SNS Stream B/D

Workshop on KPIs and KVIs

Hexa-X-II:
Vision on Use Case KPIs/KVIs

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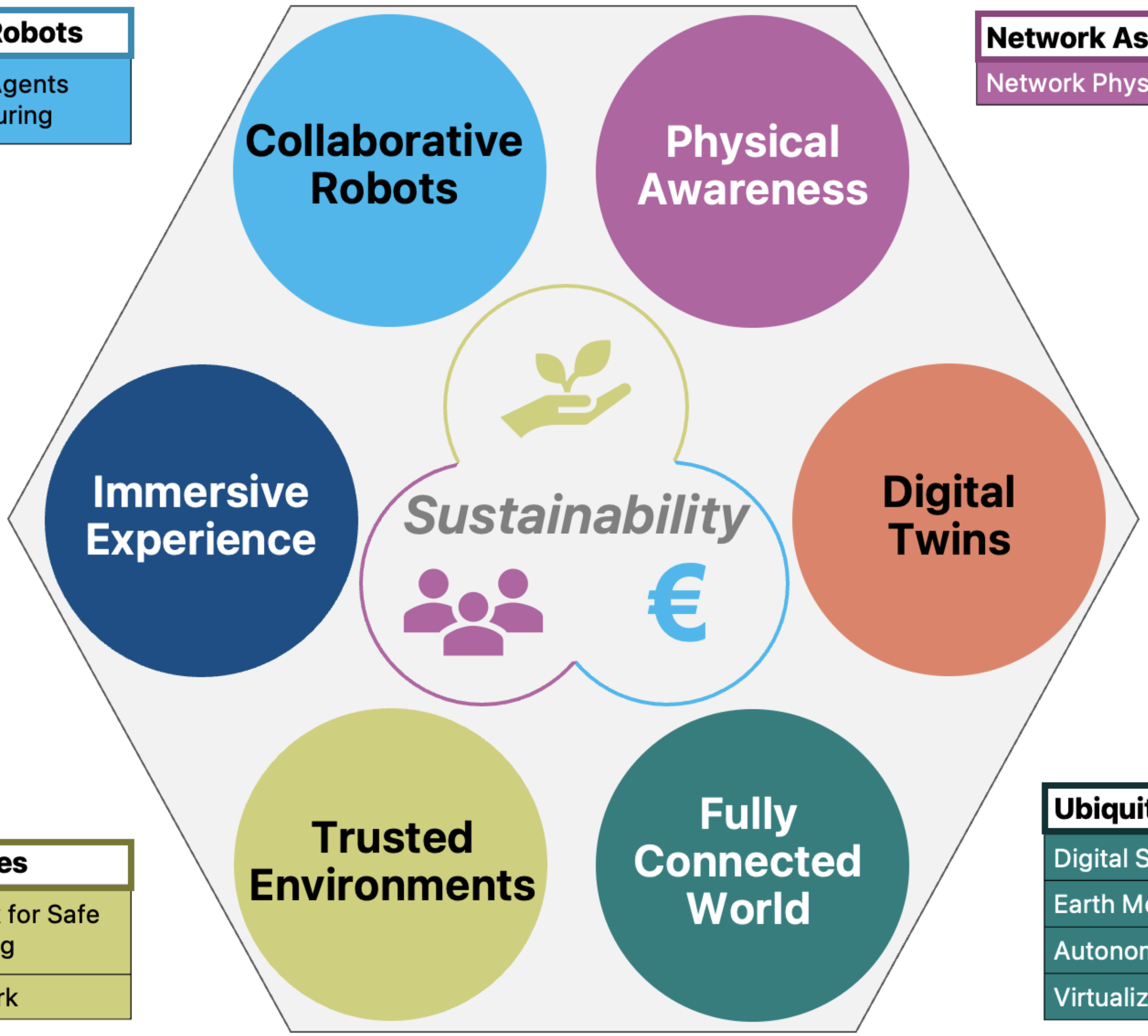
The Methodology

Hexa-X-II Use Case Families
(more details in Hexa-X-II Deliverable D1.2)

Cooperating Mobile Robots
- Autonomous Embodied Agents Within Flexible Manufacturing

Network Assisted Mobility
- Network Physical Data Exposure

Seamless Immersive Reality
- Immersive Education
- Immersive Gaming
- Live and Interactive Immersive Content Creation



Realtime Digital Twins
- Cloud Continuum
- Smart Maintenance
- Digital Twins (Building Model)

Human-Centric Services
- Industrial Sensors Network for Safe Production & Manufacturing
- Wireless In-Vehicle Network

Ubiquitous Network
- Digital Sobriety and Enhanced Awareness
- Earth Monitor, Sustainable Food Production
- Autonomous Supply Chain
- Virtualization of Device Functionalities

Hexa-X-II Use Cases with **Highlighted** Representative Use Cases

Analysis Methodology

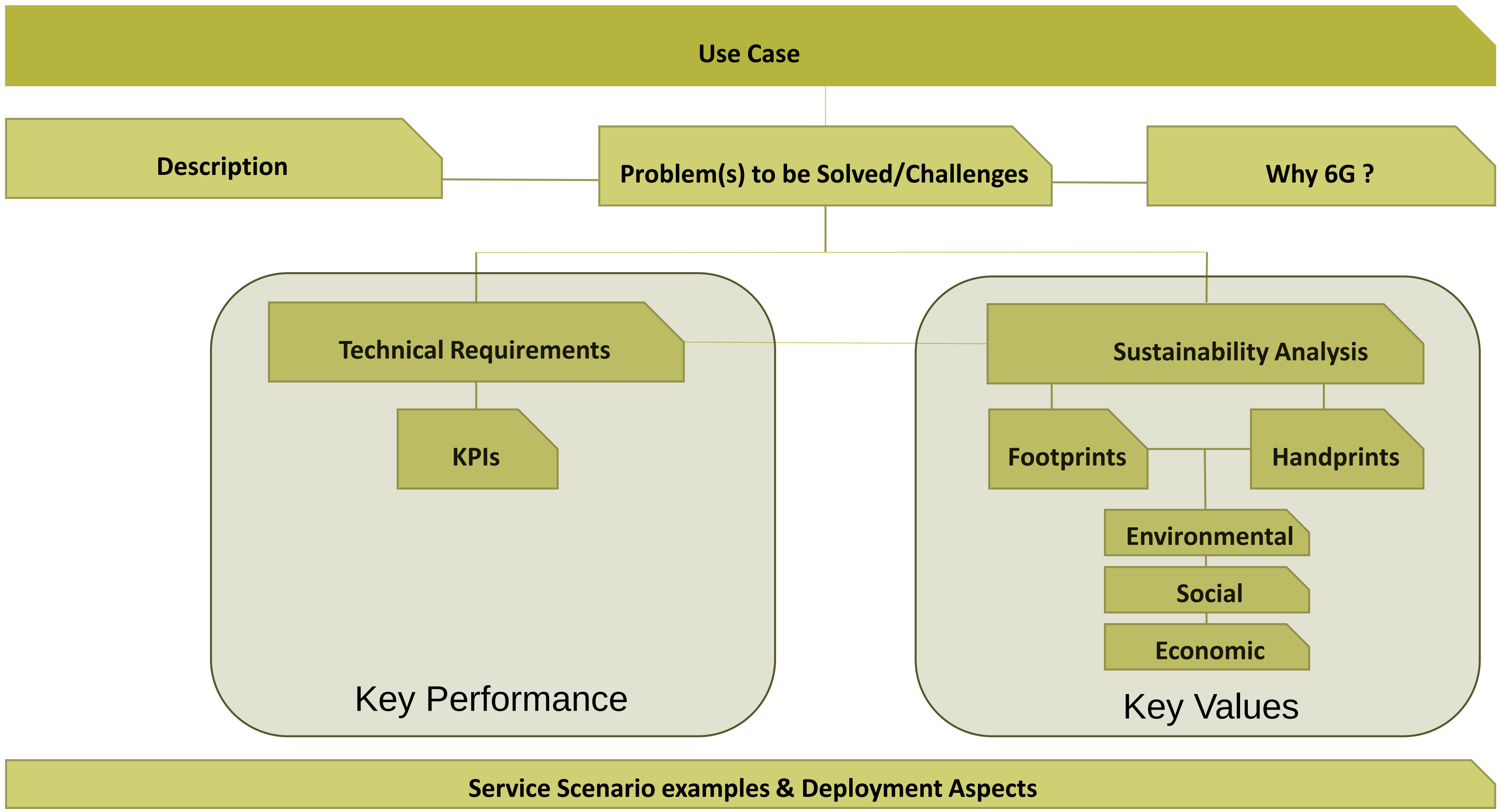
Use Case

Application of the 6G IA VSC/SNVC WG KVI process methodology to Hexa-X-II use cases & finetuning together the process

Ongoing work

1. Use Case Analysis
2. Business Model & Stakeholder Analysis
3. Preparedness for 6G - Sustainability Analysis

1 Use Case Analysis Methodology -
(more details in Hexa-X-II Deliverable D1.2)



2 Business Model & Stakeholder Analysis Methodology
(more details in Hexa-X-II Deliverable D1.3)

Business & Stakeholder Analyis
How do companies create, capture, and deliver value ?

Ecosystem business model canvas
ecosystem-level business model for the use case including identification of stakeholder

Supply Side
Stakeholders/ key partners, Resources, Activities

Ecosystem Value Propositions
Value proposition
Value co-creations
Value capture
Value co-destruction
Partnerships

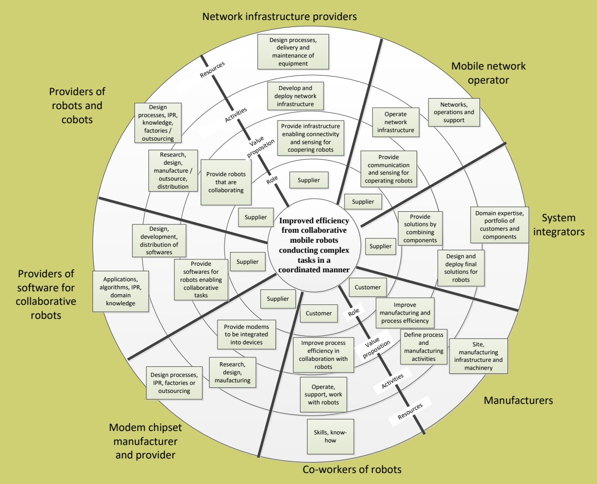
Demand side
Customer segments, Stakeholders/ key partners, Customer relationships, Channels,

Outcomes
Benefits
Revenues (revenue streams)
Pricing
Costs

Stakeholder Analaysis
analysis of key stakeholders

Stakeholders
Description
Role
Value Proposition
Activities
Ressources

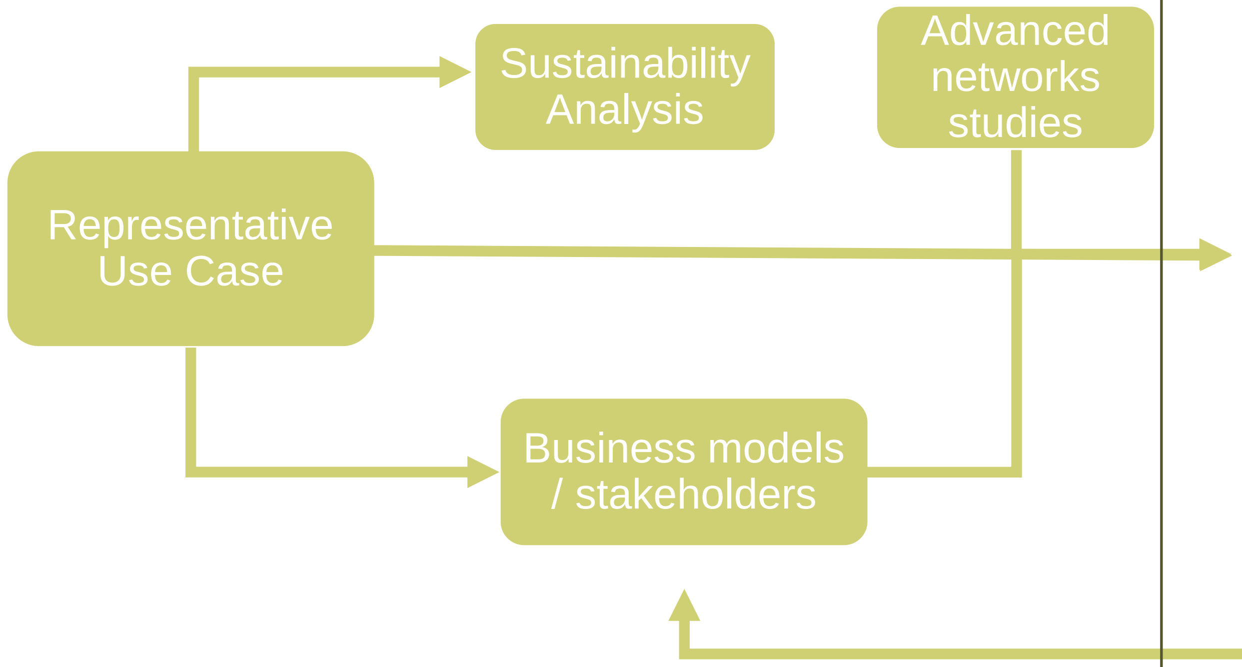
Ecosystem pie
ecosystem-level business model visualization

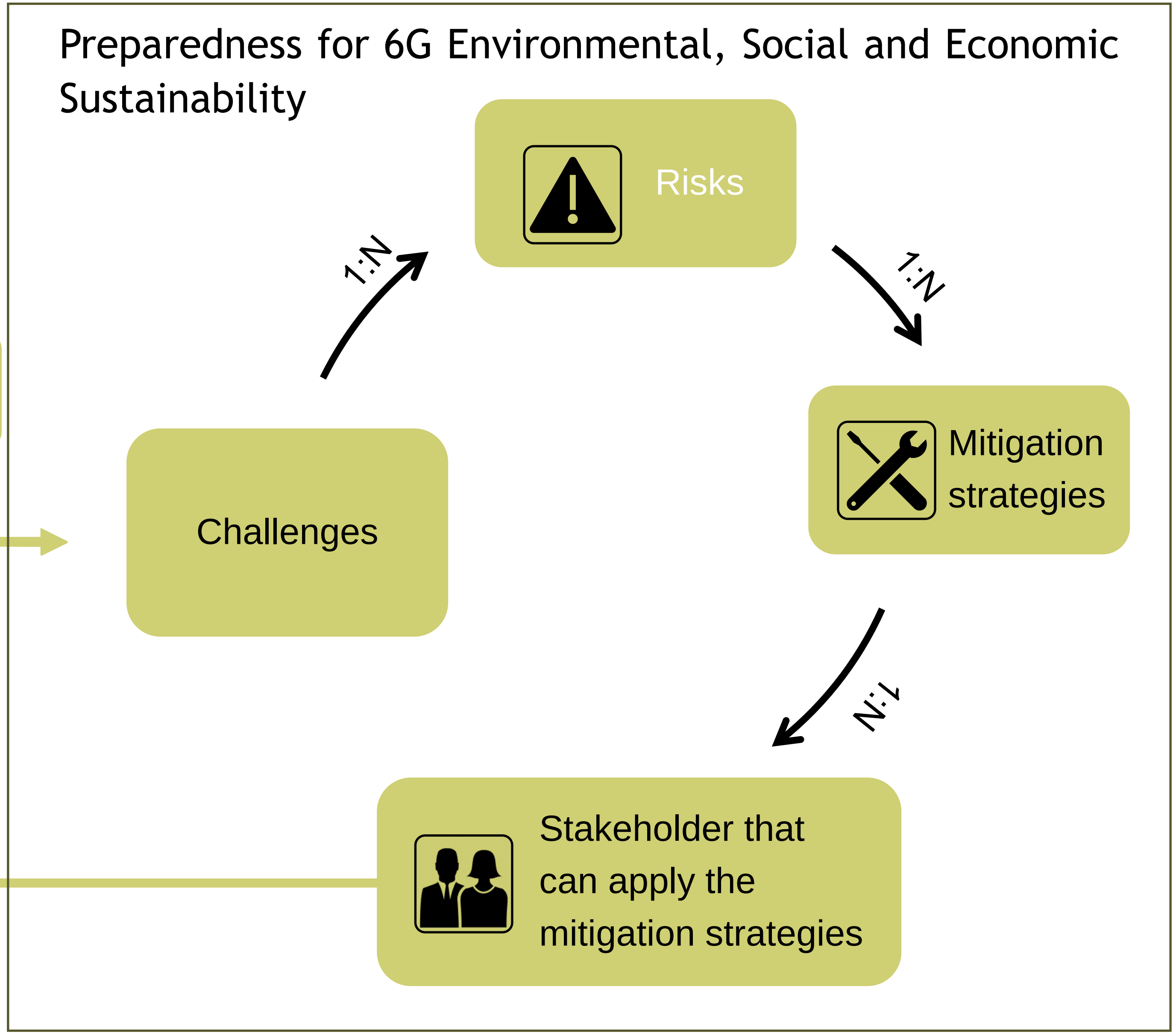


3 Preparedness for 6G Sustainability - Methodology

(more details in Hexa-X-II Deliverable D1.3)

Objective:
- Analyse challenges and risk which may counteract the sustainability targets
- Identify & apply mitigation strategies





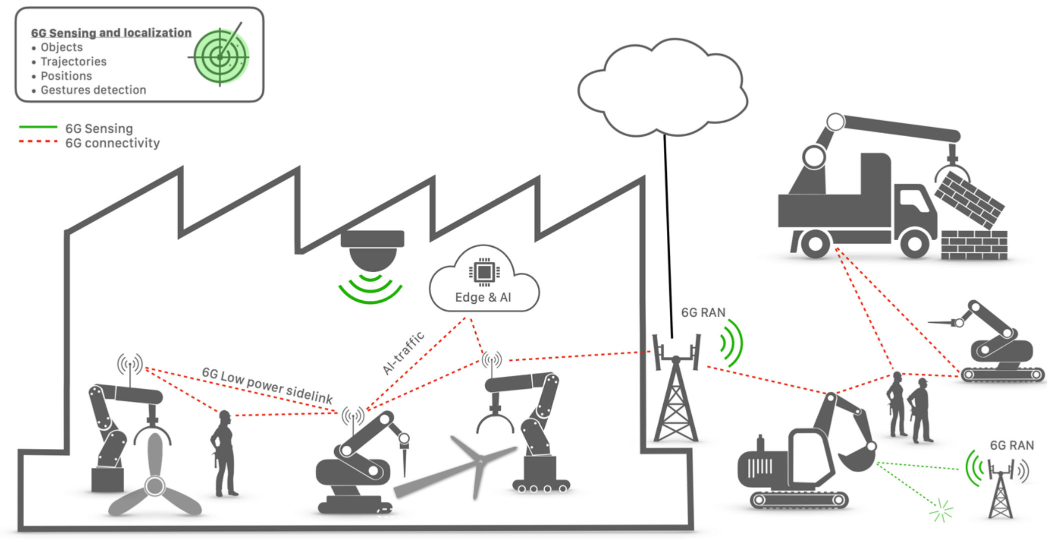
Indicative Example - Cooperating Mobile Robots

Cooperating Mobile Robots - Use Case Analysis

Collaborative Robots

Description

- Autonomous robots, possessing mobility, environmental sensing, and task-execution capabilities
- Robots engage in communication with each other, other machines, and nearby humans, collaborating to achieve common objectives



Problem(s) to be Solved/Challenges

- Understanding communication requirements of machines in the future
- Using limited resources efficiently
- Adapting to dynamic requirements of the market
- End-user access to custom manufacturing
- Safe and trustworthy interactions with tools that can make decisions

Applications

- Autonomous, collaborative, interactive, cooperative mobile robots
- Industrial manufacturing
- Smart living
- Construction sites

Sustainability Analysis / Key Values

	Handprints (benefits)	Footprints (costs)
Env.	• Increased efficiency in production processes • Reduced need for multiple machines due to function integration	• Increased material and energy consumption throughout full life cycle of the robots and associated services • Increased electronic waste
Social	• Improved accessibility from tasks beyond human capabilities • Safer working environments • M2H support	• Elimination of jobs • Uneven distribution of benefits from robots and cobots • Unauthorized use of sensors and associated privacy concerns
Eco.	• Enhanced productivity and competitiveness • New business and job opportunities	• Barriers for small businesses • Monopolization risks • Financial loss in case of service failure or cyber-attacks

Technical Requirements

- **Local ad hoc connectivity** – formation of task specific, localized, temporary subnetworks embedded in campus network
- **Reliable and low latency communications** – Service-level reliability and E2E latency
- **Mobility** – Frequent handovers as machines join and leave. Subnetworks nomandic behavior and roaming may occur
- **Sensing, positioning, and AI/ML** – within networks and devices (JCAS) introduction of AI/ML traffic types and AI/ML execution in edge nodes for enhanced coordination and accuracy

Cooperating Mobile Robots: Requirements and KPIs

Collaborative Robots

KPIs*

*KPI values as provided in D1.2. Modification possible. Final value in D1.4

	KPI	Target Range	Justification
Communication	User-experience data rate [Mb/s]	< 10	Data rate between robot and campus network. Can be significantly higher locally in a subnetwork where raw sensor data and/or AI/ML traffic is exchanged.
	Connection density [devices/m^2]	< 0.1	Mobile robots occupy an area of 1 m2, and it is assumed that they occupy at most 10% of the overall area to ensure fluent mobility. The world's largest industrial manufacturing campuses accommodate thousands of robots.
	Mobility [km/h]	< 20	Slow vehicular
	End-to-end latency [ms]	< 0.8	Industrial machines may exchange coordination messages up to 200 times per second and can be triplicated for redundancy. This results in a transfer interval of ca. 1.66 ms. E2E latency limit is set to at most half that interval to ensure enough margin for ARQ. [22.104]
	Service-level reliability [%]	99.999 – 99.99999	Application-side safety net mechanism like "survival time" and "grace period" are employed to compensate occasional packet losses and delays at link level. Selected applications may have an even more strict reliability requirement up to 99.999999% [22.104].
	Coverage [%]	—	Localized nature of a joint task makes local ad hoc connectivity favourable.
Positioning & New Capabilities	Positioning accuracy [m]	< 0.1 (fine) < 1 (coarse)	Tasks such as environment mapping, robot navigation, and inventory management require fine positioning. Tasks like robot localization need coarse positioning.
	Sensing-related capabilities [Y/N]	Y	Robots and cobots depend on capturing the environmental context. Network-integrated sensing may complement or replace dedicated on-board sensors. Efficient transport of data/information from connected external sensors likely needed.
	AI/ML-related capabilities [Y/N]	Y	Robots and cobots depend on advanced machine learning. Execution may be embedded in the device and/or offloaded at a local edge and/or provided by the network as an over-the-top service.

TVM WG Table

	KPI	
Capacity	Peak Data Rate	
	User Experienced Data Rate	10 Mb/s
	Network Capacity	
	Service Bandwidth	
	Area Traffic Capacity	<0.1 Mb/s/m2
	Connection Density	
Latency	User Plane Latency	
	Control Plane Latency	
	E2E Service Latency	<0.8 ms
	New Latency contribution components	
	E2E Application Latency – for Video processing services	
	Mission critical QoS of services – latency related	
	Runtime Delay	
	Service Setup Delay	
	Slice Setup Delay	

Packet Loss	Packet Error Rate	
	Layer2/3 packet transmission success rate	
	Packet Loss Rate	
	Frame Loss	
	Signal Packet Loss	
Compute	Edge computational resource usage	
	Operation expenditure @edge	
	Delta in network management decision	
	Availability	
	Resource utilization	
	Computing resource utilization	
Energy	Network Energy efficiency	
	Device Energy Efficiency	
	Reduced energy consumption	
	VNF Energy consumption reduction	
Security	Anomaly detection precision	
	Security conformance	
	Tenant data privacy	
Localization	Localization accuracy	<0.1 m (fine) <1 m (coarse)
	Direction and orientation accuracy	
	Localization related delays	
	Localization (error) integrity	
Service	Service availability	
	Service reliability	99.999-99.99999
	Service safety, integrity, maintainability	
	CAPEX & OPEX reduction	

PoC-
Cooperating Mobile Robots

System-PoCs

PoC A: Baseline Scenario 1 single-domain

Use Case

- **Cooperating Mobile Robots**
  - Cobot-powered warehouse operations, towards inventory management

Enablers

- Management & Orchestration (Pervasive functionality)
  - Trust aspects
  - Sustainable AI-control

Sustainability Aspects

- Social: trustworthiness (Time related KPIs, handling event)
- Environment: Energy (Power consumption)
- Economic: financial (resilience, reduced downtime), OPEX (energy)

PoC B: Scenario 2: multi-domain aspects

Use Cases

- **Cooperating Mobile Robots**
- **Human centric services (**Public safety services, Safe environments)

Enablers

- Pervasive technologies
- Network functions

Sustainability Aspects

- Social: trustworthiness: Time to handle; Data exposure security, privacy mechanisms; Digital inclusion
- Environment: Energy/Power consumption; Dynamic replanning of available device roles
- Economic: benefits in terms financial indicators, also **CAPEX**

PoC C (To be elaborated): Scenario 3 Intent-driven, multi-domain

Use Cases

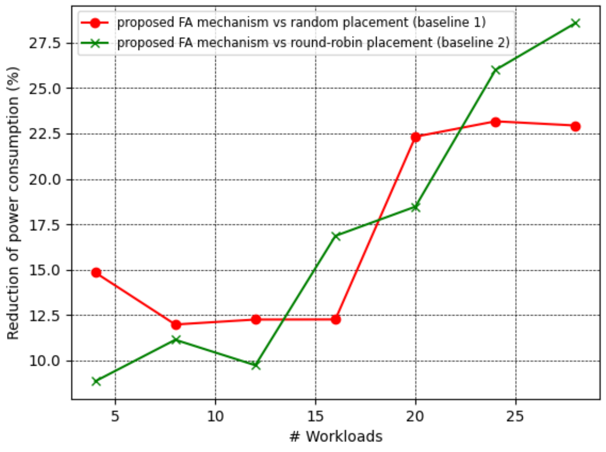
- **Cooperating Mobile Robots**
- **Human centric services (**Public safety services, Safe environments)

Enablers

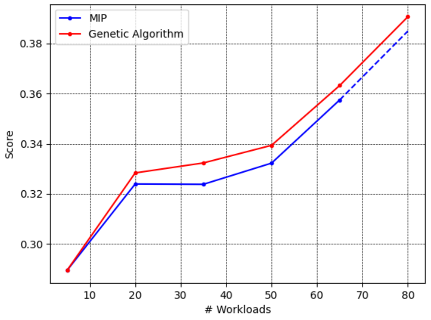
- Evolved Management & Orchestration (Pervasive functionality); Trustworthy flexible topologies; Network beyond communications: Exposure, compute, sensing
- 6G Device components; 6G Radio aspects;
- Intent-Based Network aspects
- Cobots, XR, Twinning Sensing

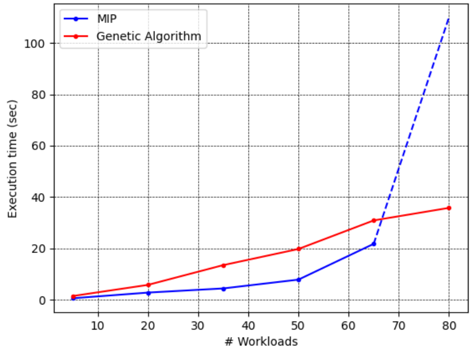
Sustainability Aspects

- Social: trustworthiness: Time to handle; Data exposure security, privacy mechanisms; Digital inclusion
- Environment: Energy/Power consumption; Dynamic replanning of available device roles
- Economic: OPEX; CAPEX



System-PoC A & B current KPIs measured	
Power consumption reduction (Functionality Allocation FA algorithm)	**~25%** (compared to two baseline algorithms)
Execution time of FA algorithm for allocating the workloads to devices	**Linear growth** (compared to the nearly exponential growth of the optimal mixed-integer programming algorithm)
Energy consumption gains of FA algorithm (Genetic algorithm capabilities)	Up to **50%**
Trustworthiness of FA algorithm (Genetic algorithm capabilities)	Up to **45%**





HEXA-X-II

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Co-funded by the European Union

6GSNS

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Cooperating Mobile Robots: Business Model Canvas

Collaborative Robots Use Case Family

Supply Side

- **Stakeholders/key partners:** suppliers / providers of robots / cobots (sector specific: manufacturers / rental companies); network infrastructure provider; network operator (public/private network); modem chipset manufacturer and provider; providers of programs/SW (for collaborative robots); system integrators; "space stakeholders"
- **Resources:** high-quality local network; robots; platform; sensing and monitoring capabilities; IoT devices; compute resources; AI algorithms; data and access to data; domain specific competence; funding; design processes; IPR.
- **Activities:** Coordination and cooperation between stakeholders and robots; R&D; design; manufacturing; deployment; sales; operation maintenance; circular business; sustainability / life cycle /ethical management; authentication; development SW solutions; production of devices; design and operation of networks; integration of solutions

Ecosystem Value Propositions

- **Value proposition**: Improved efficiency, quality, security, flexibility and reliability from collaborative mobile robots conducting complex tasks in a coordinated manner.
- **Value co-creations:** Co-creation and enabling a total solution for robots, machines and humans to efficiently conduct tasks through the exchange of information using the network.
- **Value capture:** Higher efficiency and economies of scale through collaborative automation for all involved (including moving production back to Europe); safer environment to work in (safety).
- **Value co-destruction:** Lack of collaboration due to interoperability challenges between components hindering innovation and the ability to achieve economies of scale for the solutions. People losing skills to conduct tasks and solve problems and high dependency on robots.
- **Partnerships**: robot providers and software providers (compatibility) for system partnerships; production site and robot providers; network providers and data center service providers; network providers and operators.

Demand Side

- **Customer segments**: different campuses (area with buildings) including e.g., manufacturing sites; hospitals, harbors/airport/cargo handling/logistics centers, construction sites (temporary factory); construction/campus management company; manufacturer; constructor; construction rental companies.
- **Stakeholders/key partners**: manufacturers; co-workers of cobots;
- **Customer relationships**: dedicated customer sale and care for the account; B2B; support for the solutions.
- **Channels**: digital channels for all instrumental information exchange between seller and customer; key account manager (human channel)

Outcomes

- **Benefits:** higher resource efficiency and productivity of processes; cost savings from same solution used in multiple factories; high precision leading to less waste; improved safety for workers; new business from developing and manufacturing robot/cobots; improved reuse of resources; productivity processes (construction as manufacturing); opportunity for automizing production and produce closer to customer; setting up factory rapidly; allowing remote operations; potential environmental and social benefits from bringing production to Europe.
- **Revenues (revenue streams)**: solutions as a service; whole solution from one major player that partners with others; paying per robot; building owner invests in building with the robots and rents the facility as a service/contractual agreement; manufacturing (construction, logistics) as a service.
- **Pricing**: as a service (monthly) pricing models; fixed price per component; paid per delivered unit; pricing based on customers' improved efficiency or other values (% of margin).
- **Costs**: Economic and environmental costs from the manufacturing of robots; people are replaced by robots - people need to learn new skills; coordination of robots for energy/charging; back up for robots in case of failures; high upfront investment from the deployment of the whole system (phased approach needed).

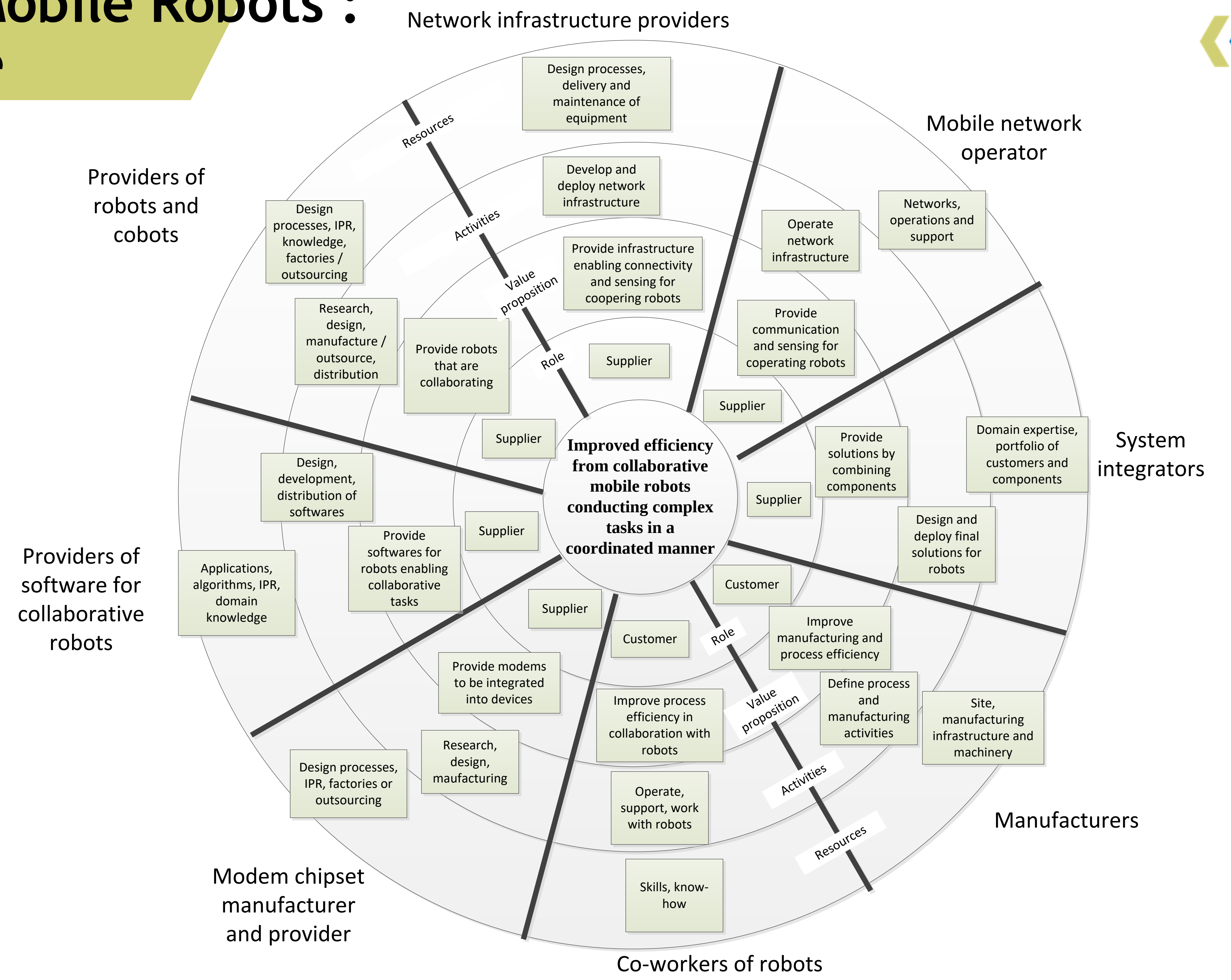
Cooperating Mobile Robots : Stakeholder Analysis

Collaborative Robots Use Case Family

Stakeholder	Description	Role	Value proposition	Activities	Resources
Suppliers/providers of robots/cobots	Providers of robots and cobots	Supplier	Provide robots, which are collaborating, using network infrastructure, for different segments, building new business opportunities.	Research, design, manufacturing (outsourced), sale/distribution,	Design processes. IPR, knowledge. People. Own factories - or outsourcing expertise.
Network infrastructure provider	Vendor of network infrastructure equipment.	Supplier	Provide infrastructure enabling communication and sensing for cooperating robots, for different purposes and customers. Extract synergy effects, keep installed base maintained and up to date.	Develop and deploy network infrastructure that support communications and sensing. Research, design, manufacturing, outsourcing, sale/ distribution	Design processes, IPR, knowledge, people, own factories, outsourcing expertise, scaling capabilities
Mobile network operator (public/private network)	Provider of local / wide area connectivity services.	Supplier	Provide communication and sensing for running cooperating robots in the target area, where investment and costs in network can be justified by the use and users, and what they pay for deploying and running the network.	Operate local / wide area network. Handle relationship with network owner/financer - and users, access rights of network. Authentication.	Local / wide area active (and passive network). Network operation and support.
Modem chipset manufacturer and provider	Manufacturer of the modem chipset	Supplier	Provide modems, which are integrated into different devices/equipment with e.g. the right form factors.	Research, design, manufacturing (outsourced), sale/distribution.	Design processes, IPR, knowledge, people. Own factories - or outsourcing expertise.
Providers of software for collaborative robots	Provider of software and applications needed for the robots to function.	Supplier	To provide software for robots to collaboratively conduct tasks enabling e.g. efficient and automatic choice of network "paths"	Design and development, sales and distribution, management of access / licenses, etc.	Algorithms, application, IPR and copyright, experts, vertical domain knowledge
System integrators	Integrators of components from different providers.	Supplier	Offer system-level solutions by recombining, reconfiguring, and handling many types of components. cost-efficiently.	Combine components into solutions. Design and deploy final solutions for robots. Contract, customer relationship	Expert knowledge, large portfolio of customers and certified tested components
Manufacturer	Company that operates the manufacturing site where the robots are located.	Customer	Improve manufacturing and process efficiency by means of collaborative robots	Define processes and manufacturing activities, define requirements, operate robots	Site, infrastructure, other manufacturing machinery and devices
Co-workers of robots	People working with robots	Customer	Improve process efficiency in collaboration with robots	Operate robots, work with robots	Skills, know-how.

Cooperating Mobile Robots : Ecosystem pie

Collaborative Robots Use Case Family



Cooperating Mobile Robots

Collaborative Robots Use Case Family

Main categories for further impact analysis

Environmental	Social	Economic
Resource efficiency	Accessibility	Productivity & efficiency
Energy consumption	Work environments	New business opportunities
E-waste	Support & Distribution	Monopolization risks
Manufacturing, extraction, transportation	Privacy & Security	Investments

Preparedness for 6G Environmental, Social and Economic Sustainability: Collaborative robots Representative UC

Collaborative Robots Use Case Family

Challenges

- increased production flexibility → increased material usage and resource allocation in (robot) production, increased energy consumption in operation and e-waste formation at the end-of-life.
- Support workers performing tasks beyond their capabilities that risk their lives (e.g., carrying large weights, working in dangerous environments) vs. job losses
- Balance new processes with existing processes
- Scaling of the collaborative mobile robots' solutions to make the use case economically feasible

Risks

- Too many robots
- Jobs eliminated
- Lack of standardization

Mitigation Strategies

- Domain tailored solutions
- Smooth transition
- Reinforce standardization

Mitigating stakeholders

- Developers and operators
- Policy makers
- Operators, SDOs, alliances

Indicative example of Risks / Mitigation / Mitigation stakeholders for each sustainability axis (environmental, social, economic)

Terminology

- Business models describe how a company creates, captures, and delivers value.
  - In Hexa-X-II, a new ecosystem-level business modelling approach has been developed for use case specific sustainability-oriented business modelling. It consists of three steps:
    - **ecosystem business model canvas**: value proposition of the use case at ecosystem level including stakeholder identification
    - **stakeholder analysis**: characterization of stakeholders' role in the ecosystem
    - **ecosystem pie**: ecosystem-level business model visualization
- Sustainability Analysis:
  - Including Environmental, Social and Economic sustainability aspects
  - **Sustainability Footprints**: In the context of Hexa-X-II, the term “footprint” is defined in alignment with ITU-T L.1480, encompassing direct, i.e., first-order negative environmental effects, extended to direct negative social and economic effects. Furthermore, the Hexa-X-II definition of sustainability footprints includes second-order and higher-order environmental, social, and economic negative effects.
  - **Sustainability Handprints**: In the context of Hexa-X-II, the term “handprints” refers to the positive effects enabled by a 6G-enabled solution. These encompass positive first-order, second-order, and higher-order environmental, social, and economic effects that do not only help mitigate and reduce direct negative effects but also generate additional positive contributions to the environment, society, and economy.

Terminology

- Preparedness for 6G Environmental, Social and Economic Sustainability
  - **Challenge** refers to difficulties or resistance that may prevent the Use case (UC) sustainability handprints and minimization of the sustainability footprints and therefore jeopardizes the potential 6G benefits for environmental, social or economic sustainability.
  - **Risks** refer to both the likelihood of not realizing the Use Case (UC) sustainability handprints and of sustainability footprints becoming larger than expected. Risks also include the likelihood of the UC resulting in not yet identified footprints. In order to identify the risks, one needs to analyse further the challenges, and describe what could go wrong so that the UC does not meet the sustainability handprints, or the sustainability footprints grow larger.
  - A **mitigation strategy** is a plan to reduce or eliminate the impact of a potential risk. The plan should take into account what technical decisions / technologies that can be applied on the 6G blueprint to help avoiding the risk not to meet environmental, social and economic sustainability targets, i.e., reduce the probability that the undesired outcome happens, or managing it in terms of reducing the undesirability of the outcome but also recommendation to stakeholders outside of the ICT sector, e.g., policy makers.