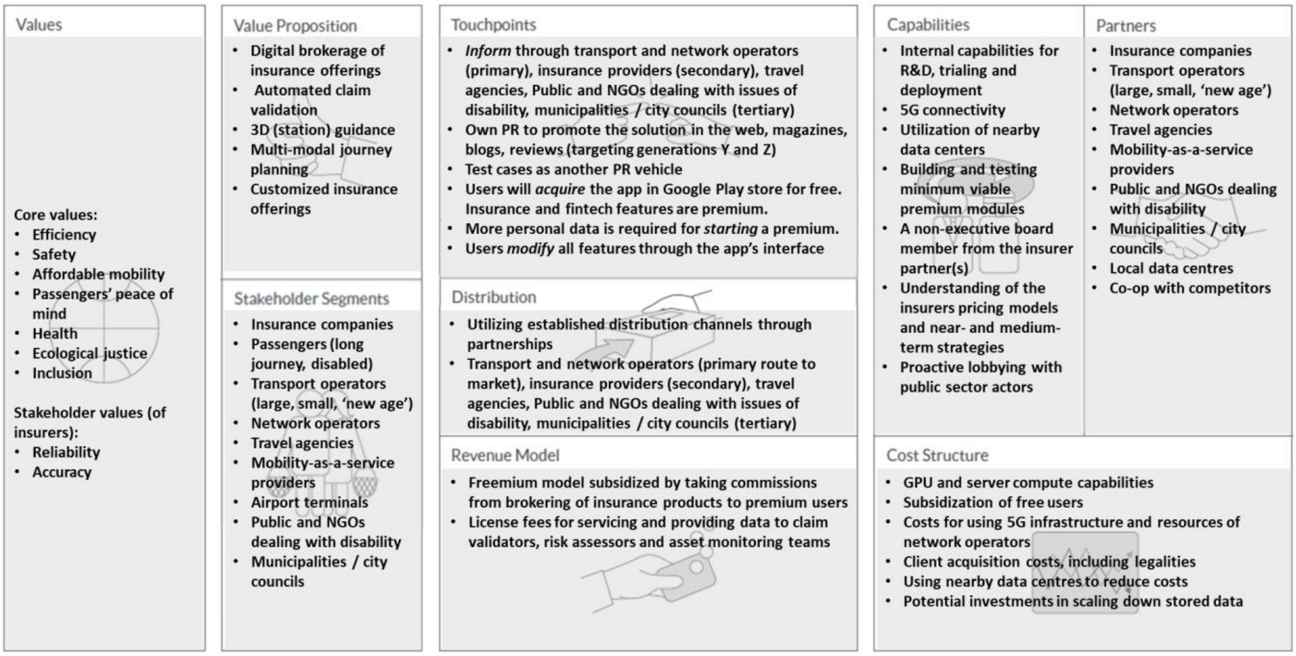


Figure 2. Business model component overview of passengers-focused rationale (B2B2C).

### Values

Core values:
- Efficiency
- Safety
- Affordable mobility
- Passengers' peace of mind
- Health
- Ecological justice
- Inclusion

Stakeholder values (of insurers):
- Reliability
- Accuracy

### Value Proposition

- 3D (station) guidance
- Multi-modal journey planning
- Customized insurance offerings
- Automated claim validation
- Digital brokerage of insurance offerings
- Fintech services (ticketing, booking)

### Stakeholder Segments

- Passengers (long journey, disabled)
- Insurance companies
- Transport operators (large, small, 'new age')
- Network operators
- Travel agencies
- Mobility-as-a-service providers
- Airport terminals
- Local businesses
- Public and NGOs dealing with disability
- Municipalities / city councils
- Fitness tracker companies

### Touchpoints

- *Inform* through transport and network operators (primary), insurance providers (secondary), travel agencies, Public and NGOs dealing with issues of disability, municipalities / city councils (tertiary)
- Own PR to promote the solution in the web, magazines, blogs, reviews (targeting generations Y and Z)
- Test cases as another PR vehicle
- Users will *acquire* the app in Google Play store for free. Insurance and fintech features are premium.
- More personal data is required for *starting* a premium.
- Users *modify* all features through the app's interface

### Distribution

- Utilizing established distribution channels through partnerships
- Transport and network operators (primary route to market), insurance providers (secondary), travel agencies, Public and NGOs dealing with issues of disability, municipalities / city councils (tertiary)

### Revenue Model

- Revenues from personalization for premium users
- Differentiated pricing depending on the speed, healthiness and emissions of mobility choices
- Revenues from fintech services (booking, ticketing) and advertisement

### Capabilities

- Internal capabilities for R&D, trialing and deployment
- 5G connectivity
- Utilization of nearby data centers
- Building and testing minimum viable premium modules
- A non-executive board member from the insurer partner(s)
- Understanding of the insurers pricing models and near- and medium-term strategies
- Proactive lobbying with public sector actors

### Partners

- Transport operators (large, small, 'new age')
- Network operators
- Insurance companies
- Travel agencies
- Mobility-as-a-service providers
- Local businesses
- Public and NGOs dealing with disability
- Municipalities / city councils
- Local data centres
- Providers of health- or environmental footprint-related data
- Co-op with competitors

### Cost Structure

- GPU and server compute capabilities
- Subsidization of free users
- Costs for using 5G infrastructure and resources of network operators
- Marketing and communication to establish a customer brand and corresponding customer relationships
- Using nearby data centres to reduce costs
- Potential investments in scaling down stored data

**Main objectives and values**

**Objectives/characteristics**

Urban Hawk is a Bristol based data intelligence scale-up company established in 2017. The company has a total of five staff members building technology, two focussing on the InsurTech business idea. It has no products yet on market, but the backbone technology has already been applied with customers (e.g. with UK insurances helping to identify risks and validate claims). The current objectives that the venture pursues can be characterised as follows:

- Develop technology that serves as a backbone for a multi-modal transportation service that provides users with assistance in customised journey planning, and insurers with automated claim validation.
- Provide real-time data to facilitate both journey planning as well as claim validation.
- Implement a freemium business model (navigation free and insurance as a premium service) to get a large user base, facilitate growth of the user base and help building up a database.

**Market gap and uniqueness**

The insurance industry as a whole is moving towards a data-driven model. Some insurers still struggle to digitize paper-based data sets. Others digitize the customer journey, but few have digitised products available on the market. Some advanced value propositions that are provided through digitalised insurance services include improving speed of data processing (towards real-time) and giving control back to the customer (e.g. when and which volumes of cover are needed) through more customisation options (e.g. usage based) (cf. Shyam, 2019). For example, Swiss Re offers parametric real-time flight delay insurance with automated claim validation and instant pay-out, and intends to expand this to whole journey travel insurance (Swiss Re, 2021a; 2021b). Another example is Chubb and its 'Pay as You Roam' travel insurance, which gets activated automatically only while customers are abroad (InsurTech Insights, 2021). According to an Insurance Industry Outlook report by Deloitte (2019), 22 percent of customers are interested in being automatically insured when buying/renting services. However, most currently available offerings just cover certain modes of transportation in contrast to the envisioned multi-modal solution provided by Urban Hawk. Its new service will create value for customers by integrating various modes of transportation from different providers into an efficient and reliable journey planning application and provision of insurances.

Participants in the workshop agreed that a critical factor for successful market penetration is the stakeholders' awareness about the problem of low-tech provision of insurance services. While there are existing and also growing needs for more personalised insurance offerings, customers are often unaware of the various solutions that InsurTech can provide in response to such needs (with InsurTech we refer to technology-driven business model innovations that aim 'to improve insurance profits and service capabilities and reduce risks'; Wang, 2020, 31). This requires insurers to adopt a proactive approach and initiate dialogue on the market in order to raise customers' awareness about latent needs as well as the potentials of reinventing traditional business models through data-driven solutions that can better respond to these needs ('creating awareness of the awareness').

On the other hand, the solution of rendering 3D spatial data to facilitate multi-modal mobility requires several technical KPIs to be continuously maintained, such as bandwidth, latency and location accuracy. Current 4G networks fall short in providing sufficient bandwidth for transmitting volumetric spatial data and get easily congested when a mass of end users is connected (e.g. at busy train stations). Wi-Fi may be used as an alternative but lacks coverage when users move away from stations. Therefore, future 5G networks will provide a significant improvement to the use of volumetric spatial data to offer B2C (e.g. to passengers) and B2B (e.g. to insurers, transport and network operators) services. Within 5G Victory, the “Berlin-Bristol” test case will provide measures and compare how the multi-modal mobility service performs with and without 5G connectivity.

**Initially identified sustainability potentials**

Initial sustainability potentials of the business idea with respect to economic, social and environmental impact were first discussed prior to the workshop:

- Economic impact: Reaching critical mass of users through a freemium approach.
- Social impact: Providing accessibility, journey planning and indoor navigation for passengers with special needs (disabilities, travelling with luggage or children). Providing safer and healthier (less congested) modes of transportation (especially relevant in times of Covid19).
- Environmental impact: Encouraging sustainable mobility through social or green freemium model (Lüdeke-Freund et al. 2021): Subsidizing sustainable modes of transportation through higher pricing of more CO2 consuming travelling options.

**Technology Readiness Level (TRL)**

Future mobility is currently on TRL4 (was 3 at the beginning of 5GVictori, will reach up to 7 when it is finished); technical live demonstration of 3D mapping and visual technology June 2021 5GVictori consortium. However, since the basic technology is TRL 5 or 6 since it already used in projects (e.g. for planning in marine port operations)

**Values and potentials for sustainable business impact**

The purpose behind the project is to utilize real time passenger data, and make multi-modal travel journeys more efficient and safer (e.g. safeguarding journeys and avoiding congestion in Covid-19 times). Correspondingly, during the workshop, the venture participants prioritised **efficiency and safety** as the most essential values pursued by their endeavor (see fig. 3). Further core values (i.e. notions of the desirable and ordered systems of priorities) include: affordable mobility, passengers’ peace of mind, health, ecological justice and inclusion. These values provide heuristics and directives that define the future development of the service towards providing enhanced and more accessible services for door to door travel planning, station guidance and insurance. In addition, insurance providers, who are essential stakeholders and primary clients, put emphasis on the values of reliability and accuracy as essential in the context of managing user data. These values also should be considered and integrated into the design and development of the business model.

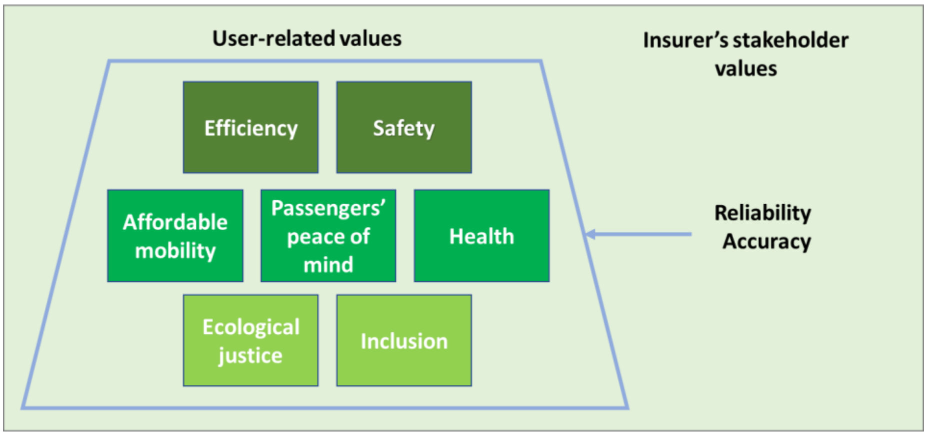


Figure 3. Hierarchy of essential values shared by the venture participants and key stakeholders, **serving as directives and heuristics for business modelling**.

The business idea is based on a **freemium revenue model**. The free service use will be subsidised by taking commission from the sales of 3rd party premium services, such as insurance and automated recommendations, while retaining basic travel and guidance features free of charge. This model will support market penetration and economic value creation by facilitating fast rollout of the service and helping to quickly reach a critical mass of end-users. Therefore, the green or 'Social Freemium' sustainable business model design pattern (Lüdeke-Freund et al., 2021) was introduced in the workshop to support participants in further elaborating on the sustainability aspects of their business idea, beyond its potential for economic value creation.

In contrast to conventional freemium strategies that focus on enhancing economic value by rapidly reaching more customers, **Social Freemium** models aim at enhancing social and/or ecological value by making sustainability-oriented solutions readily available to a broad range of market segments. A core benefit of applying the Social Freemium approach to value creation is that it enables catering to both community (social) and corporate (economic) interests (see fig. 4). On the one hand the service will provide more freedom to private users through, e.g. free 3D indoor navigation and personalised insurance coverage. On the other hand, it will encourage shared accountability among the involved stakeholders through, e.g. automated claim validation. For instance (an example one of the participants suggested), a disabled employee may use the travel planning and station guidance features for free in order to facilitate his/her daily commute, while an employer may pay to insure the said individual in order to curb the risks of time and financial losses due travel disruptions and delays.

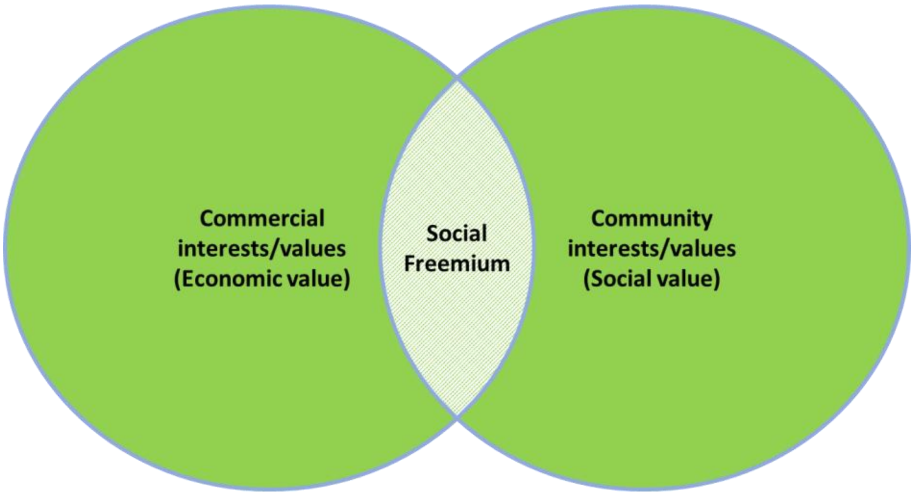


Figure 4. Venn diagram illustrating the potential of the Social Freemium sustainable

business model
pattern to align commercial and community interests and values (e.g. accountability and freedom).

In addition to promoting inclusive mobility for disabled people as indicated above, the service can also foster **accessibility** and inclusion for other passengers with special traveling needs, such as parents with small children, travellers with heavy luggage, or people with pacemakers. The journey planning and indoor navigation features can also contribute to the **health and safety** of passengers by suggesting the use of less congested modes of transportation. This is especially relevant in times of the Covid19 pandemic. Beyond transportation, the service's functionality can be used to reduce the risk of overcrowding during major events. For example, event organizers can pay for building a 'digital twin' of their venue and advise visitors to use the app for finding their way out of a stadium or a tight area.

Further benefits for the passengers' safety and **peace of mind** are realised by making multi-modal travel more convenient and easily insured. Tracking users across different modes of transportation enables the provision of automated insurance services that allow efficient claim processing and accurate underwriting. The app allows travellers to easily prove that a delay happened through no fault on their own and quickly get a refund. Automated insurance also allows to provide more affordable **insurance products**. For instance, passengers can pay only when they use a certain insurance product or according to their particular situation ('Pay as You Roam').

The workshop participants also considered different ways to incentivize the passengers in taking the **healthiest or most environmentally friendly route** for their journeys. One idea is to provide these route options along with a third option for the fastest mode of travel. When users choose the healthiest route (e.g. riding a bicycle or walking to the station, instead of driving) they can, for example, receive symbolic rewards to real credit points linked to their health insurance. If they pick the most ecological route they would pay less for their journeys, which can be subsidised by transport (e.g. railway) operators that look for new ways to pass down to their customers the increasing costs incurred from CO2 emission taxes (cf. Murauskaite-Bull & Caramizaru, 2021, 29). However, these ideas are considered mainly in the context of future service development, while the potential of combining social and economic value creation through Social Freemium is at the forefront. Features that encourage more ecological travelling choices, such as general statistics about the emission intensity of different modes of transport can be easily built in prior to the service rollout. However, the provision of more accurate statistics (such as those provided by GHGSat; 2021), or the integration of ecological aspect to extend the revenue model, require more efforts and are considered beyond the mid-term (2-year) perspective.

**Demand**

**Value Proposition**

The enhanced **situational awareness** provided by the Urban Hawk's mobile app solution brings services such as door to door travel planning, station guidance and insurance (travel, liability, life) to the next level of efficiency, safety and peace of mind for the customer. Thus, it provides a basis for passengers as well as business stakeholders from diverse sectors (e.g. transport operators, insurance providers) to realize mutual benefits.

The free value proposition of the app will offer passengers full 3D guidance in augmented reality across both indoor and outdoor environments. This feature helps passengers to easily find their way around stations and learn about relevant suggestions (e.g. wheelchair accessibility, lifts, toilets, cafés, snacks, deals, etc.). In addition, free users will benefit from optimised journey planning and syncing of multi-transport modes and journey times. These features contribute to faster, cheaper and more convenient travel.

By becoming premium users, passengers are able to access further value propositions. Through real time tracking of users, the app will enable the purchase of state-of-the-art insurance services such as automated coverage, multimodal coverage, merged all-cover and pay as you go coverages as well as more flexibility and control over the purchased insurance plans.

Main focus will be set on **insurance offerings** that cover disruptions of multi-modal journeys between a travel hub/terminal (such as airport, seaport, train station) and domestic or commercial destinations in dense urban areas. Automated claim validation that provides evidence on demand will enable fast pay outs for users. At the same time, it will reduce insurers' risks of responding to fraudulent claims. Real time user data will also improve insurers' evaluation of risks and allow for more accurate (i.e. automated) underwriting of clients. Online brokerage of insurance products will be another key value proposition addressing the insurance providers. One important challenge that has to be considered with respect to brokering insurances for multi-modal travel is how to make sure that **liabilities** are clarified between the different providers in cases of delays, i.e. how liabilities can be transferred when switching from one provider to another.

Further value propositions on the premium layer can integrate **FinTech services**. For example, the journey planning feature of the app can suggest ticketing and booking offerings or different deals that are personalised for the journey. Users may pay for these offerings directly through the app. This can open up possibilities for new value propositions and customer relationships with different businesses at train stations (accommodations, restaurants, retail, car rental companies, etc.). For example, the app may allow passengers that have booked a particular car from a rental fleet ahead of their arrival to have the preferred vehicle temporary locked and reserved for them in case of a delay.

Another value proposition discussed during the workshop was building **digital twins** of infrastructure and offering them to various stakeholders that require real-time 3D situational awareness through a standalone product. This can allow launching various use cases based on the same data and the same technology. Potential clients include railway companies (e.g. Networkrail, RSSB, UK train franchises), citywide public transport operators, airport terminals, construction companies (for facilitating the process of acquiring building permission) or logistics companies (for warehouse management and facilitating last mile deliveries).

**Stakeholder Segments**

The primary (paying) customers in the currently envisioned business model are **insurance companies**. Their most relevant offerings will be automatically recommended to the app users while the users' data will be collected to support the insurers' claim validators, risk assessors and asset monitoring teams. As discussed above, further paying customers may include transport operators, airport terminals, construction and logistics companies. It was suggested that small transport (e.g. railway) operators may have greater interest for adopting the solution. First and last mile 'new age' **transport operators**, such as car and bike hire fleets, e-scooters and autonomous vehicle companies, are another customer segment with prospect for growing relevance. Travel agencies, mobility-as-a-service companies and local businesses (such as restaurants and shops in train stations) can also be involved as customers and multipliers of the solution. **Network operators** will be involved as providers of connectivity but may take the role of customers if they are interested in integrating new offerings and revenue streams. This is considered as a likely scenario since telecommunication providers incur increasing costs for infrastructure investments while standard telecommunication services (e.g. voice, text) become less expensive, leading to low profit margins in the industry.

Although **passengers** will not be paying for using the app itself, as the end-users of the solution they play a decisive role in determining its success on the market. Therefore, an alternative business model with emphasis on facing the passengers (B2B2C) and showcasing the viability of the solution to them (as a minimum viable product) was sketched during the workshop. The passengers may be individuals or groups that travel for private or business reasons. Particularly long journey travellers are targeted by the business model, since passengers who travel short distances or regularly travel the same route do not require guidance. This means that with the growth of distance the service will become more relevant to users.

Considering the sustainability potentials to advance the business model further stakeholder groups become relevant. **Public and NGOs** supporting disabled individuals can be involved as multipliers, while disabled individuals themselves are the main social target group addressed by the model. If recommendations for taking the healthiest route available are offered to passengers, these can be integrated with the offerings of fitness tracker and pedometer app companies. If recommendations for the most ecological route are suggested, they can be endorsed by municipalities that support emission reduction. **Universities** could also be involved to provide research results on the sustainability impact of different means of transportation.

**Interaction:**

**Touchpoints**

As a small company, Urban Hawk relies on **partners** to facilitate the customer journey and enable a pleasant customer experience at the different customer touchpoint. Integrating the customer journey into these partner's journeys will be essential to ensure a frictionless experience. Substantial effort will be required to design and facilitate a rewarding customer journey, and to devise and manage all touchpoints to please customers (becoming aware, informing oneself, acquiring the service, starting it up, using it modifying it and disposing or renewing it) and clients.

Passengers should be *informed* about Urban Hawk's solution primarily through their **transport and network service providers**. Travel agencies, NGOs and municipalities are other stakeholders that can introduce potential users to the app (also see the following section on 'Distribution'). Another route to inform users is through the communication channels of the insurance providers themselves. In addition, Urban Hawk will use its own PR to promote the solution directly to end-users in websites, social media, magazines, blogs and reviews. The primary target groups that will be addressed in these interactions are users from generations Y and Z.

The **cooperation with Deutsche Bahn** as testbed provider and the upcoming field test within the 5G Victory project will serve as another PR vehicle. Empirical outcomes from these test cases provide evidence for the viability of the solution, which are specific to the sector and the problem at hand. At the same time their implications can readily be extended to other domains and use cases.

Users will *acquire* the app for free by downloading it from the Google Play **app store**. The journey planner and 3D spatial guidance features will be completely free wile InsurTech- and FinTech-based offerings will be premium and commission-based. As soon as users have downloaded the app, direct customer relationships can be built. However, the promotion of premium subscription offerings should be treated with caution since users expect to use the app for free and might become reluctant if suggested otherwise. A similar issue ('hidden pricing scheme') has been considered among the key reasons why the AR start-up Blippar, initially a strong competitor on the AR market, collapsed into administration in 2018 (Smithson, 2018).

*Starting up* the app users get connected to the back-end, which processes ~98 percent of the app's functionality. If they would like to upgrade to premium, more personal details would need to be entered and managed at the back-end. User will be able to *modify* all features through the app's interface, including personal details, preferences, and insurance coverages.

**Distribution**

The issue of scaling the business case on the market is critical for its viability. The use of **established distribution channels** is considered as the most effective strategy to foster scalability. This is because without such channels scaling may be too slow, meaning that the number of freemium users will significantly outgrow the number of premium users that can subsidize them. Approaches to handle this challenge include rolling out the service in stages or restricting the number of free users that can download the app. However, these solutions may bring discontent on the side of customers (e.g. in the form of complaints on social media) and therefore should be avoided or implemented with caution.

For distributing its solution to end-users, Urban Hawk will primarily rely on **partnerships with transport and network operators** who can inform their existing users about it. These actors offer the most significant opportunity to connect with a large base of potential users. **Travel agencies** that organize private or business trips can also be involved to promote the solution directly to passengers. A secondary channel for informing users can go through the insurance providers themselves. Again, partnerships with large enterprises with established distribution channels are seen as most advantageous. Revenue sharing is one key incentive that can be offered to these different kinds of business actors in order to establish strategic relations for partnership marketing. In addition, NGOs that deal with issues of disability, special needs and inclusion (e.g. the German Socialhelden; 2020 and their WheelMap.org) or municipalities and city councils (e.g. that support emission reductions) can be involved to further strengthen the customer outreach and raise awareness about the solution's sustainability potentials.

**Revenue model**

A **freemium** revenue model can offer free journey planning and guidance, which will be subsidised by revenues from premium users. These revenues will be generated by taking commission from the sale of 3rd party products, such as insurance, through automated recommendations and built-in premium services (e.g. 'Pay As You Roam'). The freemium strategy can facilitate fast rollout of the service and allow to quickly reach a critical mass of end-users that the company can capitalize upon afterwards. It also provides an alternative to the subscription model which was unsuccessfully used by previous businesses offering advanced location data or guidance services (as in the above example of Blippar). A key challenge and success factor for implementing the freemium strategy is to balance the number of paying and non-paying customers so that the former can fully subsidize the latter. This requires the involvement of established distribution channels as well as the provision of exceptional value through the premium offerings.

The primary revenue streams will be established by distributing the insurers' products and thus acting as their **digital brokers**. Travel insurances will be brokered to multiple underwriters instead of sticking to a single one, based on established fee structures for traditional brokers. The exact pricing is yet to be set out based on the business development outcome from negotiations with insurers/potential underwriters. A preliminary revenue calculation for a 'broker' commission monetisation model between the passengers (users) and the insurers was provided by Urban Hawk as follows:

> "The broker commissions range between 2% to 12% in motor insurance. Travel insurance average is 24%, sometimes stretching up to 50%. Conversion rate wise the closest digital comparison is online advertising. The average rate in the insurance industry is 9%. Google Ads conversion rates for both search and display networks are 7.19% and 1.75%, respectively, while about 30% of traffic to insurance websites come from search. Email marketing has an opening rate of 20.60% and a click through rate of 2.14%. Given the fact that the business model's customers (i.e. the passenger) are linked to travel 'by definition' the user base is considerably less diluted than in the online examples cited.
> A conservative 2% conversion with an average £10 travel insurance purchase on 24% commission generates £4,800 revenue; projected to 100k travellers per annum. Every year, 50 million passengers use Berlin Hauptbahnhof (central station) on long-distance journeys alone. That is £2.4 million revenue when linearly projected. By covering major stations our opportunity can scale rapidly, with future nationwide and European operations credibly bringing us toward tactical tap on a multi £100 million market."

In addition to the broker commissions, further revenues can be generated from **licence agreements** with the insurance companies for servicing and providing data to their claim validators, risk assessors and asset monitoring teams. Tailored fees can be charged to insurers for the use of Urban Hawk's data pipelines to support claim validation processes. Based on experience with insurance clients the workshop participants projected this revenue stream to also become significant.

Addressing the **passengers** directly opens opportunities for further revenue streams to be utilised. For example, different features for personalizing the user experience can be offered to passengers for a monthly fee. **Advertisements** of products and services from other (local) businesses can be integrated into the app. There are future potentials of expanding the freemium model with differentiated pricing depending on the speed, healthiness and emissions of the passengers' mobility choices. This will enhance the model's sustainability by incentivizing low emission and/or healthy modes of travel.

Another possibility is to integrate **ticketing and booking features** into the AR user experience and generate revenues from transaction fees or revenue sharing with other businesses (e.g. mobility, hospitality, restaurants, etc.). The solution can also be adopted by logistic companies to support parcel tracking and last mile deliveries, as indicated by one of Urban Hawk's existing customers from the industry. However, test cases to demonstrate the viability of these features are not envisioned within the 5G Victory project.

**Performance:**

**Capabilities**

Urban Hawk's internal capabilities will provide the R&D, trialling and deployment of the solution. The app functions with basic technology for **3D visualisation and guidance** (e.g. within big train stations based on available maps and models). The data captured from the visual world will feed the planning and situation-aware guidance (even in indoor environments). Computational capacities will be required for processing the data at the back-end. The use case requires several technical KPIs, such as **bandwidth, latency and location accuracy**, to be continuously maintained, which presupposes 5G connectivity. If 5G computation is not possible at a particular train station or terminal, then data centres in nearby locations will be used to ensure security, low latency and low emissions of the data transmission.

Further capabilities that need to be considered include:

- A non-executive or advisory board member from the insurer partner(s).
- Ever better understanding of the vertical's (insurers) pricing models and near- and medium-term strategies.
- Proactive lobbying with public sector actors (seen as significant advantage over passive competitors).
- Building and testing minimum viable premium modules, e.g. to test viability of revenue streams or the integration of environmental data to find optimal low-emission routes.
- Potentially another non-executive or advisory board member from the business partners involved in the provision of fintech services.

**Partners**

The **distribution partners** discussed above can be summarised as follows:

- Transport and network operators (primary route to market)
- Insurance providers (secondary)
- Travel agencies
- Public and NGOs dealing with issues of disability, special needs and inclusion
- Municipalities / city councils (e.g. that support emission reductions)

These distribution partnerships can be established on a domestic as well as on an international level, when replicating the business model across countries. Testbed providers (such as Deutsche Bahn) are other partners that will support the solution's marketing and provide qualified feedback on its viability. In addition, scientists and consultants can be involved to help spread the review process results online and in media.

Partnerships with **local data centres** are required to minimise costs, environmental impact and security risks of data transmission. Teaming up with data providers is needed for providing passengers with accurate recommendations on the healthiest routes of a journey. Similar partnerships can be established to acquire accurate data on the environmental footprint (e.g. per km) of different modalities (e.g. with GHGSat, 2021).

Cooperation with **competitors** were also considered during the workshop. For example, Nvidia, a market leader in GPUs (graphic processing units), AI and 3D spatial data is already involved as one of Urban Hawk's potential partners. According to the workshop participants the two companies 'share a very similar vision' on how the technology in the domain should be developed, i.e. developing a platform where 3D spatial data can be mixed together and different stakeholders can manipulate the data at the same time. In line with this shared vision Urban Hawk aims to make its service compatible with Nvidia's Omniverse platform (NVIDIA Corporation, 2021).

**Cost Structure**

Fixed costs will be incurred for running the service while the variable costs are yet unknown. The biggest factor that needs to be considered are the costs for **graphics processing** (GPU)

**and server compute capabilities**. These costs will be incurred regardless of whether Urban Hawk self-installs or uses data centres to deploy its service and will grow exponentially with the growth of app users. Initial growth of free users will lead to significant costs in the area that need to be covered before a critical mass of users can be reached and there is enough subsidisation coming from premium clients. As mentioned earlier, using nearby data centres will allow to further reduce the costs for computation. Potentially making investments towards scaling down the data stored can help to realize additional cost savings and reduce complexity and emissions.

Further costs will be incurred from using the 5G infrastructure and resources of network operators. Costs for the acquisition of business clients (e.g. insurers) and for clarifying the legal aspects of contracting with them also need to be considered. Substantial marketing and communication costs will be required to establish a customer brand and corresponding customer relationships in a B2B2C scenario.

Given the wide range of ideas at the current stage of development creates the challenge to ensure sufficient and cost-saving focus on the one hand, and allowing iterative experimentation with alternative approaches to improve market fit on the other. The prioritisation of the venture's values and the benefits can be used to keep sufficient sense of direction.

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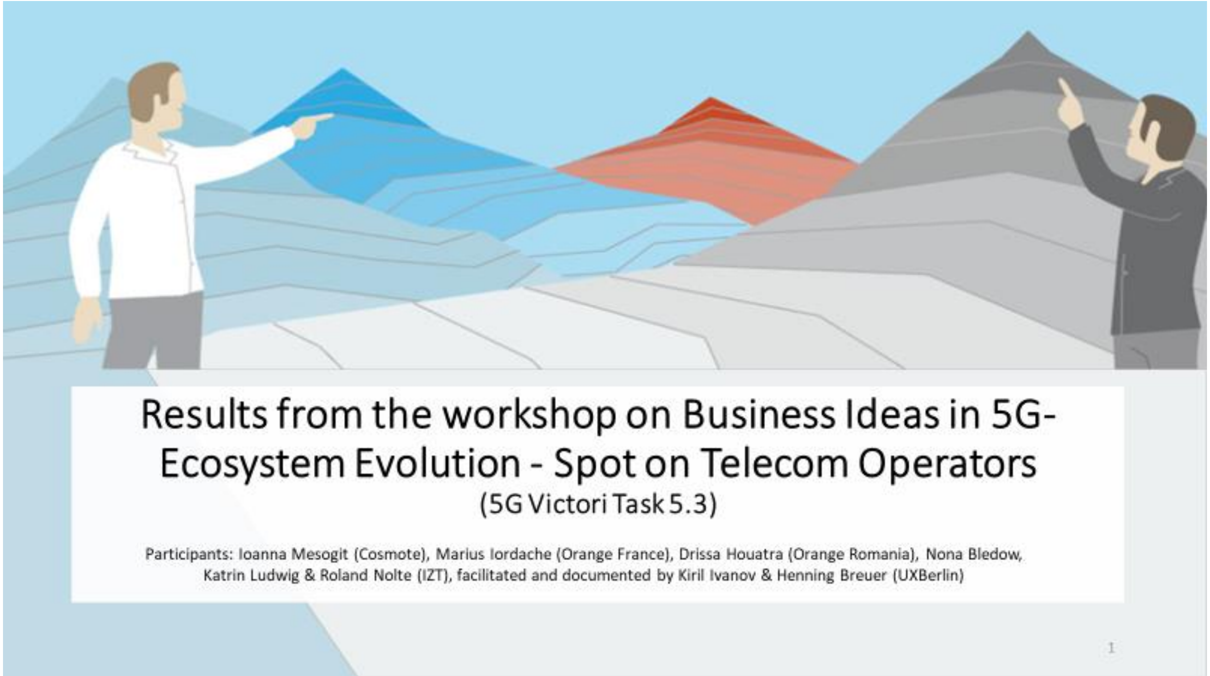
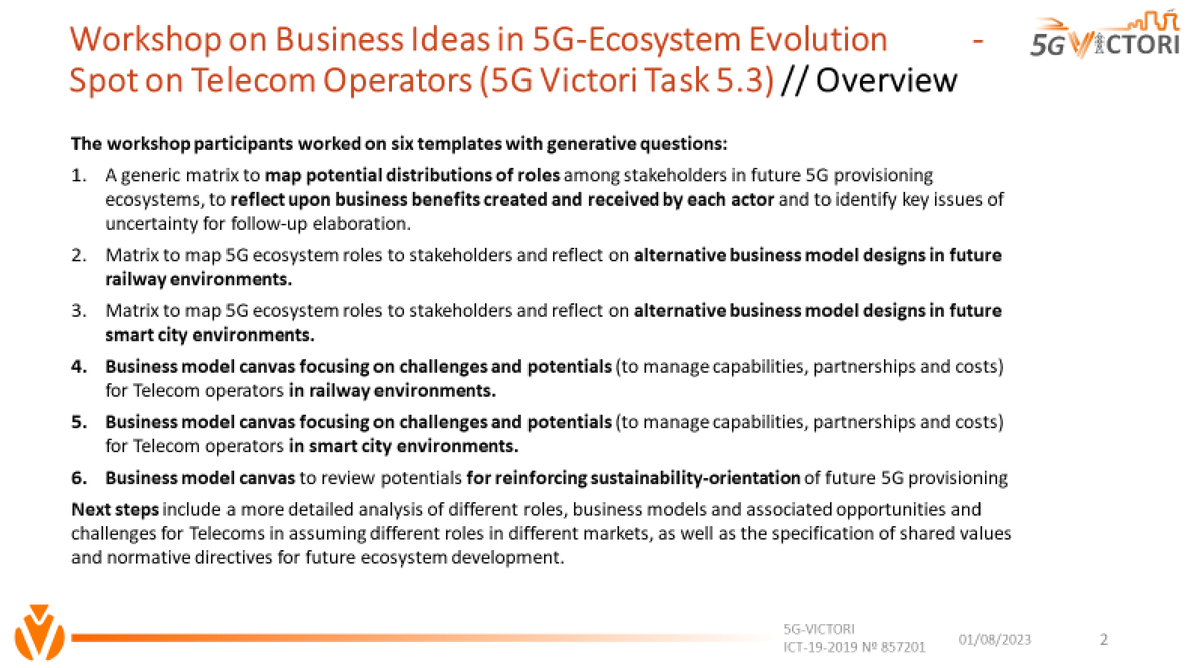
### 7.2.4 Workshop on Business Ideas in 5G-Ecosystem Evolution – Spot on Telecom Operators



Workshop on Business Ideas in 5G-Ecosystem Evolution - Spot on Telecom Operators (5G Victori Task 5.3) // Overview

**The workshop participants worked on six templates with generative questions:**

1. A generic matrix to **map potential distributions of roles** among stakeholders in future 5G provisioning ecosystems, to **reflect upon business benefits created and received by each actor** and to identify key issues of uncertainty for follow-up elaboration.
2. Matrix to map 5G ecosystem roles to stakeholders and reflect on **alternative business model designs in future railway environments.**
3. Matrix to map 5G ecosystem roles to stakeholders and reflect on **alternative business model designs in future smart city environments.**
4. **Business model canvas focusing on challenges and potentials** (to manage capabilities, partnerships and costs) for Telecom operators **in railway environments.**
5. **Business model canvas focusing on challenges and potentials** (to manage capabilities, partnerships and costs) for Telecom operators **in smart city environments.**
6. **Business model canvas** to review potentials **for reinforcing sustainability-orientation** of future 5G provisioning

**Next steps** include a more detailed analysis of different roles, business models and associated opportunities and challenges for Telecoms in assuming different roles in different markets, as well as the specification of shared values and normative directives for future ecosystem development.

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## Background // Motivation and goals for the workshop

- Complex networks of complementary actors (i.e. **ecosystems**) are replacing linear value-chains in providing 5G solutions and value to customers; **uncertainty** about ecosystem evolution and transformation of the Telekom Operator roles and business prevail.
- "Technology principles, the capabilities and the business potentials of 5G … necessitate stronger involvement of a larger set of … **actors with new key roles** in the provisioning of 5G services" (5G Ecosystems 2021, 20).
- Potential **tensions** between stakeholders in emerging 5G ecosystems require balancing of interests, mitigation of hurdles and creation of consensus (5G Ecosystems 2021, 11).
- New opportunities and values creation need to be aligned with **European and global sustainable development goals** (ibid. 3).

Where to go today

- Seek to better anticipate different evolution paths, and to understand the Telecom Operators business perspective on the provisioning ecosystem in terms of:
  - **Distribution** of stakeholders and roles in different environments (from global view to deployment environments of railway and smart city)
  - **Benefits** provided by participating ecosystem, actors
  - Telecom business model **challenges** for the different deployment environments
- Generate ideas on how to enhance sustainable (environmental, social and economic) value creation e.g. considering sustainable business model design patterns.

**Workshop Goals**: Clarify benefits in an emerging 5G provisioning ecosystem from a Telecom Operator point of view. Explore potentials to enhance sustainability-orientation.
**=> No conclusive new strategy but one more step to improve preparedness for uncertain future developments.**

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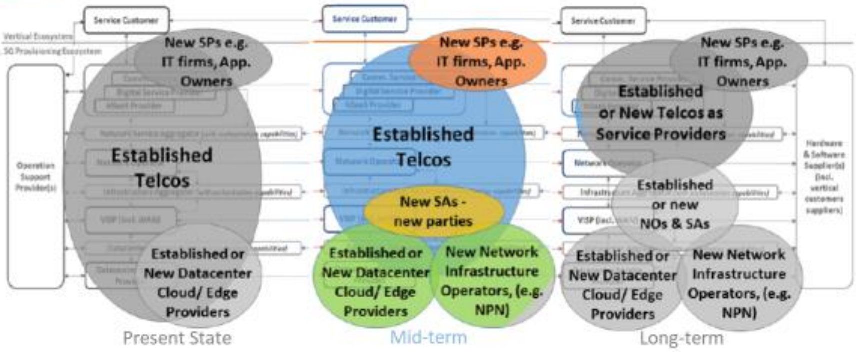
## 1. Exchanges of Business Value in Future 5G Provisioning Ecosystems




„Telecom Operators - instead of developing in-house expertise - could be willing to pay especially **for external support** in IT competences and services …. to **lease** additional **infrastructure** resources from 3rd parties …, practically outsourcing the operation of IT/Cloud/Edge infrastructure … for localized … scenarios …. They could become more open to **engage in … SW projects** …. Telecom Operators can maintain the Network Operators and Service Provider roles, while establishing collaborations with smaller … Telecom Operators and verticals undertaking the role of (cooperating) Network Operator, as well with Cloud/Edge Providers as well as with the IT industry undertaking the roles of DCSP/ VISP an Service Aggregators of that layers" (5G Ecosystems 2021, pg.26f).

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# 1. Exchanges of Business Value in Future 5G Provisioning Ecosystems

## (global view value matrix to understand business value provided by each stakeholder)

What does the stakeholder contribute? What kind of value does it create for others? Stakeholder in column 1 CREATES VALUE FOR stakeholder in column x.

| Stakeholder | | New SP | Established Telco | | New Service Aggregator | | New DCSP | Service customer |
|---|---|---|---|---|---|---|---|---|
| | Role | SP | NO | Network Service Aggregator | VSIP | Infrastructure Aggregator | DCSP | Verticals / end-users |
| New SP | SP | | • Provides IT services that result in lower TCO<br>• Allows more focused core business activities to catch up with competitors | | | | | Distributes network connectivity acquired from the Telco (increased bandwidth at low cost) |
| Established Telco | NO<br>Network Service Aggregator | • Provides increased bandwidth at low cost and...<br>• infratsructure as business enabler<br>• Allows more focused and competitive core business activities and...<br>• improved focus of personnel skills | | | Makes room in the market for the underlayers (new VISPs can enter the market) | | Provides global connectivity | Provides global connectivity and enables increased bandwith at lower costs |
| New Service Aggregator | VSIP<br>Infrastr. Aggregator | | • Decreases TCO (through increased utilization of raw resources that can be aggregated & provided to different firms)<br>• Allows more focused and competitive core business activities and..<br>• improved focus of personnel skills | | | | Makes room in the market for the underlayers (new DCSPs can enter) | |
| New DCSP | DCSP | | | | • Reduces deployment time (time to market for raw resources)<br>• Decreases TCO (through increased utilization of raw resources that can be aggregated & provided to different firms)<br>• Allows more focused and competitive core business activities and...<br>• improved focus of personnel skills | | | |

Link to the Mural templates with the value matrices and business model canvasses.

The value matrix shows different stakeholders and their roles in the emerging 5G provisioning ecosystem. Entry fields can capture (and facilitate clarification of) business values created by each actor.

# 2. Mapping of 5G Ecosystem Roles to Stakeholders in Future // Railway Environments

**Three alternative, potential ecosystem/business model developments:**

1. An established **Telco takes all roles** (as in the traditional approach) and provides connectivity to the railway operator. However, new FRMCS networks cause high deployment costs, and Telcos refrain from such investment. (Railways on the other hand don't have sufficient skills and/or capacity to independently deploy and operate them.) This may not be the way to proceed.
2. An Established **Telco takes the SP and NO roles**. Railway operators (autonomously or through a subcontractor) takes the VISP and DCSP roles.
3. An Established **Telco takes the SP role**. Railway operators (autonomously or through a subcontractor) provide the network's deployment, gaining ownership of the infrastructure and the NO, VISP, and DCSP roles.
   - **Railways can benefit from using their capacities** for preventive maintenance, train and lines' automation **as well as from leasing them to Established Telcos** for additional revenues. Telcos benefit from lower TCO.
   - **3rd party network equipment providers** (e.g. NOKIA, Ericson, Siemens) can build and connect the network (even in some cases operate it in local areas).

**Example:**
In France the railway operator (SNTF) subcontract network equipment providers to build their network, which they use for railway signalling and partner with established Telcos (e.g. Orange) for the management and commercialization of the network (SNTF is not allowed to commercialize the network to the public).

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## 3. Mapping of 5G Ecosystem Roles to Stakeholders in Future // Smart City Environments

**Three potential ecosystem/business model developments:**

1. An Established **Telco takes all roles**
   - Traditionally Telcos provide communication capacity to all other companies but **some Telcos may want to reverse the trend to benefit from network infrastructure from 3rd party organizations and provide communication and IT services on top of them**. Thus they can lower TCO for the 3rd party while utilizing the acquired capacities to enhance the network quality in the area.
2. **Municipalities (or industrial companies with large capacities) build radio networks and take the VISP and DCSP roles** (by contract with companies specialized in the installation/maintenance of network infrastructure). Established Telcos take the roles of NO and SP of communication services gaining and interworking resources from municipalities.
   - **Due to high network deployment costs municipalities** under their country's digital governance and economic agencies may decide to **foster (not economically feasible for Telcos) deployments in remote areas to reduce the digital divide** and generate social and economic benefits (attractiveness for new businesses). Municipalities can utilize their ownership of street furniture (e.g. benches, lamp posts, etc.) to deploy network equipment and reduce TCO (high rental costs) for Telcos. This is a novel business model with **high growth potential**.
   - **The VISP and DCSP roles are delegated to subcontractors**, who provide skills, deploy and maintain the municipality's network.
   - **The DCSP role can also be assumed by Telcos or existing cloud providers**, e.g. companies specialized in building and providing cloud resources to different locations such as ACAMAI. For local content delivery municipalities or small-scale cloud providers can utilize resources from established actors like ACAMAI.
   - **Radio equipment owned by municipalities can be attached to the 5G core of one or multiple NOs**. Radio networks build in the industrial campus can ease installation, **making the locality more attractive to new 5G ecosystem actors and verticals**, e.g. network service sub-operators can utilize municipalities' equipment and network capacities to extend 5G networks to industrial or transportation firms.
3. **All roles are assumed (through subcontractors) by municipalities for a very small scale (local) deployment** (e.g. operating a campus network for several companies within an enterprise 5G network). For instance, in France municipalities have their own cable network infrastructure.

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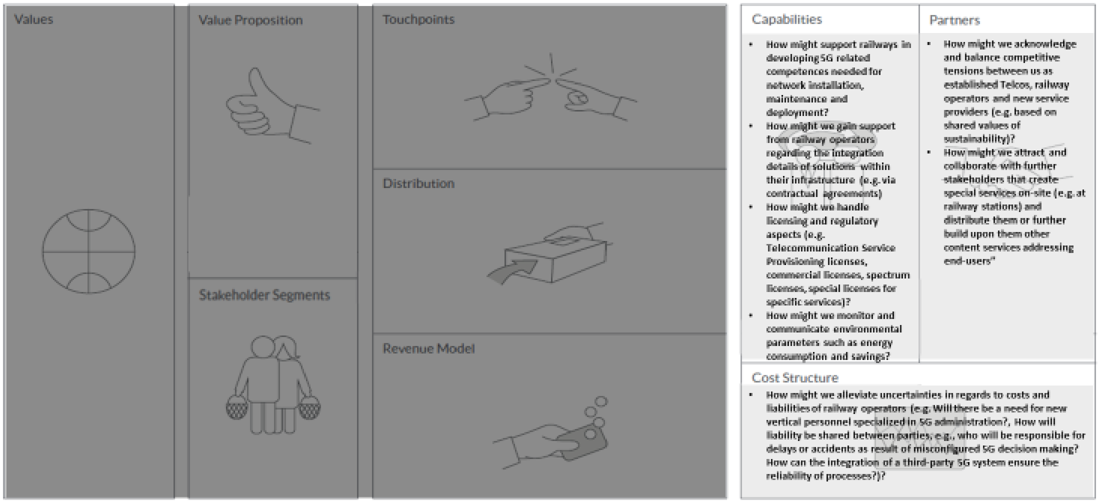
## 4. Challenges and potentials for Telecoms to manage capabilities, partnerships and costs in railway environments

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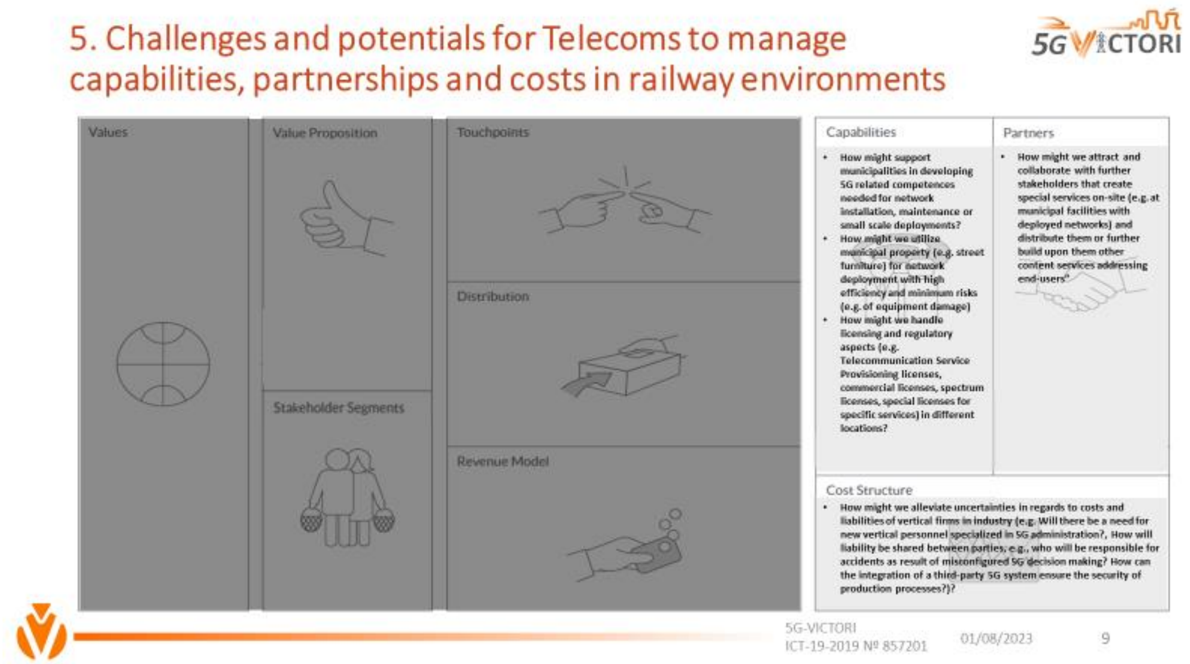
5. Challenges and potentials for Telecoms to manage capabilities, partnerships and costs in railway environments
5G VICTORI
Values
Value Proposition
Touchpoints
Distribution
Stakeholder Segments
Revenue Model
Capabilities
• How might support municipalities in developing 5G related competences needed for network installation, maintenance or small scale deployments?
• How might we utilize municipal property (e.g. street furniture) for network deployment with high efficiency and minimum risks (e.g. of equipment damage)
• How might we handle licensing and regulatory aspects (e.g. Telecommunication Service Provisioning licenses, commercial licenses, spectrum licenses, special licenses for specific services) in different locations?
Partners
• How might we attract and collaborate with further stakeholders that create special services on-site (e.g. at municipal facilities with deployed networks) and distribute them or further build upon them other content services addressing end-users"
Cost Structure
• How might we alleviate uncertainties in regards to costs and liabilities of vertical firms in industry (e.g. Will there be a need for new vertical personnel specialized in 5G administration?, How will liability be shared between parties, e.g., who will be responsible for accidents as result of misconfigured 5G decision making? How can the integration of a third-party 5G system ensure the security of production processes?)?
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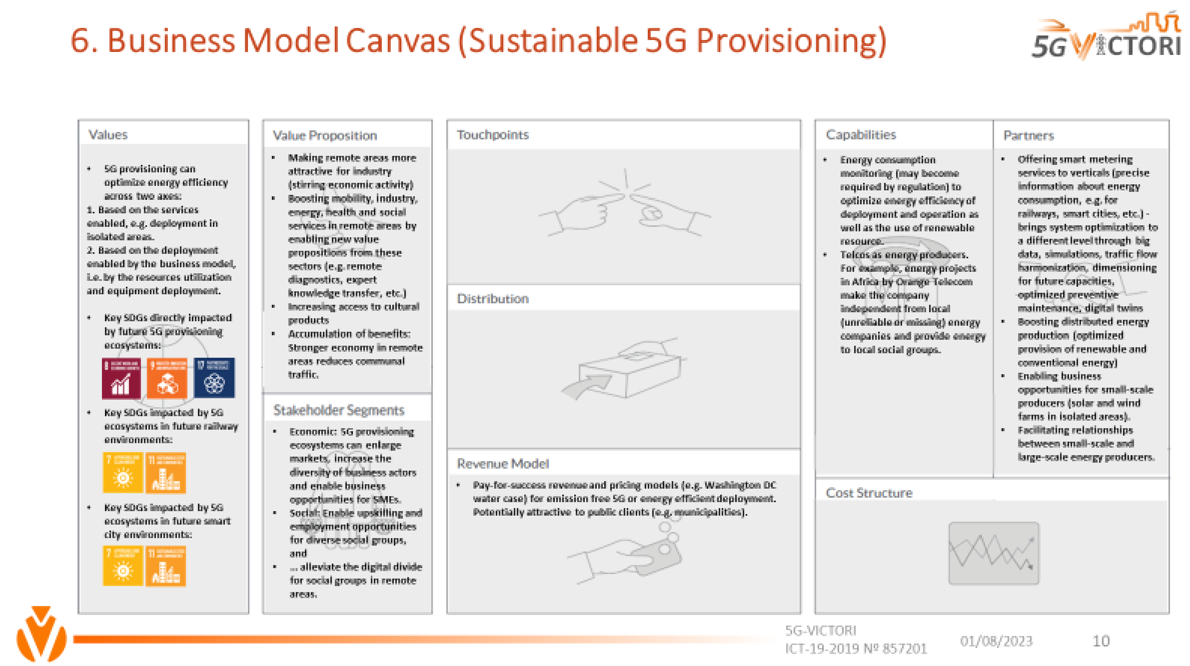
6. Business Model Canvas (Sustainable 5G Provisioning)
5G VICTORI
Values
• 5G provisioning can optimize energy efficiency across two axes:
1. Based on the services enabled, e.g. deployment in isolated areas.
2. Based on the deployment enabled by the business model, i.e. by the resources utilization and equipment deployment.
• Key SDGs directly impacted by future 5G provisioning ecosystems:
• Key SDGs impacted by 5G ecosystems in future railway environments:
• Key SDGs impacted by 5G ecosystems in future smart city environments:
Value Proposition
• Making remote areas more attractive for industry (stirring economic activity)
• Boosting mobility, industry, energy, health and social services in remote areas by enabling new value propositions from these sectors (e.g. remote diagnostics, expert knowledge transfer, etc.)
• Increasing access to cultural products
• Accumulation of benefits: Stronger economy in remote areas reduces communal traffic.
Stakeholder Segments
• Economic: 5G provisioning ecosystems can enlarge markets, increase the diversity of business actors and enable business opportunities for SMEs.
• Social: Enable upskilling and employment opportunities for diverse social groups, and
• ... alleviate the digital divide for social groups in remote areas.
Touchpoints
Distribution
Revenue Model
• Pay-for-success revenue and pricing models (e.g. Washington DC water case) for emission free 5G or energy efficient deployment. Potentially attractive to public clients (e.g. municipalities).
Capabilities
• Energy consumption monitoring (may become required by regulation) to optimize energy efficiency of deployment and operation as well as the use of renewable resource.
• Telcos as energy producers. For example, energy projects in Africa by Orange Telecom make the company independent from local (unreliable or missing) energy companies and provide energy to local social groups.
Partners
• Offering smart metering services to verticals (precise information about energy consumption, e.g. for railways, smart cities, etc.) - brings system optimization to a different level through big data, simulations, traffic flow harmonization, dimensioning for future capacities, optimized preventive maintenance, digital twins
• Boosting distributed energy production (optimized provision of renewable and conventional energy)
• Enabling business opportunities for small-scale producers (solar and wind farms in isolated areas).
• Facilitating relationships between small-scale and large-scale energy producers.
Cost Structure
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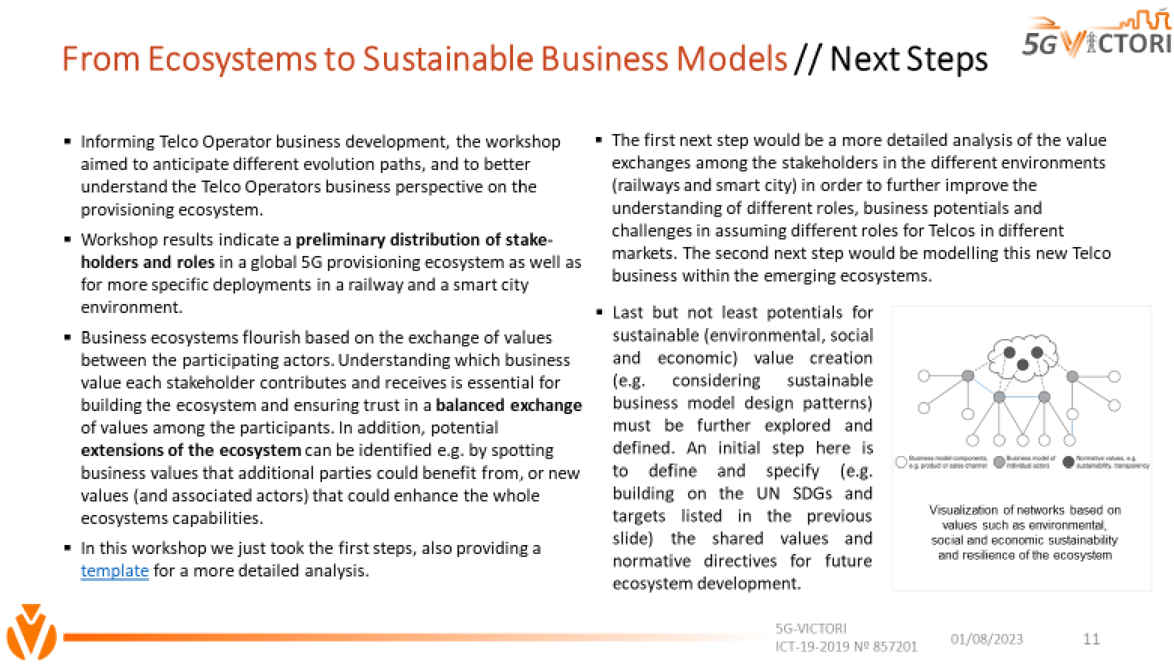


### 7.2.5 5G-VICTORI Business Modelling Refinement Workshop – On Demand Private Networks for Industry 4.0 capabilities

***Refined results from the second workshop (Sept. 28th 2022 / Task 5.3)***

***Business modelling "On Demand Private Networks for Industry 4.0 capabilities"***

**Participants**: Eleftherios Mylonas & Nikolaos Tzanis (Admie), Nona Bledow & Katrin Ludwig (IZT); workshop prepared, facilitated and results refined by Dr. Henning Breuer & Kirl Ivanov (UXBerlin – Innovation Consulting)

**Summary:**

- Due to resistance to innovations in the energy transmission market the value proposition is the essential component requiring validation and clear communication of its advantages compared with legacy solutions. Identifying and testing killer applications is a pivotal next step to demonstrate the solution's advantages. Another strong argument for the solution's advantages can be provided by monitoring and defining KPIs for its energy efficiency.
- The relationships among the collaborating parties require further coordination and contractual agreements. A single client-facing team should be formed to approach clients and create the client journey while representing the interests of the three parties.
- Development and sharing of new competencies should be coordinated to ensure sufficient expertise for interfacing across partners and clients' application domains. Detailed contractual agreements or an independent legal entity should be established to address potential trust and liability issues.
- Alternative revenue models as to whether the solution will be sold as an infrastructure extension or a use-oriented service should be validated with respect to different

markets or customer segments (e.g. through methods of stakeholder and competitor analysis or expert interviews).

**Objectives:**

- Recap recent changes in business model components that have been defined or discussed in the core team.
- Refine the (preliminary) business model in response to anticipated 5G **ecosystem developments** to leverage their potentials for improving the business idea.
- Identify the most **critical** (high-risk or uncertain) business model components and specify **assumptions** to focus on in the subsequent business development and validation.
- Specify methods **to validate** sustainability potentials, desirability and viability of the (preliminary) business model. Agree upon next steps to go to (test) market.

**Recap of recent changes in the business model sketches**[1]

- After considering two alternative business models in the first workshop, the idea providers suggest to first **focus on** the more substantial business potential of **the industry 4.0/energy transmission use case**. The second alternative of providing “Temporary On Demand 5G Coverage in Remote Areas” should be considered as an alternative for implementing the already tested core technology for other use cases, wherein the required level of customisation is lower, and the solution can be more readily provided.
- Because the solution requires a high level of **customisation**, increased engagement of the customers will be necessary to clarify the customer’s specific requirements. If the customer is approached by three independent parties who provide the solution, this may lead to lack of trust, misunderstandings and confusion with regards to whom the client should contact in case of malfunctions. Therefore, the customer will most likely be contacted by a **single client-facing team** representing all three partners. Similarly, all payments for the service will be collected from the client through this single point of contact, and then redistributed across the three partners according to their predefined agreements. Since Admie, as IPTO, is also a client of the solution, it would not assume the role of primary or first contact for the customer. It will, however, play an important role in connecting with energy transmission system operators (TSOs) in other countries and communicating with them the benefits of the solution.

**Critical assumptions and risks**

**Value proposition:** The most critical issue to be considered is the **resistance to innovations in the energy transmission market** and the need to convince clients about the (significant) advantages that new solutions can provide in comparison to the legacy solutions in use. Customer acquisition is unlikely if advantages cannot be measured or if they promise only minor improvements to legacy solutions. At present uncertainty about the advantages of 5G solutions prevails. The energy transmission industry has not yet adopted 5G applications which can benefit from the lower latency and high reliability enabled by 5G services. Prices of 5G sensors remain high (although significant price reductions are expected in the near future). When clients require lower latency and high reliability networks their stick to fibre optic networks and use wireless networks only for legacy (GSM) sensors that do not demand reliability or fast response. This requires **demonstrating and clearly communicating the advantages** of adopting new 5G applications.

Furthermore, as vertical clients in the market continue to rely on legacy sensors, telecommunication protocols and fibre optic networks rather than using new orchestration and virtualisation technologies, they must acquire **competencies** in 5G and orchestration. This is another reason for their resistance to 5G solutions. Yet another reason is the risk aversion in the energy domain and its apprehension to integrate novel solutions in order not to jeopardize the well-operating systems. However, this also presents a **business potential for** the Patras Autonomous Edge solution since it is able to support **backwards compatibility** with legacy industrial protocols, infrastructure and sensors (e.g. by using gateways to enhance the network capabilities of legacy sensors). Current **operational pressures** in the energy transmission domain (provoked by the geopolitical crisis and environmental legislations) might also contribute to the business potential of the solution as they motivate clients **to look for new ways of reducing costs and power consumption**.

**Touchpoints:** The customer journey is not well defined yet, i.e. how does the adoption of the solution take place step by step. In a first step suitable pilot clients should be identified and an initial readiness for adoption and demand should be generated through suitable publications or information materials, before special agreements can be created for pilot clients and implementations for client and user validation.

**Revenue model:** Who is taking ownership of the equipment (sensors, 5G and edge computing infrastructure) will determine if the solution providers sell **infrastructure extension or** a **use-oriented service** (as one applicable sustainable business model pattern in Luedeke-Freund et al. 2022, 232ff)[2]. If the partnering companies sell the software solution and the 5G Base Station they would also sell the solution as an integrated product, including the Patras SG Autonomous Edge and the necessary sensors. In the alternative case, when they only lease the Base Station (gNodeB e.g. for short-term deployments in isolated areas), ADMIE would also keep ownership of the sensors and the solution will be provided as a service. Which business model is selected may depend on the differences in customers' preferences, national markets and regulations for critical infrastructure.

Providing 5G solutions as a **use- or result-oriented service**[3] can be associated with several potential advantages to the provider as well as to the client, such as seamless maintenance, enhanced control and enhanced (environmental) efficiency. However, simultaneously pursuing both a conventional business model based on product sales and a use-oriented service model may be challenging due to the contradictory business logics that underly them. Moreover, firms in the energy domain have mostly not transferred their network capacities to the cloud and remain apprehensive about adopting cloud-based services to avoid potential interruptions in service provision. Legal restrictions concerning the ownership of critical (e.g. energy transmission) infrastructure and monitoring equipment may also impede the provision of the solution as a service in some markets.

**Capabilities:** The acquisition of new **competencies for interfacing with partners and clients' application domains** is a critical aspect for all parties. Admie or other industrial clients should gain competencies regarding new technologies, e.g. cloud orchestration and virtualisation, IntraCom regarding further industrial protocols that should be integrated in their IoT platform, University of Patras regarding new services for 5G in order to support clients' requirements for new services.

**Cost structure:** One major concern in a mid-term perspective will be to clarify uncertainties about how **liabilities** with respect to the stability of the system will be shared among the solution providers and the customer. This is due to the sensitivity of the energy industry towards downtimes in monitoring systems, which in some cases should not exceed a few hundred milliseconds. Furthermore, since the operability of the solution depends on the three involved parties providing it, there may be uncertainty and lack of ownership regarding who takes responsibility for occurring downtimes and process errors. However, this concern has not yet been discussed and the previous test cases, focusing on the solution's technical operability within a short timeframe, could not generate insights into how malfunctions may occur and be effectively dealt with.

**Methods to validate or address the most critical assumptions and risks**

**Value proposition:** Expert interviews with 5G standardisation authorities can help anticipate network efficiency improvements and resulting emission reductions and define corresponding **KPIs**. Subsequent impact assessment and benchmarking of environmental parameters will allow to validate the energy efficiency of the solution and communicate positive impacts with stakeholders. Reference to the relevant **SDGs** and targets allows framing and advancing a sustainable value proposition in line with an established normative framework (e.g. 7.3, 8.2, 8.4, 9.4, and 9.c)[4].

For validating **desirability for clients**, expert interviews with TSOs can help to validate their needs and requirements for reduced latency in data transmission and define corresponding KPIs. Another way to validate desirability is to clearly demonstrate the advantages of the solution. First, a small set of **killer applications** that can boost the clients' current transmission monitoring infrastructures beyond their limits and justify the use of 5G technologies should be identified (cf. real time monitoring of the power consumption of automated trains in "Use Case 4"). Next, experiments should demonstrate the effectiveness of the Patras Autonomous Edge solution for supporting the new applications better than the legacy equipment.

**Touchpoints:** Suitable touchpoints for new client acquisition and a customer journey have not been established yet. Specifying and validating them is critical for successful market introduction.

**Revenue model:** Methods of **stakeholder and competitor analysis** can help to anticipate the market demand and whether clients will be more interested in buying the solution as a product or leasing it as a service. **Expert interviews** with governmental authorities and TSO representatives can also help to better understand how the ownership of different parts of critical infrastructure is regulated and whether the local legal environment allows servitisation.

**Capabilities:** The use of open APIs by IntraCom allows continuous provision of the solution even outside the established partnerships between IntraCom, University of Patras and Admie. Thanks to their collaboration in the 5G Victory project, the involved parties can ensure sufficient development and sharing of domain-specific competencies. Still, **efforts for coordinated competency development** will need to be continued beyond the timeframe of the project and take place on a regular basis (e.g. whenever approaching new clients).

**Cost structure:** The need to clarify how liabilities will be shared between the three partners suggests piloting the solution in alternative use cases where the sensitivity to system downtimes is not as high as in the energy domain (e.g. at festivals or other events). Other ways to address this issue in advance and avoid potential conflicts is to define **detailed contractual agreements or** to appoint an **independent legal entity** that can establish which part of the solution was malfunctioning in case of an outage. Although there are existing independent authorities in the energy transmission domain, they may not be involved in solving legal disputes between different providers of the same technical solution as in the case of the Patras SG Autonomous Edge. Previous use cases in 5G ecosystems have addressed trust and liability issues between 5G services and existing IT infrastructure producing data by appointing a new "interoperability facilitator" role[5]. To avoid potential liability problems, it is also essential to ensure the quality of the sensor and equipment by procuring it from reliable suppliers.

### 7.2.6 5G-VICTORI Business Modelling Refinement Workshop – vCDN services for railways

***Refined results from the second business modelling workshop (Sept. 29th 2022 / T5.3):***

***Business** modelling " vCDN services for railways"*

**Participants**: Marievi Xezonaki (Intracom), Nona Bledow (IZT); workshop prepared, facilitated and results refined by Dr. Henning Breuer & Kirl Ivanov (UXBerlin – Innovation Consulting)

**Summary:**

- The business model for vCDN is being optimised to make public transport and mobility more attractive through quality multimedia content along the passenger's journey.
- Validation of business-related assumptions should focus on this value proposition (also spelling out the customer journey) and the revenue model (including delivery costs). Energy consumption for different scenarios should be measured to prove environmental benefits.
- Field trials coming up in 2023 with passengers should be used to gather qualitative customer insights and survey data for validation and further specification of the business model.

**Objectives:**

- Recap recent changes in business model components that have been defined or discussed in the core team.
- Refine the (preliminary) business model in response to anticipated 5G ecosystem developments to leverage their potentials for improving the business idea.
- Identify the most critical (high-risk or uncertain) business model components and specify assumptions to focus on in the subsequent business development and validation.
- Specify methods to validate sustainability potentials, desirability and viability of the (preliminary) business model. Agree upon next steps to go to (test) market.

**Recap of recent changes**

- **Feasibility**: The proposed vCDN (virtualised Content Delivery Network) solution for high-quality multimedia content distribution in railway environments has been successfully tested in a lab environment with local network components, emulating the real railway premises. It is planned that the solution will be deployed on real trains and evaluated on-site over the next months.
- Readily achievable technical **KPIs** have been specified for the Greek market, such as having 3 to 4 minutes train stops at stations and transferring about 15 GB of content

during this period. These KPIs are also readily scalable, e.g. by deploying two installations of the hardware or including more content channels.

- Building on last year's workshop results, efforts to foster sustainable development now focus on enhancing its **environmental and energy efficiency** by attracting more passengers to use public transport instead of private vehicles. In the context of making public transport more appealing to passengers and promoting its use over private transport, a potential new vision has also been considered as a future extension to the business model. Specifically, the proposed vCDN solution for high-quality multimedia content distribution could potentially also be used in public buses, trams and metro lines, apart from railways – also in mobility hubs such as railway stations. In this way, it will be more likely to target the entirety of the most common means of public transport and attract a larger number of passengers (also to utilize prefetched rather than individually accessed content. This new vision, if added, could therefore contribute to the sustainability enhancement of the business idea, as it would further reduce energy consumption and $CO_2$-emissions of the whole system (*resource efficiency & productivity* pattern[6]).
- The solution providers are still open to different **revenue models**, and need to decide for one to start with.
- No exemplary **cost calculations** have been made yet. However, it is certain that the costs will largely vary depending on the volume of data transferred via data showers, which in turn depends on the number of customers using the service, the train stop duration and the duration of the train journey. Costs need to be estimated in the upcoming field tests.

**Critical assumptions and risks in the business model[7]**

**Value proposition:** The *central value proposition* is making uninterrupted, high quality multimedia content accessible for passengers. They need to adopt and appreciate the new solution and for instance install or utilize an app to do so.

The *energy efficiency* of the solution can add a strong argument to the value proposition for the passengers as well as for the railway operators, who may benefit from lowering their environmental footprint. The solution is energy efficient because it allows passengers to acquire content from a single connection to the CDN provider, instead of requesting content individually. Taking an individual (rather than an ecosystem) perspective, some railway operators may consider that the solution will add on to their energy consumption, which they would usually outsource to individual passengers and their data plans. Nevertheless, the currently engaged railway operators are positive about solution's environmental benefits and put more weight on the prospect of attracting more passengers by having the data shower service associated with their services and their brand.

*Differentiating* the value proposition to engage other target customer groups offers potentials for strengthening the business case. For example, station owners (who may differ from the railway operator) and other businesses in the proximity of the station (e.g. restaurants, public facilities) can utilize the data shower solution and be engaged as an additional customer segment, providing better quality and more energy efficient connectivity to end-users. This can be especially relevant at large stations where 4G networks are easily overloaded. Alternative types of content such as immersive media and VR could also be provided to passengers. However, the desirability of such offerings has not been validated yet.

**Revenue model:** Although alternative revenue schemes and pricing strategies (e.g. fixed price, subscription, pay-per-view, sustainability-oriented business models such as differentiated or social / green freemium pricing)[8] can be adapted to the requirements of different national markets or types of railway operators (e.g. private vs public), most likely, only one of these alternatives will be selected upon market entry. For now, a preferred revenue model is deemed the scenario in which passengers pay a fixed price to the railway operator, the railway operator pays the network operator for the connectivity along the railway infrastructure and also the service provider for the vCDN installed at the railway premises and the service provider pays to the content provider(s).

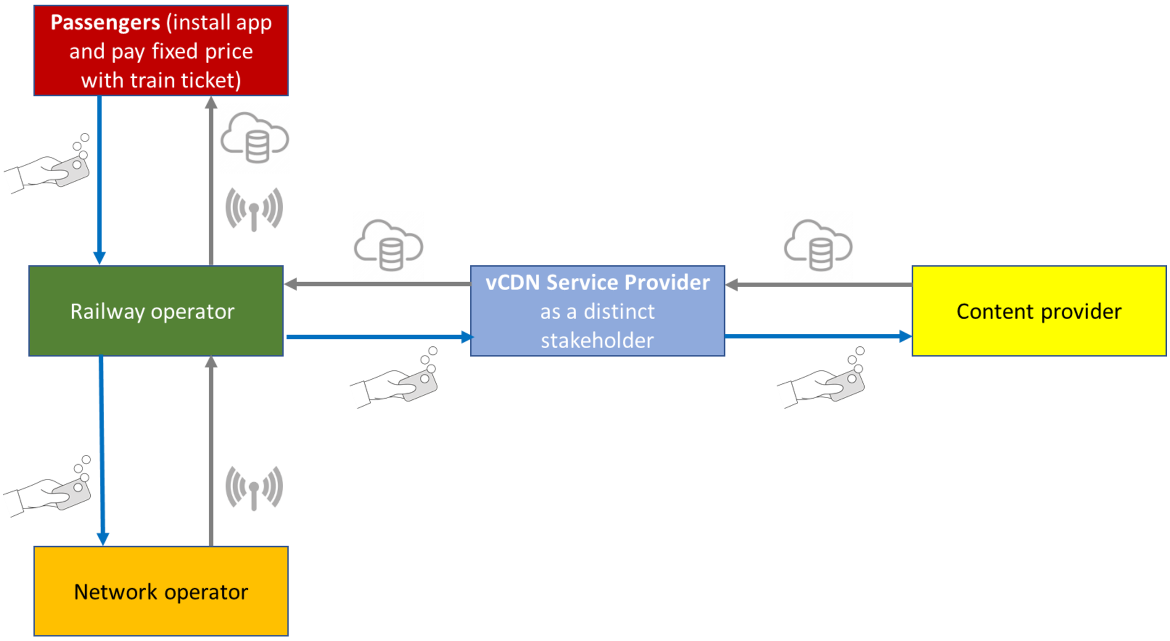


Image: Potential exchange of services and payments among the actors

**Partners:** The quality and continuity of the service may be undermined due to train delays, which prolong the trains' time spent between stations and reduce their halt time. Interruptions from the side of the content provider can also occur and undermine the end-user experience. This makes the service provision significantly dependent on the operability of partners.

### Methods to validate or address the most critical assumptions and risks

**Value proposition:** The *central value proposition* of making uninterrupted, high quality multimedia content accessible for passengers is the key assumption to validate. *Guiding questions* include: Do customer utilize, perceive and appreciate the benefit (compared to a less reliable access through their individual data plans)? Can we achieve a high adoption of the service, also by designing an engaging customer journey including individual adoption of the new or integrated (to the railway providers) app?

Online **surveys** provide feasible and affordable means for validating customer desirability. They should be carefully designed and recruit respondents that correspond to the customer target groups (e.g. passengers of a particular railway company). Another way to validate the solution's desirability and (re-)define alternative value propositions and pricing strategies is through a **cohort study** with different customer segments. However, online surveys and cohort studies will likely provide insufficiently valid data since respondents have no actual experience of using the solution.

Planned **field tests** in the beginning 2023 will take place at railway premises together with **UoP** and using content from **COSM**. Further testing is planned to take place with passengers within operational time shortly afterwards. This will provide an opportunity to validate not only the technical feasibility of the solution but also its desirability and key aspects of business viability. Field surveys administered during the upcoming field trials will provide more accurate and reliable data from passengers who had real experience with the usability and benefits of the solution during their commute. Further expert or **field interviews** can be conducted with passengers and related organisations, including passengers with special needs (e.g. children, elders, disabled, etc.) and requirements (e.g. LOHAS) to validate the solution's desirability (end-user needs and preferences).

Quantitatively assessing and monitoring how the solution contributes to optimised **energy efficiency** in comparison to conventional use of 4G or 5G data plans on an individual basis can strengthen the value proposition. Such assessment is also planned to take place during the field tests in 2023. In addition, relevant **SDGs** and targets can allow framing and advancing the sustainable value proposition in line with an established normative framework (e.g. 11.2 and 9.c[9]). Expert interviews with standardisation authorities can help to anticipate network efficiency improvements and resulting emission reductions and define corresponding KPIs. Compliance with environmental standards for 5G services (e.g. ETSI, ITU-T, 3GPP, or ATIS standards[10]) can enable impact assessments, benchmarking and communication of positive environmental impacts with stakeholders.

**Revenue model:** In addition to validating the desirability of the value proposition, different survey methods can be used to analyze the passengers' **willingness to pay** and prioritize appropriate pricing schemes (e.g. through a Van Westendorp's Price Sensitivity Meter). In the future, test market entries implementing different pricing strategies for different railway routes can also help to compare and validate alternative pricing schemes.

**Partners:** Implications of different scenarios in which the interaction of the partners does not work should be evaluated. Agreements with railway operators and content providers should clarify how interruptions of the service due to train delays or other problems will be handled and communicated to the end users. Sustainability criteria and KPIs (e.g. based on the SDGs) can be integrated into the assessment system for selecting and involving partners who align with the values and purpose of the business idea (to encourage more sustainable travel options and use of multimedia services).

### 7.2.7 5G-VICTORI Business Modelling Workshop – Urban Hawk's Simulation Business Ideas (formerly InsureTech)

***Refined results from the second business modelling workshop (on Nov. 17th 2022 / T5.3):***

## *Business Modelling Urban Hawk's Simulation Business Ideas*

(*formerly* InsurTech, documented by UXBerlin)

**Summary:**

- The major **challenge to find a viable path for market entry** was already identified in the 2021 workshop, essentially: Which business models to pursue and to start with. From the (now significantly advanced) technological point of view the solution enables numerous possible applications and corresponding use cases to be pursued. This creates a wide breath of ideas to be considered and brings a major challenge of finding the right focalisation and a sense of direction for the venture from the very early stages of its development. The prioritisation of the venture's values and the benefits that it can provide to clients helps to establish and strengthen this sense of direction.

- A key point of uncertainty is related to the viability of the **cost structure and** how to manage it to accommodate a **scaling user base**. This poses the need for mapping costs in relation to different personas or different types of users (e.g., operating at different times of the day) as well as business cases (addressing different clients and industries).
- Cost estimations and benchmarking should be performed in relation to **alternative revenue models** (on-prem, edge-based, cloud-based, freemium, etc.) to scrutinize the trade-offs between them.
- Different **agreements** will need to be established to address varying levels of data sensitivity across stakeholders and potential clients.
- Further **stakeholder feedback** needs to be collected, e.g. through expert interviews, field interviews, surveys, e.g. with station owners, insurance providers, and other potential clients as well as end users and public and standardisation authorities. Several assumptions can be evaluated, such as:
    - What is the business potential of value propositions related to decarbonisation, e.g., monitoring of railway vehicles' energy consumption (during acceleration and breaking) through simulations?
    - How does new legislation (Protect Duty) affect insurance providers and facility owners, and their need for real-time 3D simulations? How to manage liabilities across different stakeholders and modes of travel?

**Objectives:**

- Recap recent changes in business model components that have been defined or discussed in the core team.
- Refine the (preliminary) business model in response to anticipated 5G ecosystem developments to leverage their potentials for improving the business idea.
- Identify the most critical (high-risk or uncertain) business model components and specify assumptions to focus on in the subsequent business development and validation.
- Specify methods to validate sustainability potentials, desirability and viability of the (preliminary) business model. Agree upon next steps to go to (test) market.

**Participants**: Robert Sugar (Urban Hawk), John Tapsfield (Urban Hawk), Roland Nolte (IZT), Nona Bledow (IZT); workshop prepared, facilitated and results refined by Kiril Ivanov & Henning Breuer (UXBerlin – Innovation Consulting)

**Recap of recent changes**

- The technological solution is being developed into a platform (Polaron), accessible through a browser.
- An API-driven roll out and beta testing are planned for 2023.

- Interviews have been conducted to explore customer needs and potential partnerships with hardware providers.
- Letters of intent have been submitted by investors from different industries and initial deals are underway. Depending on the industrial background of investors and the respective business models that will be pursued, Urban Hawk will expand and compartmentalize its business structure to manage different projects and associated costs independently. A new European satellite office in the EU is planned to facilitate relationships with European investors, partners, and clients.

There are several newly introduced specifications to the previously defined business models, including new potential value propositions, target groups, capabilities, revenue models, etc. (see figure 2 for an overview) – some of which also imply new underlying values. These developments also premise new potentials for positive impact on sustainability, e.g., concerning passenger safety, privacy, disabled access models, efficient maintenance, and energy consumption (figure 1 below). However, the multitude of predefined values, business model assumptions and potential sustainability impacts increase the complexity of the business model and undermine potentials for validation with respect to key metrics and clear strategic goals. This necessitates reprioritizing and redefining still relevant values and sorting out irrelevant ones. Specifying a clear set of values to pursue will provide criteria to streamline prospective activities (e.g., for engagement of investors, validation of assumptions, test market entry) and the business model rationale.

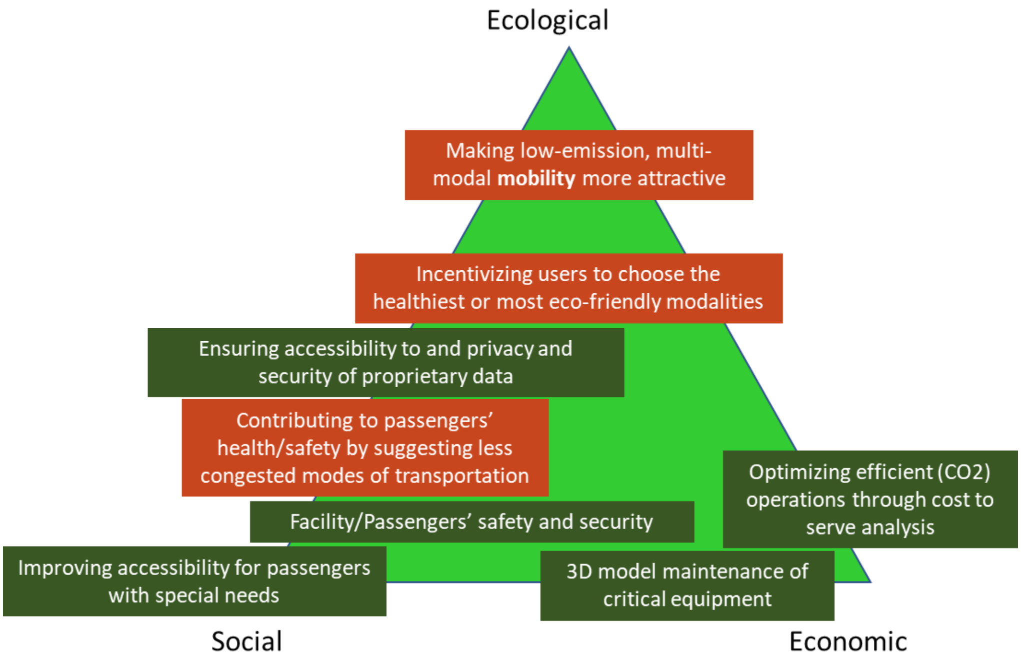


Figure 1. Key sustainability benefits of the business idea (newly specified benefits in green boxes).

Several (new) **value propositions** have been specified, such as:

- Efficient mapping of facilities (e.g. stations) to update obsolete CAD **data for multiple purposes**.
- Making proprietary data of facility owner that is not accessible on public platforms such as Google maps, available for new services (e.g. creating spatial awareness) to users, including users with special needs, such as firefighters, police, disabled, etc.
- **Commissioning third party developers** for access to the Polaron solution or models it generates.
- Suggest **optimal routes to passengers** (based on simulations and statistics), e.g. allowing passengers to utilize limited transfer time at stations to buy commodities or food, without being concerned that they might miss their connection. Tracking and prediction of demand waves to manage delays and improve passenger experience.
- Enabling end-users to use their smartphones for generating 3D models, thereby creating **new passenger experiences** (e.g. passengers can record specific data and recall it in case of travel issues, e.g. to specify the location of lost luggage).
- **Energy efficiency** and reducing CO2 emissions (also see *Resource Efficiency and Productivity* pattern [2]): Heating modelling, optimizing energy consumption, operation and traffic management and lighting management. Running simulations to monitor energy efficiency across different conditions, e.g. seasonal changes, diurnal cycles, varying levels of generated energy from renewables. Real time 3D simulations can also be used to monitor the performance of thermal systems or emission reduction technologies or processes and account for inefficient implementations (e.g. faulty equipment, need for insulation) or energy losses (e.g. from open windows).
- Another potential is the monitoring of railway **vehicles' energy consumption** (during acceleration and breaking) through simulations as opposed to conventional hardware sensors, which require high effort and special permissions to be installed on trains/stations.

**Stakeholder segments:** The passenger multimodal transport experience that was developed as the core business idea is transferrable to other types of industries, which provide promising business opportunities. (New) value propositions can be of interest to other industries, such as logistics, maritime ports, nuclear power plants.

- Logistics: Efficiency modelling based on statistical data to optimize cost (fuel) efficiency of package delivery.
- Sea traffic management: Using life data for economic and environmental simulation model to predict the cost and impact of port operational delays on the fuel consumption of offshore vessels pending berthing and unloading (statistical analysis test case performed).

**Capabilities:** Urban Hawk is hiring back and front-end developers (to expand capacity and interoperability of APIs etc.). A potential knowledge transfer partnership program can allow hiring postgraduates and exchange of knowledge with academic institutions. Based on data from the Berlin and Bristol test cases, several KPIs have been formulated to assess operations, software and service performance, and user desirability.

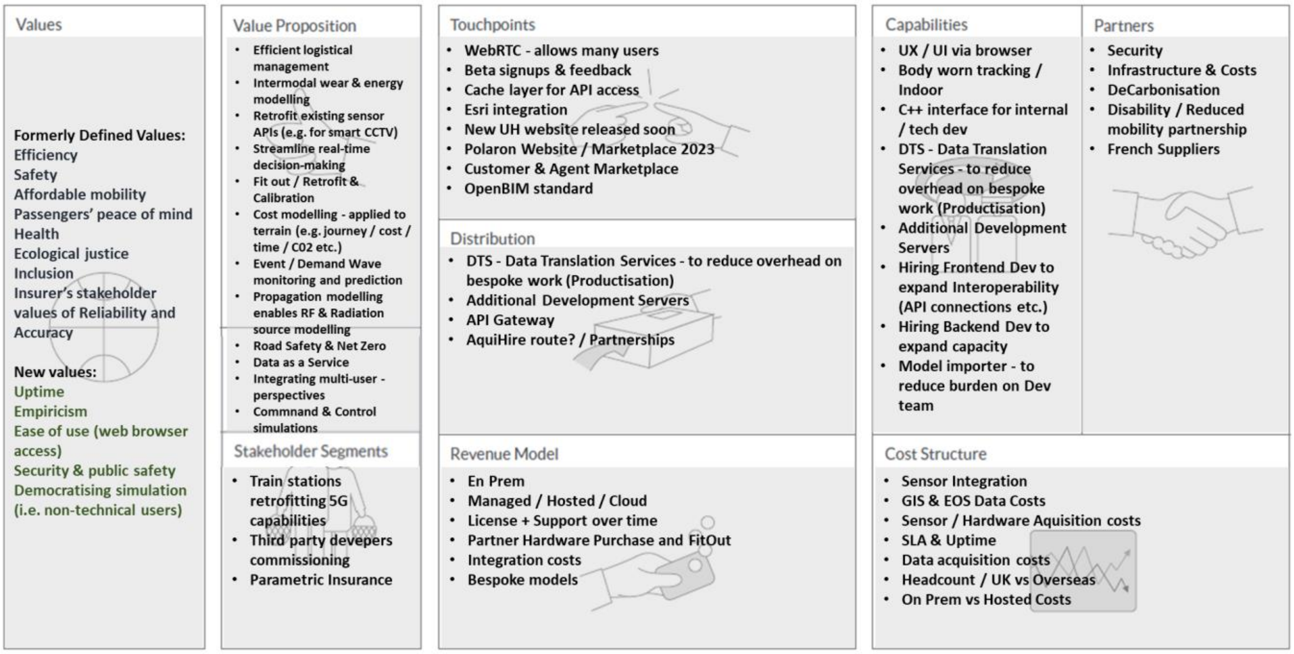


Figure 2. Overview of newly introduced business model specifications and values (new values in green) – also see MURAL Board

### Critical assumptions and risks

**Value propositions and stakeholders:** One key challenge in the development of new value propositions and the engagement of further stakeholders (e.g., **3rd party businesses** at stations) is to clarify uncertainties regarding the ownership of data, i.e. whether Urban Hawk can utilize the data generated for and from its simulation services. A related challenge is the requirement of **station operators** for newly installed sensors to be embedded within their network infrastructure. This limits data access from public APIs restricted by the network's firewall and necessitates to securely extract portions of restricted data to an external cloud service. Urban Hawk has developed a model and a roadmap to address this issue and in Q1 of 2023. Notwithstanding, different **agreements** are needed to address varying levels of data sensitivity for stakeholders and potential clients. For example, commercial stakeholders, who are more interested in maintaining complete ownership of their proprietary data, need to be distinguished from **public stakeholders** (e.g., communities, municipalities) who are readier to share their proprietary data to purchase and contribute to the development of community-based solutions for the common good, e.g. for facilitating multimodal travel or emission reduction (as an example see Smart Aarhus Strategy [1]).

Another alternative business model pattern to consider here is called *Data for Social Good* [2]. It addresses the challenge finance free offerings for sustainable products and services to a social group (e.g. passengers with or without special needs) by accumulating, curating, and commercializing data drawn from this targeted social group to a third party (e.g. railways, station owners, or local shops, service providers or real-estate companies with an interest in passenger flows or even real-time data). A alternative or complementary approach is the *Social Freemium* [2] model already discussed in last years workshop. Here the idea was to combine social value creation (e.g. through free 3D indoor navigation for passengers with disabilities and special needs) and economic value creation (e.g. through automated and more accurate validation of insurance claims for premium users and business clients) – see 2021 report for more details and associated challenges.

Companies from the insurance sector are already involved as potential investors and clients of the Polaron solution. However, the technological aspects of the solution need to be further advanced in order to enable tests and validation of the data quality and integration. Furthermore, the implementation of the initial business model sketch addressing **insurance providers** has been postponed towards a longer-term development in light of emerging changes in the insurance market and anticipated legislations. Insurance providers are increasingly utilizing the services of third-party data brokers (i.e. big data companies) to facilitate underwriting and customer justification and are less interested in storing data on their own or having immediate relationships with advanced location data service providers, such as Urban Hawk. Furthermore, insurance providers are less interested in passenger specific simulations but rather in extracting key data points from cached models of travel graphs, which they can use to calculate an insurance premium price. However, anticipated legislations (e.g., UK's Protect Duty [3]) will place more liability on facility owners for managing public safety and the modelling and planning of their facilities. These requirements will also create new business opportunities for real-time situational awareness services on the insurance market. In addition, a new customer group has been prioritised for the InsureTech business model, namely business travellers and travellers to locations with high risk (e.g., war and conflict zones). Real-time situational awareness can be used to assess and compare risks in these areas to support insurance underwriting processes.

**Touchpoints:** A key challenge with regards to making the Polaron platform accessible to end-users (e.g., passengers) is to ensure sufficient usability and human-centered design.

**Revenue model:** Alternative revenue models are envisioned **depending on the use case and delivery channel**:

1.1 On-premise solution – installing the software solution on station's own hardware.

1.2 Edge-based embedded solution – installing the hardware and the software product, which necessitates SLAs supporting training and maintenance as well as software license costs. It also involves maintenance and sensor integration costs (depending on the client's level of expertise). It is a more cost intensive and difficult to scale alternative.

2. Cloud-based and hybrid – a subscription model, including costs for SaaS hosting and customer integration. In this case, shared tenant versus private tenant options and related trade-offs in terms of costs, maintenance, data security, integration, and customisation capacity, etc. have to be evaluated and prioritised.

3. Public service - selling simulation as a service, allowing users to add components and adapt simulations to local data variables. Freemium model for public consumption (building upon the B2B2C InsurTech rationale from 2021). Freemium access to public models and agents, but limited storage and expiry and external connection. Cheap to upgrade cover costs or extend access.

**Capabilities:** The efficiency of the simulation service requires further improvement to ensure the feasibility and scalability of the business case. As more users (e.g. passengers) become engaged, Polaron's simulations can be improved based on their data. However, streaming live simulations to a large number of users will be inefficient and therefore simulations will be fed with cache data from the simulations that enables scaling the user base and reducing bandwidth costs.

Another challenge is related to the high **labour intensity** of performing initial scans of spatial data (e.g. Berlin Central station scan took 10 hours plus one week for modelling), also due to legal restrictions to using drones in public facilities in some countries (e.g. Germany). New partnership with a robotics company allows providing any facility staff member with a handheld device that enables efficient scanning as well as updating the model whenever changes take place or mapping more specific details, such as different types of railway vehicles. Still, such practical challenges and potential barriers to implementation and scaling need to be addressed as soon as possible and considered for the **decision which business models to pursue and to start with**.

**Cost structure:** An emerging customer need is to not only scan facilities for creating digital twins but also maintaining the digital twins up to date (living digital twin). This requires tying the software solution to a **sensor network** – which can create additional bottlenecks. Ideally such a network should already exist within the clients' facilities, since Urban Hawk is not a hardware vendor and would need to bear additional costs. However, hardware installations may also reveal opportunities for establishing lucrative partnerships with hardware and end providers to enable the provision of end-to-end solutions and accommodation of various customer needs.

**Uncertainties**: A key point of uncertainty that implicates the business model addressing insurance providers is the sharing of liabilities in cases when station operators are to be held accountable for passenger claims, especially, since the solution is highly dependent on cooperation with stations and the utilisation of their infrastructures and proprietary data. Since the value proposition for the end customer (rail passenger) is dependent on relationships with railway operators and the availability of rail data they can provide (which is still limited in most EU countries, including the UK), in some cases business model wherein station operators are engaged as main (end) users of the Polaron solution rather than intermediaries will be more appropriate.

Yet another point of uncertainty is related to the viability of the cost structure and how to manage it to accommodate a scaling user base. This requires precise estimations for efficient operation, and mapping costs in relation to different personas or different types and numbers of users (e.g., operating at different times of the day) as well as business cases (addressing different clients and industries).

**Methods to validate or address the most critical assumptions and risks**

- The roadmap for field tests and validation of business assumptions needs to be concretised, including how to utilize partnerships with Network Railway and Deutsche Bahn and their facilities.
- Planned tests with beta users should be utilised to iteratively prototype and refine the usability and human-centric design of the platform.
- Cost mapping should be performed in relation to different personas and different types of users (e.g., operating at different times of the day) as well as business cases (addressing different clients and industries).
- Cost estimations and benchmarking should be performed in relation to alternative revenue models (on-prem, edge-based, cloud-based, freemium, etc.) to scrutinize the trade-offs between them.
- Further stakeholder feedback needs to be collected, e.g., through expert interviews, field interviews, surveys, e.g., with station owners, insurance providers, and other potential customers as well as end users and public and standardisation authorities. Several assumptions can be evaluated, such as:
  - What is the business potential of value propositions related to decarbonisation, e.g., monitoring of railway vehicles' energy consumption (during acceleration and breaking) through simulations?

- How does new legislation (Protect Duty) affect insurance providers and facility owners and impacts the need for real-time 3D simulations?
- How to manage liabilities across different stakeholders and modes of travel?
- What are business potentials for retrofitting remote or small stations?

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## 7.4 Scenario Wizard outputs

### 7.4.1 CIB-Matrix

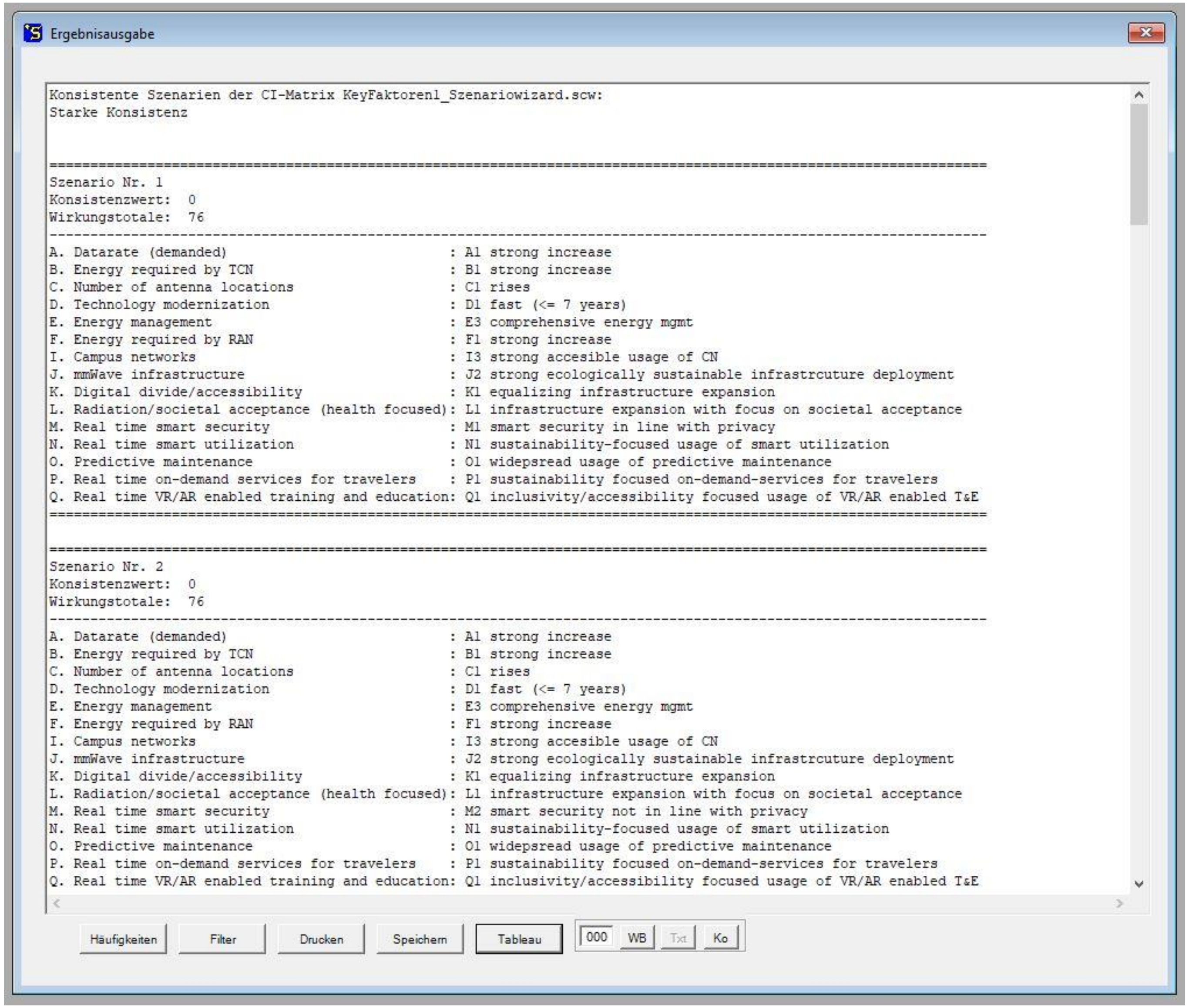
Cross-Impact Matrix

| KeyFaktoren1_Szenariowizard.scw | A | A | A | B | B | C | C | D | D | E | E | E | F | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A1 | A2 | A3 | B1 | B2 | C1 | C2 | D1 | D2 | E1 | E2 | E3 | F1 | F2 |
| A. Datarate (demanded): | | | | | | | | | | | | | | |
| A1 strong increase | | | | 2 | -2 | 1 | -1 | 1 | 0 | 0 | 0 | 0 | 3 | -2 |
| A2 medium increase | | | | 1 | -1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | -1 |
| A3 weak increase | | | | -1 | 1 | -1 | 1 | 0 | 0 | 0 | 0 | 0 | -1 | 1 |
| B. Energy required by TCN: | | | | | | | | | | | | | | |
| B1 strong increase | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B2 weak increase | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C. Number of antenna locations: | | | | | | | | | | | | | | |
| C1 rises | 0 | 0 | 0 | 1 | 0 | | | 1 | 0 | 0 | 0 | 0 | -1 | 1 |
| C2 does not rise | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| D. Technology modernization: | | | | | | | | | | | | | | |
| D1 fast (<= 7 years) | 0 | 0 | 0 | -1 | 2 | 0 | 0 | | | 0 | 1 | 2 | -2 | 0 |
| D2 slow (>7 years) | 0 | 0 | 0 | 1 | -1 | 0 | 0 | | | 0 | -1 | -1 | 1 | 2 |
| E. Energy management: | | | | | | | | | | | | | | |
| E1 no energy mgmt | 0 | 0 | 0 | 2 | -1 | 0 | 0 | 0 | 0 | | | | 2 | -1 |
| E2 energy mgmt light | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | | | | 1 | 0 |
| E3 comprehensive energy mgmt | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | | | | 0 | 1 |
| F. Energy required by RAN: | | | | | | | | | | | | | | |
| F1 strong increase | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| F2 weak increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| I. Campus networks: | | | | | | | | | | | | | | |
| I1 limited usage of campus networks | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| I2 strong privileged usage of CN | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| I3 strong accesible usage of CN | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| J. mmWave infrastructure: | | | | | | | | | | | | | | |
| J1 limited infrastructure deployment | 0 | 0 | 0 | -1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | 1 |
| J2 strong ecologically sustainable infrastrcuture deployment | 0 | 0 | 0 | 2 | -1 | 2 | -1 | 2 | 0 | 0 | 1 | 2 | 2 | -1 |
| J3 strong ecologically unsustainable infrastrcuture deployment | 0 | 0 | 0 | 3 | -2 | 2 | -1 | 1 | 0 | 0 | 0 | 0 | 3 | -2 |
| K. Digital divide/accessibility: | | | | | | | | | | | | | | |
| K1 equalizing infrastructure expansion | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| K2 unequal infrastructure expansion | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| L. Radiation/societal acceptance (health focused): | | | | | | | | | | | | | | |
| L1 infrastructure expansion with focus on societal acceptance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| L2 infrastructure expansion without focus on societal acceptance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M. Real time smart security: | | | | | | | | | | | | | | |
| M1 smart security in line with privacy | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| M2 smart security not in line with privacy | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

| KeyFaktoren1_Szenariowizard.scw | I | I | I | J | J | J | K | K | L | L | M | M | M | N | N | N | O | O | P | P | P | Q | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I1 | I2 | I3 | J1 | J2 | J3 | K1 | K2 | L1 | L2 | M1 | M2 | M3 | N1 | N2 | N3 | O1 | O2 | P1 | P2 | P3 | Q1 | Q2 |
| A. Datarate (demanded): | | | | | | | | | | | | | | | | | | | | | | | |
| A1 strong increase | 0 | 2 | 2 | -1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| A2 medium increase | 0 | 1 | 1 | -1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| A3 weak increase | 0 | 0 | 0 | 2 | -1 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B. Energy required by TCN: | | | | | | | | | | | | | | | | | | | | | | | |
| B1 strong increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B2 weak increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C. Number of antenna locations: | | | | | | | | | | | | | | | | | | | | | | | |
| C1 rises | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | -2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 0 |
| C2 does not rise | 0 | 0 | 0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D. Technology modernization: | | | | | | | | | | | | | | | | | | | | | | | |
| D1 fast (<= 7 years) | 0 | 1 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D2 slow (>7 years) | 0 | 0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E. Energy management: | | | | | | | | | | | | | | | | | | | | | | | |
| E1 no energy mgmt | 0 | 0 | 0 | 0 | -2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E2 energy mgmt light | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E3 comprehensive energy mgmt | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| F. Energy required by RAN: | | | | | | | | | | | | | | | | | | | | | | | |
| F1 strong increase | 0 | 1 | 0 | 0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| F2 weak increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| I. Campus networks: | | | | | | | | | | | | | | | | | | | | | | | |
| I1 limited usage of campus networks | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | -1 | 1 | 0 | 0 | 0 | -1 | 1 | 0 | 0 | 0 | -1 | 1 |
| I2 strong privileged usage of CN | | | | 0 | 1 | 1 | -1 | 1 | -1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| I3 strong accesible usage of CN | | | | 0 | 1 | 1 | 1 | -1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| J. mmWave infrastructure: | | | | | | | | | | | | | | | | | | | | | | | |
| J1 limited infrastructure deployment | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| J2 strong ecologically sustainable infrastrcuture deployment | 0 | 1 | 1 | | | | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| J3 strong ecologically unsustainable infrastrcuture deployment | 0 | 1 | 1 | | | | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| K. Digital divide/accessibility: | | | | | | | | | | | | | | | | | | | | | | | |
| K1 equalizing infrastructure expansion | 0 | -1 | 1 | 0 | 0 | 0 | | | 2 | -2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| K2 unequal infrastructure expansion | 0 | 1 | -1 | 0 | 0 | 0 | | | -2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| L. Radiation/societal acceptance (health focused): | | | | | | | | | | | | | | | | | | | | | | | |
| L1 infrastructure expansion with focus on societal acceptance | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| L2 infrastructure expansion without focus on societal acceptance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M. Real time smart security: | | | | | | | | | | | | | | | | | | | | | | | |
| M1 smart security in line with privacy | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M2 smart security not in line with privacy | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | -1 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K. Digital divide/accessibility: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| K1 equalizing infrastructure expansion | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1 | 1 | 0 | 0 | 0 | | | 2 | -2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| K2 unequal infrastructure expansion | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | -1 | 0 | 0 | 0 | | | -2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| L. Radiation/societal acceptance (health focused): | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| L1 infrastructure expansion with focus on societal acceptance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| L2 infrastructure expansion without focus on societal acceptance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M. Real time smart security: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M1 smart security in line with privacy | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M2 smart security not in line with privacy | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | -1 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M3 limited smart security usage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| N. Real time smart utilization: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N1 sustainability-focused usage of smart utilization | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| N2 cost reduction focused usage of smart utilization | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| N3 limited usage of smart utilization | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| O. Predictive maintenance: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| O1 widepsread usage of predictive maintenance | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 |
| O2 limited usage of predictive maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 |
| P. Real time on-demand services for travelers: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P1 sustainability focused on-demand-services for travelers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 |
| P2 comfort and growth focused on-demand-services for travelers | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 |
| P3 limited usage of on-demand-services for travelers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 |
| Q. Real time VR/AR enabled training and education: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Q1 inclusivity/accessibility focused usage of VR/AR enabled T&E | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Q2 limited usage of VR/AR enabled T&E | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |

### 7.4.2 Result list of consistent scenarios (example)




```
Konsistente Szenarien der CI-Matrix KeyFaktoren1_Szenariowizard.scw:
Starke Konsistenz


==============================================================================================================
Szenario Nr. 1
Konsistenzwert:  0
Wirkungstotale:  76
--------------------------------------------------------------------------------------------------------------
A. Datarate (demanded)                           : A1 strong increase
B. Energy required by TCN                        : B1 strong increase
C. Number of antenna locations                   : C1 rises
D. Technology modernization                      : D1 fast (<= 7 years)
E. Energy management                             : E3 comprehensive energy mgmt
F. Energy required by RAN                        : F1 strong increase
I. Campus networks                               : I3 strong accesible usage of CN
J. mmWave infrastructure                         : J2 strong ecologically sustainable infrastrcuture deployment
K. Digital divide/accessibility                  : K1 equalizing infrastructure expansion
L. Radiation/societal acceptance (health focused): L1 infrastructure expansion with focus on societal acceptance
M. Real time smart security                      : M1 smart security in line with privacy
N. Real time smart utilization                   : N1 sustainability-focused usage of smart utilization
O. Predictive maintenance                        : O1 widespread usage of predictive maintenance
P. Real time on-demand services for travelers    : P1 sustainability focused on-demand-services for travelers
Q. Real time VR/AR enabled training and education: Q1 inclusivity/accessibility focused usage of VR/AR enabled T&E
==============================================================================================================

==============================================================================================================
Szenario Nr. 2
Konsistenzwert:  0
Wirkungstotale:  76
--------------------------------------------------------------------------------------------------------------
A. Datarate (demanded)                           : A1 strong increase
B. Energy required by TCN                        : B1 strong increase
C. Number of antenna locations                   : C1 rises
D. Technology modernization                      : D1 fast (<= 7 years)
E. Energy management                             : E3 comprehensive energy mgmt
F. Energy required by RAN                        : F1 strong increase
I. Campus networks                               : I3 strong accesible usage of CN
J. mmWave infrastructure                         : J2 strong ecologically sustainable infrastrcuture deployment
K. Digital divide/accessibility                  : K1 equalizing infrastructure expansion
L. Radiation/societal acceptance (health focused): L1 infrastructure expansion with focus on societal acceptance
M. Real time smart security                      : M2 smart security not in line with privacy
N. Real time smart utilization                   : N1 sustainability-focused usage of smart utilization
O. Predictive maintenance                        : O1 widespread usage of predictive maintenance
P. Real time on-demand services for travelers    : P1 sustainability focused on-demand-services for travelers
Q. Real time VR/AR enabled training and education: Q1 inclusivity/accessibility focused usage of VR/AR enabled T&E
```

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