D2.3 Real-World Problems and Case Studies

5G-DiGITs

Cross-sectorial education and talent development for beyond 5G Digital and Green Industrial Technologies.

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Abbreviations

Acronym	Full Term
3GPP	3rd Generation Partnership Project
4G/5G	Fourth/Fifth Generation of the Mobile System
6G-IA	6G Smart Networks and Services Industry Association
AI	Artificial Intelligence
A/M/X/VR	Augmented/Mixed/eXtended/Virtual Reality
B5G	Beyond-5G
CAPEX/OPEX	Capital / Operating Expenditure
CDT	Curriculum Development Team
D*x.y*	Deliverable *x.y*
EC	European Commission
ECTS	European Credit Transfer and Accumulation System
ECVET	European Credit System for Vocational Education and Training
EIT	European Institute of Innovation and Technology
EMBB	Enhanced Mobile BroadBand
ENISA	European Network and Information Security Agency
EPO	European Patent Office
EQAVET	European Quality Assurance in Vocational Education and Training
ETSI	European Telecommunications Standards Institute
EU	European Union
FRAND	Fair, Reasonable, and Non-Discriminatory
GDPR	General Data Protection Regulation
GSMA	GSM Association
HEI	Higher Education Institution
ICT	Information and Communication Technologies
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IP	Intellectual Property
ITU	International Telecommunication Union
KPI/KVI	Key Performance/Value Indicator
KSA	Knowledge, Skills, and Abilities
LCA	Life-Cycle Assessment
LTE	Long-Term Evolution
MEC	Multi-Access Edge Computing
MIMO	Multiple Input Multiple Output
ML	Machine Learning
mMTC	Massive Machine Type Communication
MOOC	Massive Open Online Course
MVP	Minimum Viable Product
NGO	Non-Governmental Organization
OECD	Organization for Economic Cooperation and Development
PBL	Problem-Based Learning
QoE/QoS	Quality of Experience/Service

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RAN	Radio Access Network
R&D	Research and Development
SEP	Standard Essential Patent
SLA	Service Level Agreement
SNS JU	Smart Networks and Services Joint Undertaking
SME	Small and Medium-sized Enterprise
TTO	Technology Transfer Office
UI/UX	User Interface/eXperience
URLLC	Ultra-Reliable Low-Latency Communication
V2I/V2X	Vehicle to Infrastructure/Everithing
VET	Vocational Education and Training
WIPO	World Intellectual Property Organization
WP*x*	Work Package *x*

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Executive Summary

Deliverable **D2.3 – Real-World Problems and Case Studies** describes the first key outcome of **Task T2.3** under **Work Package 2 (WP2)** of the **5G-DiGITs** Project. It discusses the introduction of the **Problem-Based Learning (PBL)** methodology in the design and development of the 5G-DiGITs educational curriculum, which is composed by eight courses covering topics in the context of digital and green technologies, entrepreneurship, and innovation strategies related to 5G and Beyond-5G (B5G) systems, Internet of Things (IoT), and the application of Machine Learning (ML) and Artificial Intelligence (AI) to these domains.

The 5G-DiGITs Curriculum Development Team identified seven **Case Studies** and developed them through a rigorous methodology, in order to support the modular learning approach targeted by the Project. This approach, well-aligned with the PBL methodology, targets both Higher Education (HE) learners and Vocational Education and Training (VET) professionals seeking upskilling or reskilling.

The **Case Studies**, listed below, are self-contained learning units but also contribute to a coherent learning path as they are fully integrated in the 5G-DiGITs courses:

1. **Designing 5G Infrastructure for Smart Cities: A Sustainable Mobility Use Case;**
2. **Identifying KPIs and KVIs for Beyond-5G Use Cases: Remote and Immersive eHealth Education;**
3. **Designing and Evaluating Sustainable 5G Network Deployment Strategies;**
4. **Leveraging Digital Skills for Intelligent 5G Network Management in Smart Cities;**
5. **Optimising Urban Mobility with Edge-Enabled 5G Systems: A Minimum Viable Product Approach;**
6. **Strategic Intellectual Property and Tech Transfer in 5G: Startup Case Studies;**
7. **Advancing Precision Agriculture through 5G-Enabled Smart Farming: A Design-Driven Innovation Framework.**

As detailed in the present document, the development of the Case Studies was facilitated by a **common template** where, among other, learning outcomes, learning/training tasks, assessment methods, and mapping to the 5G-DiGITs courses are reported in detail.

Deliverable D2.3 thus provides a comprehensive overview on how the PBL methodology is being leveraged by the 5G-DiGITs Project. By combining technical depth, transversal competencies, and educational flexibility, the designed Case Studies provide a powerful tool for training the next generation of professionals capable of leading and transforming 5G/B5G-enabled societies.

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1. Introduction

1.1. Purpose of the deliverable

Deliverable D2.3 – Real-World Problems and Case Studies describes a key output of 5G-DiGITs Work Package 2 (WP2) – Joint Curriculum Development. Its primary goal is indeed to discuss one of the main activities carried out in Task T2.3, i.e., the introduction of the Problem-Based Learning (PBL) methodology in the educational framework being developed by the Project, which resulted in the design of seven Case Studies that complement the curriculum and corresponding courses being implemented by WP2.

The work of Task T2.3 continues the activities of Task T2.1 and Task T2.2, which resulted in:

Deliverable D2.1 – Needs Assessment Report: D2.1 reports and analyses the results of a study, conducted during the first phase of the Project through surveys and interviews with key stakeholders (educators, students, industry professionals, and policy-makers) across EU countries, aimed at identifying critical skills gap, industry expectations, and requirements necessary for the successful implementation of a learning curriculum covering topics in the context of digital and green technologies, entrepreneurship, and innovation strategies related to 5G and Beyond-5G (B5G) communication systems, Internet of Things (IoT), and the application of Machine Learning (ML) and Artificial Intelligence (AI) to these domains. The study revealed key insights that helped deriving proper strategies on how to design and develop such an advanced curriculum.

Deliverable D2.2 – Modular Curriculum Structure and Learning Materials: D2.2 describes the curriculum being implemented by the 5G-DiGITs Consortium. Composed by eight modular courses that address the critical skills gap identified in the D2.1, the curriculum reflects the collaborative work of a cross-sector development team, comprised of Higher Education Institutions (HEIs), Vocational Education and Training providers (VETs), and industry stakeholders. The development of each course in the curriculum was built around the Knowledge-Skills-Abilities (KSA) framework, ultimately ensuring pedagogical consistency and vertical learning progression.

By leveraging the insights in D2.1 while aligning with the curriculum implementation reported in D2.2, Task T2.3 focused its initial activities on introducing the PBL methodology in the context of 5G, B5G, and IoT systems, AI/ML application to network domains, digital and green technologies, entrepreneurial and innovation skills, ultimately resulting in the design of seven Case Studies that are (a) aligned with the skill requirements determined in the needs assessment (D2.1), and (b) integrated into the 5G-DiGITs curriculum and courses (D2.2).

D2.3 describes the identified Case Studies and provides an initial analysis of their mapping with the skills gap and requirements assessed in Task T2.1 and their integration into the courses forming the 5G-DiGITs curriculum under development in Task 2.2. Further details on how the PBL methodology is applied to the 5G-DiGITs Project will be discussed in **Deliverable D2.4 – Problem-Based Learning Implementation Guide**, where we also plan to provide additional guidelines for educators on how to leverage the Case Studies defined for the educational domains targeted by the Project.

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1.2. Structure of the deliverable

Apart from the Introduction, D2.3 is organised into four main sections.

Section 2 provides an overview of the PBL methodology, discussing rationale and educational benefits before analysing its relevance to the 5G-DiGITs Project and to WP2 activities.

Section 3 describes Task T2.3 approach, detailing the corresponding activities carried out towards integrating the PBL methodology in the 5G-DiGITs courses, which led to the design and development of the Case Studies.

Section 4 presents the identified Case Studies, which were designed by adopting a unified template in order to provide:

a) general information, introduction, and a detailed description of each Case Study;
b) details on the learning/training tasks forming the Case Studies;
c) usage guidelines, examples, and curated lists of resources, materials, and tools for supporting both deep understanding and flexible use of the Case Studies;
d) mappings between the Case Studies and the courses forming the 5G-DiGITs curriculum.

Section 5 summarizes the achievements of Task T2.3 while discussing next steps and activities.

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2. The PBL Methodology and its Role in 5G-DiGITs

2.1. Definition, Rationale, and Educational Benefits

PBL is an educational methodology that places students at the center of the learning process by engaging them in real-world problem scenarios that require the application of critical thinking, collaborative skills, and domain-specific knowledge. Originating in medical education [1][2][3], PBL has since been widely adopted across disciplines, particularly in engineering, technology, and business education, due to its capacity to simulate the challenges professionals face in real-world complex and dynamic environments [4][5][6].

In PBL settings, students are typically presented with a scenario, often ill-structured or open-ended, that mirrors a realistic challenge they might encounter in the workplace. Working independently or in groups, they analyse the problem, identify what they know and what they need to learn, conduct independent and/or collaborative research, and propose and evaluate potential solutions. PBL thus encourages active inquiry, self-directed learning, and the integration of knowledge across disciplinary boundaries, by instantiating iterative processes of questioning, investigation, and synthesis that ultimately promote deep learning and the development of transferable competencies.

A central principle of PBL is the notion of *constructivism*, a theory of learning which posits that individuals build new knowledge upon the foundation of previous understanding. PBL leverages constructivism by situating learning in contexts that are relevant and meaningful, thereby promoting cognitive engagement and knowledge retention. Moreover, the collaborative aspect of PBL provides opportunities for learners to articulate their ideas, confront perspectives, and negotiate meaning, all of which contribute to a richer and more durable understanding.

The benefits of PBL are well-documented in educational research. Studies have shown that students engaging in PBL tend to develop stronger problem-solving abilities, enhanced communication skills, and greater motivation to learn [7]. Furthermore, PBL fosters self-regulation and lifelong learning habits, as students are required to set learning goals, monitor their progress, and reflect on outcomes. These attributes are especially valuable in professional settings characterized by uncertainty, complexity, and the need for continual upskilling. PBL also aligns closely with modern competency-based educational frameworks, which prioritize the development of KSA over the accumulation of content. As such, PBL is particularly suited to preparing students for careers in modern markets and economies where adaptability, teamwork, and innovation are of paramount importance. Finally, the impact of PBL is not limited to individual learning outcomes, as it also influences institutional culture. When integrated systematically, PBL can transform curricula, pedagogical practices, and assessment methods. It promotes interdisciplinary collaboration, the redesign of learning spaces to support group work, and the development of assessment tools that mirror real-world tasks [8][9].

Facilitation is of paramount importance for an effective PBL. As a matter of fact, instructors transition from traditional lecturers to learning facilitators, guiding student inquiry, supporting group dynamics, and helping learners reflect on their problem-solving processes. This shift in instructor role is critical to empowering students to take ownership of their learning and to develop critical-thinking and problem-solving skills and strategies. Facilitators provide strategic support that fades over time, ultimately enabling learners to gradually assume greater responsibility for their educational journey.

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2.2. Relevance to 5G-DiGITs Vision and Objectives

The 5G-DiGITs Project is designed to address the skills gap in emerging deep technologies, particularly those aligned with the digital and green transitions as emphasized in the EU's strategic frameworks such as the European Skills Agenda and the Digital Education Action Plan.

As identified by the Project, flexible and learner-centred educational approaches are essential in the context of rapidly evolving technologies such as 5G/B5G communication systems, IoT, ML/AI, digital and sustainable entrepreneurship and innovation. In this context, a key ambition of the Project is to contribute to the preparation of learners for lifelong learning and successful entry into or progression within the job market. When used in parallel with more traditional learning approaches, PBL offers an ideal pedagogical framework to support this ambition and its corresponding learning objectives as it helps to mirror complex, ambiguous problems professionals encounter in dynamic work environments. In doing so, PBL helps students develop what are often called *21st-century skills*, including critical thinking, digital literacy, ecological awareness, and entrepreneurial initiative. Moreover, PBL aligns well with the multidisciplinary and applied nature of the 5G-DiGITs Project, as it allows learners to engage with real-world scenarios that reflect the interconnected nature of digital infrastructure, advanced communication systems, environmental sustainability, and innovation-driven entrepreneurship, ultimately ensuring that the learning process is not only about knowledge acquisition but also about capability development. Students learn how to identify knowledge gaps, locate reliable information, test solutions, and adapt to feedback. These capacities are crucial in a job market shaped by rapid technological change and environmental challenges.

Through the Case Studies designed by the 5G-DiGITs Curriculum Development Team (CDT), students are not only exposed to technical competencies but also to the socio-economic, environmental, and ethical dimensions of technology design and deployment. On the one hand, the integration of green and digital skills in the Case Studies reflects the EU's digital-and-green transition strategy. Students not only engage with digital tools but also explore how these can be harnessed to achieve sustainability. Such integrated learning is essential for developing professionals who contribute meaningfully to the European Green Deal and the Digital Compass targets. On the other hand, the Case Studies include collaborative and reflective aspects in order to cultivate transversal skills such as teamwork, communication, creativity, and adaptability, which are critical for navigating the complex ecosystems of future digital industries and services. These attributes resonate strongly with the Project's commitment to fostering resilient mindsets and entrepreneurial capacities among vocational and higher education learners.

The adoption of PBL within the 5G-DiGITs Project is thus a strategic choice that aligns pedagogical innovation with the demands of a fast-evolving digital and green economy. By situating learning within authentic problem contexts, PBL fosters not only technical expertise but also the broader competencies required for responsible, resilient, and sustainable innovation. It enables learners to become not just consumers of knowledge but active contributors to technological and societal advancement. As such, PBL is a foundational pillar in the Project's effort to equip Europe's future workforce with the skills, mindsets, and ethical grounding necessary to thrive in a 5G-enabled world.

Table 1 reports a summary of overarching 5G-DiGITs educational objectives, along with a comment on how the PBL methodology helps achieving them.

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Table 1. Mapping between 5G-DiGITs educational objectives and the PBL methodology.

Objective	Role of PBL
Foundational understanding of 5G systems	PBL is effective in supporting foundational knowledge because it encourages students to actively investigate and contextualize complex technical developments, rather than memorizing static information. This results in a deeper and more retained understanding of 5G as a technological paradigm shift.
Knowledge of 5G architecture and protocols	To effectively understand complex architectures and network protocols, learners must be able to conceptualize abstract systems and see how individual components interact. PBL supports this by pushing learners to engage with system-level problems that require technical reasoning and architectural decision-making.
Understanding the role of 5G/B5G in IoT and smart cities services and applications	The interconnected nature of 5G/B5G systems, IoT, and smart city applications requires learners to apply systems thinking, which is a core strength of the PBL methodology. By working on multifaceted problems, students are encouraged to consider technical and societal impacts of their designs.
Recognizing the role of green networking in 5G network design, management, and usage	Sustainability challenges are inherently interdisciplinary, requiring both technical and ethical considerations. PBL fosters holistic thinking by encouraging students to weigh trade-offs between performance, cost, and environmental impact, making it highly effective for teaching sustainable design principles.
Innovation and entrepreneurship in 5G-enabled ecosystems	Entrepreneurial learning thrives in PBL because learners are placed in high-agency, decision-oriented contexts where they must navigate uncertainty, risk, and strategic planning. This promotes initiative-taking and practical innovation skills.
Advancing digital and analytical skills in 5G-enabled ecosystems	Advanced digital skills are best developed through hands-on experimentation and data manipulation. PBL encourages iterative exploration and tool use, enabling learners to build confidence and proficiency in complex digital workflows.
Advancing professional and managerial skills in 5G-enabled ecosystems	Because PBL is inherently collaborative and student-led, it naturally cultivates professional competencies like communication, leadership, conflict resolution, and time management. These soft skills develop organically as students navigate the logistics and interpersonal dynamics of group projects.

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2.3. Relevance to 5G-DiGITs WP2 Activities

The use of the PBL methodology within the 5G-DiGITs Project is not incidental but is deeply embedded in the activities being carried out in WP2, altogether aiming at achieving one of the key objectives of the Project, i.e., "*develop a comprehensive and multidisciplinary curriculum in advanced 5G technologies and green skills for higher education and vocational education and training institutions".*

As mentioned in Section 1.1, WP2 was kicked off with Task T2.1 and Task T2.2.

In **Task T2.1**, concluded after 4 months from the Project start, the Consortium conducted a needs assessment to identify the skills requirements and knowledge gaps in the educational domains targeted by the Project (i.e., 5G/B5G communication systems, IoT, ML/AI, digital and sustainable entrepreneurship and innovation). Statistically significant sets of relevant stakeholders, i.e., industry professionals, educators, policy-makers, and students, were identified and surveys/questionnaires were developed for each stakeholder group. Responses from the stakeholders were collected and analysed by using qualitative and quantitative methods, in order to identify specific skills and knowledge gaps in the aforementioned education domains. The findings of such analysis, reported in Deliverable D2.1, outlined the identified skills requirements and provided recommendations for the design and development of the 5G-DiGITs curriculum.

In **Task T2.2**, started at Month 4 and lasted until Month 10, the main focus was on the design and development of the 5G-DiGITs curriculum and corresponding courses. In order to achieve a coherent and cohesive implementation, a 9-step methodology was applied during this task, as detailed in Deliverable D2.2 and summarized in the following:

1. **Confirming pre-identified learning outcomes**: The learning outcomes defined during the Project proposal phase were reviewed, and the Consortium confirmed their validity and relevance;
2. **Mapping learning outcomes to industrial and educational needs**: The learning outcomes were mapped onto the activities of Task T2.1 by analysing the results in D2.1. Statements and responses from the stakeholder groups were aligned with the learning outcomes, ultimately ensuring that the curriculum and, thus, the content of the courses forming it, would be academically rigorous and aligned with real-world expectations;
3. **Validating learning outcomes based on content analysis**: A quantitative analysis was performed to ensure that learning outcomes were proportionally relevant to industry and educational demands. Three methods were used, i.e., (a) frequency analysis (measuring how often topics related to each learning outcome appeared in D2.1), (b) sentiment and emphasis analysis (assessing the importance and urgency of these topics according to the stakeholders' perspectives), and (c) stakeholder weighting (assigning different weights to different stakeholder groups to reflect their influence on the content of each course);
4. **Linking learning outcomes and KSA items**: The validated learning outcomes were further aligned with the specific KSA items defined for each course. The KSA framework was selected for guiding the development of the courses forming the 5G-DiGITs curriculum due to its proven effectiveness in bridging academic learning with real-world demands in deep-tech sectors. The framework emphasizes three main educational objectives: (a) **Knowledge**, defined as the theoretical understanding required for a subject in terms of concepts, principles, and methodologies; (b) **Skills**, defined as the practical abilities to develop in order to apply knowledge in real-world scenarios; and (c) **Abilities**, defined as broader competencies integrating both knowledge and skills, enabling individuals to analyse, evaluate, and innovate in

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complex situations. The CDT thus defined the KSA items for each course and aligned them with the learning outcomes validated through the previous steps;

5. **Structuring course modules to KSA items**: The CDT proceeded by structuring the KSA items of each course into **modules**, in order to ensure that courses had a logical flow and covered necessary competencies while maintaining pedagogical coherence;
6. **Defining the syllabus structure**: A **syllabus template** was agreed across the Project Consortium, in order to ensure that all courses followed a consistent format while allowing flexibility for different types of content and learning methods;
7. **Developing the syllabus and course modules**: Once course modules and syllabus template were finalized, the CDT proceeded by (a) breaking down course modules into **units and sections**, ensuring a logical sequence of topics; (b) selecting proper teaching methodologies across theoretical lectures, exercises, case studies, and other tools; and (c) determining assessment strategies (e.g., quizzes, hands-on labs, and individual/collaborative projects and reports);
8. **First CDT Advisory Board review**: The syllabi of the courses were formally reviewed by an appointed internal advisory board, in order to ensure that courses were aligned with the Project's pedagogical principles, workload expectations, and the broader goals of the 5G-DiGITs initiative. Three independent reviewers assessed each course using a standardized template organized into several categories. Each item was scored, and reviewers also provided comments for the items where they requested major or minor revisions. Once the reviews were received, the CDT documented an action plan and actuated modifications in new syllabus drafts;
9. **Final CDT Advisory Board review and consolidation**: A second and final round of reviews was conducted by the advisory board, in order to validate the modifications, ensure that feedback was properly integrated, and confirm the readiness of the eight courses for pilot implementation.

This above process ensured that the 5G-DiGITs curriculum is not only pedagogically coherent and technically accurate but also aligned with the standards set by the European Credit Transfer and Accumulation System (ECTS) and European Quality Assurance in Vocation Education and Training (EQAVET) in terms of accessibility and expected workload. From Task T2.3 perspective, the process ultimately resulted into a unified reference course structure on which the PBL methodology could be instantiated in terms of Case Studies, for the eight courses forming the 5G-DiGITs curriculum, as listed below:

- Course 1: **Introduction to Advanced 5G Technologies**;
- Course 2: **Network Architecture and Protocols**;
- Course 3: **IoT, Industry 4.0, and Smart Cities**;
- Course 4: **Energy Efficiency and Sustainability in Advanced 5G Technologies**;
- Course 5: **Entrepreneurship and Innovation in Advanced 5G Technologies**;
- Course 6: **Digital Skills for Beyond 5G Technologies**;
- Course 7: **Green Skills for Beyond 5G Technologies**;
- Course 8: **Entrepreneurial Skills for Beyond 5G Technologies**.

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3. Task T2.3 Approach and Activities

Within the WP2 context and as a follow up of Tasks T2.1 and T2.2, Task T2.3 had a main initial goal of integrating the PBL methodology into the 5G-DiGITs curriculum/courses. This entailed the definition of at least five real-world Case Studies related to 5G-DiGITs educational domains, aligned with the skills requirements determined in the needs assessment, integrated in the eight courses under development, and ultimately accounting for approximately 40% of the total learning experience at curriculum level.

In order to achieve the above objectives, the first part of Task T2.3, running from Month 7 to Month 10, was organized in a set of activities, as documented in the following sub-sections.

3.1. Definition of a Competence Framework

The integration of the PBL methodology began with the development of a competence framework. This framework aimed at outlining the specific learning outcomes and KSA items that students can expectedly acquire by leveraging specific Case Studies.

For this activity, Task T2.3 relied on the structured approach established in earlier Tasks T2.1 and T2.2. As a matter of fact, in order to initiate the development of the 5G-DiGITs courses, Task T2.2 already confirmed learning outcomes and mapped/validated them onto the needs assessment and stakeholders' consultation in Task T2.1 (Steps 1-3 in Section 2.3). Moreover, for each course, KSA items were defined and linked to such learning outcomes (Step 4), and modules, units, and sections were designed through a closed-loop review-and-consolidation process (Steps 5-9). Therefore, it felt natural and efficient to rely on this established structure at the beginning of Task T2.3, to maintain coherency and consistency across WP2 activities while also considering that a needed outcome of this Task is the integration of Case Studies into courses. As a result, Task T2.3 leveraged the same competence framework of Tasks T2.1 and T2.2 meaning that, during the development of Case Studies, the same mapping between learning outcomes and the KSA items of each course was considered.

As further detailed in Section 4, where the developed Case Studies are presented, a required outcome during the Case Study definition was the establishment of a direct mapping between (a) a Case Study and *at least* one of the eight courses, and (b) the identification of the course learning outcome(s) and KSA item(s) that each Case Study supports to achieve.

3.2. Identification of Real-World Scenarios

The second activity focused on identifying scenarios that mirror real-world challenges at the intersection of advanced 5G/B5G technologies, sustainability, entrepreneurship and innovation.

For this activity, the Project Consortium acknowledged the need for establishing cross-domain teams composed by HEI, VET, and relevant industry personnel, in order to share ideas on scenarios and refine thematics to be included in the Case Studies. Also in this case, the development structure adopted for Task T2.2 was maintained, considering that the sub-teams forming the CDT (one sub-team for each course) were already HEI/VET/industry hybrid teams. Iterative brainstorming sessions within the course sub-teams were thus facilitated during this phase, in order to identify relevant real-world scenarios, where industry partners had the opportunity to bring current technical limitations, regulatory constraints, and market priorities for a given scenario, while educators contributed pedagogical perspectives to ensure that the scenarios were appropriately defined for achieving the targeted learning outcomes and KSA items, as well as student engagement.

This phase was key for converging on scenarios to be used in multidisciplinary Case Studies that, as further shown in Section 4, balance complexity and feasibility satisfactorily while ensuring that they are open-ended and feature multiple solution paths across human-centred narratives (e.g., conflicting stakeholder demands).

3.3. Mapping of Scenarios to 5G-DiGITs Curriculum

The third activity focused on mapping the scenarios identified in the previous step onto the 5G-DiGITs courses, while leveraging the competence framework defined in the first activity.

The approach adopted for the previous activity, i.e., to leverage course sub-teams for the identification of scenarios, was beneficial in this step, because it naturally helped to map Case Study scenarios onto courses. However, the Consortium acknowledged the need for establishing another layer of collaboration, i.e., across sub-teams, in order to analyse how/if the identified scenarios could be merged towards defining Case Studies that could be integrated into multiple courses. Brainstorming sessions across course sub-teams were thus facilitated during this phase, so as to identify overlaps across scenarios, courses, learning outcomes, and KSA items, ultimately resulting in synergies across sub-teams. By systematically mapping these elements, this alignment activity enabled coherent integration, minimized duplication, and made explicit how Case Studies could be shared across the curriculum while also serving course-specific aims. In this phase, the sub-teams also started to quantify the expected workload of each Case Study. The agreement was to design them as independent units composed by at least 24 learning hours, with the latter reasonably split across lectures, exercises, and independent study time. The reason for this decision was two-fold: (a) following the Project proposal, the PBL methodology is targeted to account for approximately 40% of the total learning experience of the 5G-DiGITs courses, and (b) 5G-DiGITs courses are composed by 2 ECTS each, i.e., 60 learning hours.

This phase was key for achieving Case Studies that, as further detailed in Section 4, have the flexibility and modularity needed for being integrated not only into the 5G-DiGITs courses but can also be easily reused outside the 5G-DiGITs curriculum, e.g., by educators wishing to include the PBL methodology in their educational frameworks, e.g., in their own courses on advanced 5G/B5G systems and technologies.

3.4. Development of a Case Study Template

The fourth activity focused on creating a standard template for designing and developing the Case Studies, aiming at ensuring a consistent description across development teams.

The template was intended to not only be a layout tool but also a pedagogical guide embedding key principles of the PBL methodology. For this reason, as shown in Section 4, the sections composing the template[1] include Case Study context description and problem statement, as well as the definition of learning/training tasks, usage guidelines for educators, suggested resources, assessment criteria, and a mapping of the Case Study to the learning outcomes and KSA items of the targeted 5G-DiGITs courses. This structured yet flexible format ensured that teams

[1] Note that, the template sections correspond to Sections 4.*X*.1-4.*X*.7 in the present document, where *X* identifies a specific Case Study, as numbered in the present document.

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focusing on different scenarios could produce Case Studies with equivalent pedagogical quality while enabling easier translation into different teaching environments for further reuse beyond the Project scope.

3.5. Design and Development of Case Studies

By leveraging the outcomes of previous activities, the last step was the actual design and development of the Case Studies. In this phase, the template was used by the development teams in order to provide comprehensive and coherent descriptions, along with a clear mapping onto the 5G-DiGITs curriculum/courses.

The outcome of the above process is the set of seven Case Studies reported in Table 2, where a high-level mapping to specific 5G-DiGITs courses is also provided. Full descriptions of the Case Studies are provided in Section 4.

Table 2. Mapping between 5G-DiGITs Case Studies and 5G-DiGITs Courses.

Case Study	Courses
Designing 5G Infrastructure for Smart Cities: A Sustainable Mobility Use Case	Introduction to Advanced 5G Technologies Network Architecture and Protocols IoT, Industry 4.0, and Smart Cities
Identifying KPIs and KVIs for Beyond-5G Use Cases: Remote and Immersive eHealth Education	Introduction to Advanced 5G Technologies Network Architecture and Protocols
Designing and Evaluating Sustainable 5G Network Deployment Strategies	Energy Efficiency and Sustainability in Advanced 5G Technologies Green Skills for Beyond 5G Technologies
Leveraging Digital Skills for Intelligent 5G Network Management in Smart Cities	Digital Skills for Beyond 5G Technologies
Optimising Urban Mobility with Edge-Enabled 5G Systems: A Minimum Viable Product Approach	Entrepreneurship and Innovation in Advanced 5G Technologies Entrepreneurial Skills for Beyond 5G Technologies
Strategic Intellectual Property and Tech Transfer in 5G: Startup Case Studies	Entrepreneurship and Innovation in Advanced 5G Technologies
Advancing Precision Agriculture through 5G-Enabled Smart Farming: A Design-Driven Innovation Framework	Entrepreneurship and Innovation in Advanced 5G Technologies Entrepreneurial Skills for Beyond 5G Technologies

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4. 5G-DiGITs Case Studies

In this Section, we describe the Case Studies developed by the 5G-DiGITs Consortium, aimed at being an integral part of the Project educational curriculum.

As detailed in the following, each Case Study is a self-contained learning experience that progressively guides students from easy to more complex tasks. Initial tasks often focus on collecting relevant background information so that students acquire the knowledge needed to address the following tasks, where they face experiences related to design and planning, ultimately enriching skills and abilities in line with the KSA items of the targeted course(s). The Case Studies also incorporate assessment criteria aligned with the PBL framework. These include formative assessments such as writing tasks and reports, peer evaluations, and group presentations, ultimately emphasizing not only technical accuracy but also collaboration and ethical reasoning.

4.1. **Case Study 1 –** Designing 5G Infrastructure for Smart Cities: A Sustainable Mobility Use Case

4.1.1. General Information on Case Study 1

General information on Case Study 1 is provided in Table 3.

Table 3. General Information for Case Study 1.

Case Study	Designing 5G Infrastructure for Smart Cities: A Sustainable Mobility Use Case
Learning Outcomes	• Explain the role of 5G in innovative applications and use cases; • Understand 5G technologies such as New Radio, MIMO, and edge computing; • Clarify how 5G core network functions enable vertical-specific services; • Evaluate use case potential for 5G in urban mobility and sustainability contexts; • Assess implementation challenges and future trends beyond 5G.
Total Learning Hours	**Lectures:** 2 hours **Practical Work:** 10 hours **Independent Study:** 12 hours **Total:** 24 hours
Prerequisites	• Basic understanding of mobile network architecture; • Familiarity with 5G access and core technologies.

4.1.2. Introduction to Case Study 1

As urban areas face growing pressures from population density, climate change, and mobility demands, the role of 5G systems becomes increasingly vital as a transformative enabler.

This Case Study focuses on the application of 5G networks in urban mobility and smart city infrastructures. It challenges students to design a 5G-based solution to enhance real-time traffic management, sustainability, and public safety in a medium-sized city. Students will explore how technologies like network slicing, edge computing, and massive Multiple Input Multiple Output (MIMO) contribute to improved service delivery in urban areas. By completing this Case Study,

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students will deepen their understanding of the use of 5G in solving real-world problems, analyse its enablers, and reflect on challenges toward 6G evolution.

The use of 5G systems in smart cities represents a multidisciplinary convergence of telecommunications, urban planning, data science, and sustainability. Therefore, students will also reflect on broader societal and environmental impacts, such as inclusivity, energy efficiency, and citizen engagement, which are key pillars of smart city strategies. This Case Study thus encourages learners to take a system-thinking approach to problem-solving, considering how technical architectures interact with policy, regulatory frameworks, and user needs.

The Case Study promotes critical evaluation of ethical and sustainable practices in network deployment. Students are expected to assess the trade-offs between performance optimization and energy consumption, explore equitable access to digital infrastructure, and propose strategies for resilient network design. Therefore, learners not only gain engineering insight but also develop awareness of the broader societal responsibilities attached to advanced technology deployment. By integrating these dimensions, the Case Study provides a comprehensive learning experience that equips students with the knowledge and critical thinking skills required to contribute meaningfully to the design and implementation of future smart city ecosystems.

4.1.3. Detailed Description of Case Study 1

Cities worldwide are adopting smart technologies to improve urban life. A critical component of this transformation is smart mobility, encompassing real-time traffic management, autonomous vehicle support, dynamic public transportation systems, and environmental monitoring. These services demand ultra-low latency, high bandwidth, high reliability, and scalable connectivity, which are key attributes enabled by 5G networks.

Scope and Stakeholders. In this Case Study, students assume the role of network consultants advising a municipal government in designing a 5G-enabled smart mobility infrastructure. The city in question is planning a comprehensive rollout of digital urban mobility services to reduce congestion, enhance emergency response coordination, and monitor environmental conditions such as air quality in real time. Students are tasked with proposing a tailored 5G network design that addresses three integrated goals:

- **Smart traffic systems**, supporting traffic signal control, vehicle-to-infrastructure (V2I) and vehicle-to-everything (V2X) communication, and congestion analytics;
- **Emergency response coordination**, enabling ultra-reliable low-latency communication (URLLC) for first responders, incident detection, and situational awareness;
- **Environmental monitoring**, facilitating large-scale sensor deployments for air quality, noise levels, and emissions tracking via massive machine-type communication (mMTC).

The proposed solution must not only meet technical performance requirements but also adhere to principles of digital inclusion, environmental sustainability, and long-term scalability.

The following groups of stakeholders are involved in this Case Study:

- **City transportation department**, acting as the primary decision-maker and coordinator for infrastructure deployment. This department is responsible for integrating 5G into traffic management and public transport systems. Priorities include congestion reduction, commuter safety, and multi-modal transport optimization;
- **Emergency services**, depending on URLLC for dispatch, coordination, and response in time-critical situations. Their participation ensures that the 5G network meets reliability and availability requirements under stress conditions;

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- **Citizens (end users)**, representing the ultimate beneficiaries of the system. They use connected mobility services, mobile apps, and rely on safe, efficient urban travel. Citizens play a key role in shaping public sentiment and adoption, making trust, transparency, and data privacy critical components;
- **Mobile network operators**, owning and operating the physical and virtual network infrastructure. They provide connectivity, manage network slicing for diverse service types, and ensure Service Level Agreements (SLAs) are met. Their role includes assessing commercial viability and aligning investments with city planning goals;
- **Technology vendors**, supplying access network and core components, e.g., base stations, Multi-Access Edge Computing (MEC) servers, software platforms, and IoT devices. Their collaboration is key in selecting interoperable, future-proof technologies that match the city functional and scalability needs.

Challenges. The following challenges are addressed in this Case Study:

- **Managing URLLC services**: Services such as emergency vehicle prioritization and accident alerts require URLLC support. Designing network slices that can deliver low latency under congestion is technically demanding and central to system performance;
- **Integrating legacy systems with modern infrastructures**: Existing traffic management platforms and emergency coordination centers are often built on outdated, siloed technologies. Integrating these into a unified, cloud/edge-native 5G architecture involves both technical and institutional complexity;
- **Ensuring security and privacy of transmitted data**: The Case Study involves vast amounts of sensitive data, from citizen movement patterns to emergency information. Implementing end-to-end encryption, access controls, and compliance with regulations like General Data Protection Regulation (GDPR) is essential for legal operations;
- **Guaranteeing service-level agreements via network slicing**: Different applications (e.g., video surveillance, environmental sensing, V2I/V2X messaging) have different Quality of Service (QoS) requirements. Configuring and maintaining network slices that ensure isolation, prioritization, and SLA compliance is both a challenge and an opportunity;
- **Sustainability and energy efficiency**: Dense deployment of 5G macro and small cells, edge servers, and IoT sensors may increase energy consumption unless optimized. Designing a solution that balances performance with sustainability (e.g., through energy-aware routing, renewable-powered infrastructure) aligns with smart city goals.

External References. Students will review and analyse technical documentation such as 3GPP Release 16 standards, relevant scientific papers on smart cities and 5G, and vendor white papers, as further detailed in Section 4.1.5.

4.1.4. Learning/Training Tasks of Case Study 1

The Case Study consists of three Tasks that guide students from background research to architecture proposals, culminating in the design and assessment of a 5G architectural proposal for smart mobility applications.

As detailed in Table 4, Task 1 introduces students to foundational concepts related to smart city applications and 5G systems. Students will explore how they are interconnected, in order to start mapping service requirements and system characteristics and capabilities.

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Table 4. Case Study 1: Description of Task 1.

Task 1	Analysing Smart City Needs
Learning Hours	6 hours (1 lecture + 2 practical + 3 independent)
Learning Outcomes	• Identify key 5G performance features for smart city applications • Map urban challenges to 5G capabilities
Description	The task includes the following steps: 1. Review provided documentation on smart cities and 5G architecture; 2. Identify three urban challenges and explain how 5G could address them; 3. Classify the type of 5G services required (URLLC or mMTC); 4. Consider how social and environmental factors (accessibility, energy use, public participation etc.) influence network design choices.
Expected Outcomes	A 2-page report mapping use cases to 5G system features and capabilities
Prerequisites	None

As detailed in Table 5, in Task 2, students are tasked to derive a 5G architecture proposal meeting the requirements of the service under analysis.

Table 5. Case Study 1: Description of Task 2.

Task 2	5G Architecture Proposal for Smart Mobility
Learning Hours	8 hours (1 lecture + 3 practical + 4 independent)
Learning Outcomes	• Design a basic 5G system including access and core elements; • Understand the role of edge computing and network slicing in the scenario.
Description	The task includes the following steps: 1. Design a logical 5G architecture (block diagram) for the smart mobility system; 2. Select appropriate technologies (e.g., massive MIMO, MEC); 3. Justify technology selection using latency/bandwidth/performance needs; 4. Address privacy and security considerations.
Expected Outcomes	A 4-page technical proposal with architectural diagram
Prerequisites	Task 1

Task 3, detailed in Table 6, requires students to work in groups towards synthesizing their architectural proposals while also providing a feasibility study and future trends assessment.

Table 6. Case Study 1: Description of Task 3.

Task 3	Feasibility & Future Trends Assessment

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Learning Hours	10 hours (5 practical + 5 independent)
Learning Outcomes	• Evaluate real-world implementation issues and future trends; • Understand the evolution from 5G to 6G.
Description	The task includes the following steps: 1. Research existing 5G smart mobility pilots (e.g., EU or Asia-based cities); 2. Identify key limitations and implementation lessons; 3. Predict how 6G trends (e.g., ML/AI-based automation, Terahertz communications) might affect the scenario under analysis; 4. Evaluate how the proposed solutions align with sustainability goals and ethical deployment principles.
Expected Outcomes	A 3-page essay summarizing findings and proposing enhancements for future scalability and presentation
Prerequisites	Tasks 1 and 2

4.1.5. Usage Guidelines and Examples for Case Study 1

Tasks may be completed individually or in small groups of 2-3 students. They can be assigned separately in short workshops or combined for a capstone project.

Group discussion should be strongly encouraged during Task 2 to foster design thinking. Instructors may also facilitate short debates or role-playing exercises to help students consider different stakeholders' perspectives (e.g., citizen concerns, operator costs, municipal priorities). The use of real datasets or city case studies is also strongly encouraged for Task 3.

4.1.6. Resources and Materials for Case Study 1

The following is a curated and recommended list of resources that provide the foundational knowledge and technical background necessary to understand the Case Study and complete the assigned tasks. While these materials offer a strong starting point, we recommend instructors to encourage students to explore additional sources and build their own library of references to deepen their understanding and broaden their perspective on 5G system architecture, smart city scenarios, and smart mobility services.

- Intel White Paper, "5G Networks: Enabling Digital Transformation of Smart Cities and Intelligent Transportation";
- ITU-T White Paper, "5G for Smart Sustainable Cities";
- A. Banerjee et al., "5G enabled smart cities: A real-world evaluation and analysis of 5G using a pilot smart city application," Internet of Things, vol. 28, 2024;
- A. Saxena et al., **"**5G-Enabled Smart Cities," Turkish Journal of Computer and Mathematics Education, vol. 11, no. 2, 2020;
- Sand Tech. White Paper, "5G and Smart Cities: Unlocking Tomorrow's Potential";
- 3GPP documentation, "3GPP Release 16 technical documentation";
- IEEE online documentation, "IEEE Smart Cities Official Site";
- C. X. Mavromoustakis et al. (ed.), "Internet of Things in 5G Mobile Technologies";
- C. Yang et al., "Using 5G in smart cities: A systematic mapping study," Intelligent Systems with Applications, vol. 14. 2022.

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4.1.7. Mapping of Case Study 1 to 5G-DiGITs Courses

With respect to the courses developed in the 5G-DiGITs Project, the Case Study is designed to support the learning framework of **“Introduction to Advanced 5G Technologies”**, **“Network Architecture and Protocols”**, and **“IoT, Industry 4.0, and Smart Cities”** courses.

On the one hand, the learning outcomes of the Case Study map and extend the learning outcomes of the above courses. On the other hand, the above courses include Modules/Units relevant to the Case Study, as they are related to:

- **5G Applications and Use Cases**
  - “Introduction to Advanced 5G Technologies” – Module 3, Unit 3.1;
  - “Network Architecture and Protocols” – Module 1, Unit 1.3.
- **B5G/6G concepts and evolution**
  - “Introduction to Advanced 5G Technologies” – Module 3, Unit 3.2;
  - “Network Architecture and Protocols” – Module 4, Units 4.1 and 4.2.
- **Introduction to IoT, its typical application area, and role of 5G**
  - “IoT, Industry 4.0, and Smart Cities” – Module 1, Units 1.1 and 1.2.
- **IoT Smart Cities**
  - “IoT, Industry 4.0, and Smart Cities” – Module 3, Unit 3.1.

KSA items covered by the Case Study also map with the KSA covered by the above courses:

Knowledge items covered by the Case Study

- From “Introduction to Advanced 5G Technologies” course:
  - Evolution of Mobile Communications;
  - Applications and Use Cases;
  - Challenges and Future Trends.
- From “Network Architecture and Protocols” course:
  - 5G Network Architecture;
  - 5G Protocols and Standards;
  - Towards 6G: Vision, Key Technologies, and Challenges;
  - Use Cases and Applications.
- From “IoT, Industry 4.0, and Smart Cities” course:
  - Introduction to IoT, Industry 4.0, and Smart Cities;
  - Smart Cities Infrastructure and Technologies.

Skill items covered by the Case Study

- From “Introduction to Advanced 5G Technologies” course:
  - Understanding Wireless Network Evolution;
  - Knowledge of Key 5G Technologies;
  - Problem-solving for 5G Deployment Challenges;
  - Practical Skills in 5G Network Analysis.
- From “Network Architecture and Protocols” course:
  - Analyse 5G Network Architectures.
- From “IoT, Industry 4.0, and Smart Cities” course:
  - Selecting IoT Communication Technologies;
  - IoT Protocol Implementation.

Ability items covered by the Case Study

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- From "Introduction to Advanced 5G Technologies" course:
  - Analyse the Evolution of Wireless Networks;
  - Differentiate Between 5G Service Categories;
  - Assess 5G Applications in Various Industries;
- From "Network Architecture and Protocols" course:
  - Network Optimization Problem Solving;
  - Research-Oriented Learning;
  - Collaboration and Communication.
- From "IoT, Industry 4.0, and Smart Cities" course:
  - Analyse and Explain the Interconnectivity of IoT in Urban Environments.

The allocation of learning hours (24 hours) for the Case Study accounts for up to 40% of the learning hours constituting a 5G-DiGITs course (60 hours, i.e., 2 ECTS). Therefore, when used in combination with one of the above courses, the Case Study can be used to either extend the learning hours or to replace parts (e.g., exercises, lab sessions, and presentations) of the target course, depending on how the instructor decides to leverage the provided material.

4.2. **Case Study 2 –** Identifying KPIs and KVIs for Beyond-5G Use Cases: Remote and Immersive eHealth Education

4.2.1. General Information on Case Study 2

General information on Case Study 2 is provided in Table 7.

Table 7. General Information for Case Study 2.

Case Study	Identifying KPIs and KVIs for Beyond-5G Use Cases: Remote and Immersive eHealth Education
Learning Outcomes	• Understand the evolution from 4G to 5G/B5G/6G architectures and protocols; • Identify 5G technologies, standards, and applications; • Comprehend the architecture, components, and key protocols of 5G networks; • Recognize the potential use cases of 5G in various industries; • Evaluate system performance based on Key Performance Indicators (KPIs); • Investigate the role of Key Value Indicators (KVIs) in B5G/6G design; • Analyse the alignment of 5G/B5G/6G systems with societal, environmental, and industry-specific needs; • Apply strategic thinking to derive performance and value metrics for specific vertical use cases.
Total Learning Hours	**Lectures:** 2 hours **Practical Work**: 10 hours **Independent Study:** 12 hours **Total:** 24 hours
Prerequisites	• Introduction to mobile and wireless networks; • Basic knowledge of 4G/5G architectures and protocols; • Familiarity with network KPIs (e.g., latency, throughput); • Basic understanding of use case analysis and modelling; • Familiarity with eHealth and/or remote education verticals.

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4.2.2. Introduction to Case Study 2

The advent of 5G systems has marked a pivotal moment in the evolution of mobile communication networks. While earlier generations, e.g., 4G Long Term Evolution (LTE), focused on expanding connectivity and data rate, the B5G/6G vision, driven in Europe by initiatives such as Horizon Europe, the Smart Networks and Services Joint Undertaking (SNS JU) public-private partnership, and corresponding projects (e.g., Hexa-X and Hexa-X-II), calls for a human-centric approach, addressing not only technical enhancements through Key Performance Indicators (KPIs) but also societal impact through Key Value Indicators (KVIs).

This Case Study invites students to explore this paradigm shift through the lens of a high-impact vertical: Remote and Immersive eHealth Education. The COVID-19 pandemic accelerated the adoption of digital health and learning platforms, revealing both their potential and limitations. In coming years, healthcare professionals will increasingly rely on immersive technologies, e.g., virtual reality (VR), augmented reality (AR), extended reality (XR), and haptic feedback, to participate in real-time, remote healthcare education, including surgical training, (pre-)hospital assistance, virtual anatomy labs, and global collaborative diagnostics.

These applications pose demanding requirements on B5G/6G networks, e.g., in terms of latency, reliability, security, accessibility, and sustainability. Quantification of such requirements goes beyond the traditional use of KPIs and necessitates the integration of KVIs, e.g., trust, inclusiveness, and environmental efficiency, in the design of B5G/6G networks.

By the end of this Case Study, students will have learned how to:

- Translate a real-world vertical scenario into quantifiable KPIs/KVIs;
- Identify features in 5G/B5G/6G architectures and protocols enabling the support of a target vertical scenario;
- Propose a high-level system architecture and policy strategy to support the achievement of KPI/KVI requirements of the targeted use case.

4.2.3. Detailed Description of Case Study 2

The use case addressed in this Case Study is centered around the design and deployment of remote and immersive eHealth education services, with a focus on real-time medical and/or nursing training enhanced by technologies such as VR/AR/XR and haptic feedback. These services are increasingly seen as essential components of modern healthcare education, especially considering the global disparities in access to healthcare expertise and infrastructure. The COVID-19 pandemic accelerated the shift toward remote healthcare and online learning but also exposed fundamental limitations in the current communication infrastructure, especially when it comes to supporting highly interactive and latency-sensitive educational formats.

Scope and Stakeholders. This Case Study positions itself within the broader transformation from 4G to 5G/B5G/6G networks, where performance is no longer evaluated solely on technical grounds, e.g., via throughput, latency, and other KPIs, but also on societal and ethical impact. This shift is captured through the concept of KVIs, which complement KPIs by addressing dimensions such as trustworthiness, sustainability, and digital inclusion. The scenario analysed in this Case Study demands the assessment of both performance and value: remote and immersive eHealth training must be technically robust to enable seamless, real-time collaboration among students and instructors, and value-aware to ensure the technology serves diverse populations and communities fairly and responsibly. From

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a system design perspective, the scenario entails the delivery of high-definition, real-time multimedia content and interactive learning environments and contents to multiple users across geographically distributed locations. This introduces stringent requirements in terms of data rates, latency, reliability, real-time synchronization of inputs (e.g., for applications involving AR/VR/XR content and/or haptic feedback), and the use of AI/ML for data processing and management. Such requirements go beyond the capabilities of 4G systems and rely on several innovations introduced in 5G and extended in B5G/6G research.

The stakeholders involved in this scenario are diverse and span multiple domains.

- **Healthcare institutions and universities** are primary content providers and service consumers, seeking to train future personnel using advanced and inclusive tools;
- **Telecommunications operators and infrastructure vendors** are responsible for ensuring that the underlying network infrastructure can support the demanding requirements of immersive education services;
- **Policy makers and regulators** play a key role in shaping the frameworks that govern the trustworthiness, safety, and environmental sustainability of these systems;
- **Technology providers** for AR/VR/XR/haptics solutions as well as for medical instrumentation are also central to this ecosystem, providing the devices and platforms through which students access the content.

Challenges. The primary challenge posed by this Case Study is to balance performance and value in network design, implementation, and evaluation. Students are not only asked to identify technical features that support the use case, but also to assess how these features can be mapped to broader societal goals. For instance, ensuring ultra-low latency may satisfy a KPI; in parallel, achieving digital inclusion, i.e., ensuring the service is accessible in underserved or remote regions, may address a KVI. Another challenge is translating qualitative societal requirements into measurable indicators that can guide network design and policy. By the end of the Case Study, students will have developed a comprehensive understanding of how to co-design system architectures and performance/value evaluation frameworks for advanced verticals in the B5G/6G era.

External References. To fully understand and analyse the technical and value-driven aspects of this Case Study, students will engage with a curated selection of external documentation and research outputs (see Section 4.2.5). These include Deliverables from the Hexa-X and Hexa-X-II Projects, along with relevant white papers, e.g., from the 6G Smart Networks and Services Industry Association (6G-IA), and research papers, where the foundational concept of KVIs is introduced and discussed along with its mapping to B5G/6G system design. Moreover, for insights into architectural enablers, students will reference technical standardization documents (e.g., from 3GPP) and additional research contributions, which define and analyse the 5G/B5G architecture, protocol stack, and corresponding features, making it possible for students to understand how KPIs and KVIs can be quantified and mapped onto the mobile system.

4.2.4. Learning/Training Tasks of Case Study 2

The Case Study consists of four Tasks that guide students from background research to architecture proposal, culminating in the design of a solution for the targeted scenario.

As detailed in Table 8, Task 1 introduces students to the foundational concepts of KPIs and KVIs, which are central to the B5G/6G vision. Students will explore how KPIs and KVIs differ and why both are necessary for evaluating modern communication systems that serve societal goals.

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Table 8. Case Study 2: Description of Task 1.

Task 1	Understanding the KPI/KVI Paradigm in B5G/6G Systems
Learning Hours	4 hours (1 lecture + 1 practical + 2 independent)
Learning Outcomes	• Differentiate KPIs and KVIs and explain their complementary roles; • Understand societal drivers for B5G/6G design; • Identify relevant stakeholders and their priorities.
Description	The task includes the following steps: 1. Attend a 1-hour lecture introducing KPIs and KVIs in B5G/6G systems; 2. Read relevant documentation from the list in Section 4.2.5; 3. Write a 2-page summary explaining (a) differences between KPIs and KVIs, (b) why both metrics are needed in modern network design, and (c) at least three KPIs and KVIs that apply to immersive remote eHealth education scenarios.
Expected Outcomes	A 2-page individual report
Prerequisites	None

As detailed in Table 9, Task 2 focuses on translating the immersive remote eHealth education use case into a set of functional requirements and performance/value metrics. Students will identify key stakeholders, system demands, and applicable KPIs and KVIs, forming the basis for architectural mapping in the following tasks.

Table 9. Case Study 2: Description of Task 2.

Task 2	Defining the Requirements of Remote and Immersive eHealth Education
Learning Hours	6 hours (0.5 lecture + 2 practical + 3.5 independent)
Learning Outcomes	• Specify functional, performance, and value requirements for a vertical use case; • Identify use case stakeholders and service constraints; • Extract indicators from system demands.
Description	The task includes the following steps: 1. Participate in a 30-minute lecture introducing remote and immersive eHealth education use cases; 2. Review relevant documentation from the list in Section 4.2.5; 3. Fill in a use case template including (a) functional overview, (b) stakeholder roles and needs, (c) required KPIs and KVIs (with rationale), and (d) target thresholds for the identified KPIs and KVIs (with rationale).
Expected Outcomes	Completed use case template (2 pages)
Prerequisites	Task 1

Having defined the KPIs and KVIs for the target use case, students will now explore the technical capabilities introduced in 5G/B5G architectures. As reported in

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Table 10, the focus of Task 3 is thus on identifying and explaining how these 5G/B5G features address the KPI/KVI requirements of remote and immersive eHealth education services.

Table 10. Case Study 2: Description of Task 3.

Task 3	Identifying 5G/B5G Architectural Solutions
Learning Hours	6 hours (3 practical + 3 independent)
Learning Outcomes	• Map system features to KPI and KVI requirements; • Understand architectural evolution from 4G to 5G/B5G; • Identify gaps or limitations in legacy systems.
Description	The task includes the following steps: 1. Read relevant documentation from the list in Section 4.2.5; 2. Review 5G/B5G features that can help supporting the target use case (e.g., ultra-reliable low-latency mechanisms in the radio access network, network slicing, multi-access edge computing, ML/AI-native control loops); 3. Analyse how KPI/KVI requirements (from Task 2) map to system features; 4. Compare with 4G LTE capabilities; 5. Produce a table showing (a) KPI/KVI requirements, (b) 4G limitations not allowing to achieve them, (c) 5G/B5G features allowing to achieve them, and (d) forward-looking view on how 6G could better support the use case.
Expected Outcomes	Brief report + technical comparison table (2 pages)
Prerequisites	Tasks 1 and 2

In Task 4, as detailed in Table 11, students will work in groups to synthesize their previous findings and design a high-level, KPI/KVI-aware network architecture for the remote and immersive eHealth education use case. This collaborative task emphasizes strategic thinking, technical integration, and stakeholder alignment.

Table 11. Case Study 2: Description of Task 4.

Task 4	Designing a KPI/KVI-Aware 5G/B5G Solution
Learning Hours	8 hours (0.5 lecture/instructor guidance + 4 practical in group + 3.5 independent)
Learning Outcomes	• Synthesize technical and societal indicators into a cohesive system proposal; • Collaborate on a design problem; • Communicate findings effectively.
Description	The task includes the following steps: 1. Join a 30-minute instructor-guided kick-off; 2. Form groups (3-5 students); 3. Consolidate KPI/KVI findings and architectural mappings; 4. Propose (a) a high-level 5G/B5G system architecture, (b) KPI/KVI-aware network policy suggestions, and (c) monitoring solutions for KPIs and KVIs; 5. Prepare (a) a 10-minute presentation, and (b) a final report (max 3 pages).

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Expected Outcomes	Group report and presentation
Prerequisites	Tasks 1, 2, and 3

4.2.5. Usage Guidelines and Examples for Case Study 2

The Case Study has been designed to be adaptable across a range of educational contexts, including semester-long university courses, short-term workshops, or independent learning modules. While the four tasks are logically structured to build upon each other, instructors may choose to use them either sequentially or in a modular way depending on the learning outcomes they wish to emphasize. For example, Tasks 1 and 2 could be used independently in a course focused on B5G/6G concepts or vertical use case analysis, while Tasks 3 and 4 are well-suited to advanced network architecture and design courses.

The Case Study is appropriate for both individual and collaborative learning: earlier tasks emphasize personal reflection and research, while the final task encourages teamwork and solution synthesis, making it ideal for PBL formats. When used in collaborative settings, tools such as shared documents, online discussion platforms, and collaborative diagrams (e.g., Miro, Google Jamboard) can enhance student interaction and coordination. For hybrid or asynchronous learning environments, the limited lecture content can be delivered through recorded videos or self-study materials, ensuring flexibility without sacrificing depth. Instructors are encouraged to adapt the task complexity based on the students' background, allowing the Case Study to serve both introductory and advanced levels of network education.

4.2.6. Resources and Materials for Case Study 2

The following is a curated and recommended list of resources that provide the foundational knowledge and technical background necessary to understand the Case Study and complete the assigned tasks. While these materials offer a strong starting point, we recommend instructors to encourage students to explore additional sources and build their own library of references to deepen their understanding and broaden their perspective on KPIs, KVIs, and B5G/6G system design in the context of the target use case.

- G. Wikström et al., "Key value indicators: A framework for values-driven next-generation ICT solutions," Telecommunications Policy, 48(6), 102778, 2024;
- Hexa-X Project, D1.1 "6G Vision, use cases, and key societal values";
- Hexa-X Project, D1.2 "Expanded 6G vision, use cases, and societal values";
- Hexa-X-II Project, D1.1 "Environmental, social, and economical drivers and goals for 6G";
- Hexa-X-II Project, D1.2 "6G use cases and requirements";
- Hexa-X-II Project, D1.3 "Environmental and social view on 6G";
- Hexa-X-II Project, Webinar "Key Values and Key Values Indicators";
- 6G-IA, "What societal values will 6G address? Societal Key Values and Key Value Indicators analysed through 6G use cases";
- O. L. Chávez et al., "A comparative case study of 2D, 3D and immersive-virtual-reality applications for healthcare education," International Journal of Medical Informatics, 141, 104226, 2020;
- B. Kizilkaya et al., "5G-enabled education 4.0: Enabling technologies, challenges, and solutions," IEEE Access, 9, 166962-166969, 2021;

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- M. Gapeyenko et al., "Standardization of extended reality (XR) over 5G and 5G-advanced 3GPP new radio," IEEE Network, 37, 4, 22-28, 2023;
- A. A. Esswie and M. Repeta, "Evolution of 3GPP standards towards true extended reality (XR) support in 6G networks," In 2023 IEEE International Black Sea Conference on Communications and Networking (BlackSeaCom), pp. 7-14. IEEE, 2023;
- S. Rajak et al., "Revolutionizing Healthcare with 6G: A Deep Dive into Smart, Connected Systems," IEEE Access, 12, 194150-194170, 2024;
- S. Kharche and J. Kharche, "6G Intelligent Healthcare Framework: A Review on Role of Technologies, Challenges and Future Directions," Journal of Mobile Multimedia, 19, 3 603-644, 2023.

4.2.7. Mapping of Case Study 2 to 5G-DiGITs Courses

With respect to the courses developed within the 5G-DiGITs Project, the Case Study is designed to support the learning framework of **"Introduction to Advanced 5G Technologies"** and **"Network Architecture and Protocols"** courses.

On the one hand, the learning outcomes of the Case Study map and extend the learning outcomes of both courses. On the other hand, both courses include Modules/Units relevant to the Case Study, as they are related to:

- **5G Applications and Use Cases**
  - "Introduction to Advanced 5G Technologies" – Module 3, Unit 3.1;
  - "Network Architecture and Protocols" – Module 1, Unit 1.3.
- **B5G/6G concepts and evolution**
  - "Introduction to Advanced 5G Technologies" – Module 3, Unit 3.2;
  - "Network Architecture and Protocols" – Module 4, Units 4.1 and 4.2.

KSA items covered by the Case Study also map with the KSA covered by the above courses:

Knowledge items covered by the Case Study

- From "Introduction to Advanced 5G Technologies" course:
  - Evolution of Mobile Communications;
  - Applications and Use Cases;
  - Challenges and Future Trends.
- From "Network Architecture and Protocols" course:
  - 5G Network Architecture;
  - 5G Protocols and Standards;
  - Towards 6G: Vision, Key Technologies, and Challenges;
  - Use Cases and Applications.

Skill items covered by the Case Study

- From "Introduction to Advanced 5G Technologies" course:
  - Understanding Wireless Network Evolution;
  - Knowledge of Key 5G Technologies;
  - Problem-Solving for 5G Deployment Challenges;
  - Practical Skills in 5G Network Analysis.
- From "Network Architecture and Protocols" course:
  - Analyse 5G network architectures.

Ability items covered by the Case Study

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- From "Introduction to Advanced 5G Technologies" course:
  - Analyse the Evolution of Wireless Networks;
  - Differentiate Between 5G Service Categories;
  - Assess 5G Applications in Various Industries.
- From "Network Architecture and Protocols" course:
  - Network optimization problem solving;
  - Research-oriented learning;
  - Collaboration and communication.

The allocation of learning hours (24 hours) for the Case Study accounts for up to 40% of the learning hours constituting a 5G-DiGITs course (60 hours, i.e., 2 ECTS). Therefore, when used in combination with one of the above courses, the Case Study can be used to either extend the learning hours or to replace parts (e.g., exercises, lab sessions, and presentations) of the target course, depending on how the instructor decides to leverage the provided material.

4.3. **Case Study 3 –** Designing and Evaluating Sustainable 5G Network Deployment Strategies

4.3.1. General Information on Case Study 3

General information on Case Study 3 is provided in Table 12.

Table 12. General Information for Case Study 3.

Case Study	Designing and Evaluating Sustainable 5G Network Deployment Strategies
Learning Outcomes	• Analyse energy consumption of 5G access and transport networks; • Design 5G rural sites powered by renewable and/or hybrid energy systems; • Optimize 5G urban rollouts to cut CO_2 emissions while maintaining QoS; • Apply Life-Cycle Assessment (LCA) and circular economy principles to network equipment selection, procurement, and end-of-life strategies; • Audit compliance with EU and national energy-efficiency regulations for telecom infrastructures; • Formulate policy and market-based incentives (tax credits, green bonds, etc.) that encourage green 5G deployments; • Balance environmental performance, total cost of ownership, and regulatory constraints in a techno-economic evaluation.
Total Learning Hours	**Lectures:** 8 hours **Practical Work:** 12 hours **Independent Study:** 10 hours **Total:** 30 hours
Prerequisites	• Fundamentals of 5G Radio Access Network (RAN) and Core Network; • Basics of electrical power systems and renewables (solar photovoltaic, wind, battery storage); • Introductory knowledge of sustainability concepts (carbon footprint, circular economy, LCA); • Familiarity with network planning and/or simulation tools (not mandatory).

4.3.2. Introduction to Case Study 3

This Case Study provides a real-world lens into the sustainable deployment of 5G networks, one of the most pressing challenges in the telecommunications field

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today. It is framed within Europe's twin digital-and-green transition, thus aligning with EU sustainability targets.

The scenario invites learners to tackle multidimensional challenges that blend technological design, energy efficiency, circular economy principles, life-cycle thinking, environmental policy, and strategic business planning, reflecting the complexity of 5G network planning and operation in both rural and urban contexts. By focusing on a fictional yet realistic national operator's need to deploy climate-neutral 5G infrastructures, students explore technical, regulatory, and strategic pathways to cut environmental impact without sacrificing service quality or cost-effectiveness.

Concretely, a fictional operator must craft, in less than a year, a nationwide plan that remains commercially viable while meeting stringent green targets. In this scenario, learners confront four intertwined decision fronts:

- **Rural challenge**: dimension off-grid macro sites where diesel is unacceptable and hybrid renewables must guarantee uptime;
- **Urban challenge**: optimise dense small-cell clusters in stadiums, rail hubs, and city districts to stay within CO_2 budgets;
- **Lifecycle challenge**: demonstrate circular economy compliance for radio, backhaul, and power components, from procurement to end-of-life;
- **Policy & finance**: unlock green-bond funding, tax credits, and spectrum-fee rebates, all conditional on audited sustainability KPIs.

The Case Study is readily adaptable to courses on energy-efficient 5G engineering, sustainable Information and Communication Technology (ICT) design, and circular economy thinking. Instructors can select tasks to match their learning objectives, delivery format, and workload.

Learning objectives include:

- Technical design of renewable-powered 5G deployments;
- Environmental and energy auditing;
- Regulatory and compliance knowledge;
- Business models and policy incentives for green technologies;
- LCA and circular economy applications in network design.

4.3.3. Detailed Description of Case Study 3

As 5G infrastructure deployments rapidly expand, network operators face increasing pressure to reduce carbon emissions, integrate renewable energy sources, and adopt lifecycle thinking. Previous solutions often relied on grid power or diesel generators in rural contexts, while dense urban deployments contributed significantly to energy consumption and environmental burden.

Given the above context, this Case Study addresses the challenges of a fictional national mobile network operator that is tasked with a large-scale 5G deployment strategy in alignment with the European Green Deal and national sustainability objectives. The aim is to design and implement an infrastructure that is not only technologically advanced but also meets energy efficiency standards, incorporates circular economy principles, and reduces environmental impact.

Scope and Stakeholders. The scenario covers both rural and urban areas and includes a broad range of stakeholders:

- Network infrastructure providers and equipment vendors;
- National regulatory authorities and public policy-makers;

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- Environmental Non-Governmental Organizations and citizens' advocacy groups;
- Academic researchers and consultants in sustainability and telecommunications;
- Local governments and municipalities;
- Equipment-financing institutions and supply-chain partners.

Challenges. Challenges addressed by the Case Study include:
- Limited or unreliable grid power at remote rural sites;
- High Capital Expenditure (CAPEX) and Operating Expenditure (OPEX) of hybrid renewable systems and storage;
- Circular economy integration in equipment procurement and vendor contracts;
- Absence of harmonised metrics for energy-intensity and recyclability;
- Regulatory fragmentation and weak incentives for green investments;
- Balancing network performance and sustainability KPIs in urban network densification.

These pain points encourage learners to weigh technical, economic, and policy trade-offs rather than seeking a single solution.

External References. To fully engage with this Case Study, students are expected to review and make reference to:
- EU Green Deal and Fit-for-55 legislation packages;
- ITU "Green ICT" guidelines and ITU-T L.1470 energy-efficiency recommendations;
- National 5G strategies and sustainability benchmarks;
- GSMA Mobile Net Zero & Green Future initiatives;
- Technical white papers on energy-efficient RAN design, LCA (ISO 14040/44), and circular procurement models.

These resources provide the necessary technical, regulatory, and strategic background to enable a thorough analysis and response to the problems posed in the learning tasks.

4.3.4. Learning/Training Tasks of Case Study 3

The Case Study is organized in eight tasks that guide learners from rural/urban energy-efficient network design to circular economy planning. Tasks can be run sequentially or selected depending on programme needs and/or time constraints. The learning-hour breakdown keeps the overall workload at 30 hours and aligns with information provided in Section 4.3.1.

As reported in Table 13, Task 1 explores rural connectivity and renewable energy technologies.

Table 13. Case Study 3: Description of Task 1.

Task 1	Designing Renewable Energy Solutions for Rural 5G Towers
Learning Hours	4 hours (1 lecture + 2 practical + 1 independent)
Learning Outcomes	• Design energy-efficient 5G systems using renewable sources; • Evaluate the feasibility of hybrid systems (e.g., solar + battery).
Description	The task includes the following steps: 1. Study a rural area with no access to grid electricity; 2. Identify renewable energy options (e.g., solar, wind) based on local climate; 3. Design a hybrid power system for a 5G network; 4. Analyse cost-benefit, sustainability metrics, and performance indicators.

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Expected Outcomes	Report (max 5 pages) detailing system design and performance evaluation
Prerequisites	None

In Task 2, students address the 5G environmental footprint in urban settings (see Table 14).

Table 14. Case Study 3: Description of Task 2.

Task 2	Developing Green Deployment Strategies for Urban 5G Networks
Learning Hours	4 hours (1 lecture + 2 practical + 1 independent)
Learning Outcomes	• Analyse energy consumption patterns in urban 5G deployments; • Propose modifications for environmental sustainability.
Description	The task includes the following steps: 1. Select a city area and collect/analyse data on planned or existing 5G rollouts; 2. Use modelling tools to assess energy consumption; 3. Recommend green modifications (e.g., smart scheduling, load balancing, renewable integration); 4. Quantify CO_2 reduction and energy savings.
Expected Outcomes	Presentation with comparative analysis (baseline vs. optimized solutions)
Prerequisites	Task 1

In Task 3, students explore concepts related to regulatory compliance and energy auditing for the 5G infrastructure, as further detailed in Table 15.

Table 15. Case Study 3: Description of Task 3.

Task 3	Regulatory Compliance and Energy Auditing in 5G Infrastructure
Learning Hours	3 hours (0.5 lecture + 1 practical + 1.5 independent)
Learning Outcomes	• Understand regulatory frameworks related to telecom energy use; • Perform auditing and benchmarking of energy performance.
Description	The task includes the following steps: 1. Study EU and national energy regulations for telecom networks; 2. Analyse the compliance of the given 5G deployments (fictional case); 3. Propose benchmarking and reporting mechanisms for the operator.
Expected Outcomes	Audit report with regulatory gap analysis and suggestions for improvement
Prerequisites	Task 2

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For Task 4, students step into the shoes of policy advisors, designing mechanisms to accelerate sustainable 5G adoption at a national scale (see Table 16).

Table 16. Case Study 3: Description of Task 4.

Task 4	Creating Policy and Market Incentives for Green 5G Adoption
Learning Hours	4 hours (1 lecture + 2 practical + 1 independent)
Learning Outcomes	• Design policies to support green 5G deployments; • Evaluate economic impact and feasibility of incentive schemes.
Description	The task includes the following steps: 1. Analyse successful green telecom incentive programs globally; 2. Draft a national strategy including subsidies, tax credits, or green bonds; 3. Simulate economic outcomes and environmental impact.
Expected Outcomes	Policy brief (max 3 pages) summarizing proposal with justifications
Prerequisites	Task 3

Task 5, detailed in Table 17, introduces students to green ICT principles and how they apply to 5G network infrastructure design and planning.

Table 17. Case Study 3: Description of Task 5.

Task 5	Evaluating Green ICT Principles in Network Planning
Learning Hours	3 hours (0.5 lecture + 1 practical + 1.5 independent)
Learning Outcomes	• Design policy-based mechanisms to support green 5G deployments; • Evaluate economic impact and feasibility of incentive schemes.
Description	The task includes the following steps: 1. Review foundational principles of green ICT; 2. Assess energy use in network components and data centres; 3. Identify strategies for reducing idle energy draw and improving performance.
Expected Outcomes	Analytical report summarizing energy impacts and design recommendations
Prerequisites	Basic knowledge of ICT systems and sustainability

Task 6 guides learners through the application of greed strategies in the design and assessment of 5G hardware (see Table 18).

Table 18. Case Study 3: Description of Task 6.

Task 6	Evaluating Green ICT Principles in Network Planning

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Learning Hours	4 hours (1 lecture + 2 practical + 1 independent)
Learning Outcomes	• Apply eco-design principles to 5G hardware; • Evaluate environmental impacts of design choices.
Description	The task includes the following steps: 1. Study component lifecycle and material sourcing; 2. Draft a 5G base station redesign considering recyclability and efficiency; 3. Justify design decisions based on the sustainability trade-off.
Expected Outcomes	Annotated design concept with sustainability rationale
Prerequisites	Familiarity with 5G architecture and eco-design concepts

As reported in Table 19, Task 7 focuses on developing student competencies in conducting a simplified LCA for alternative 5G deployment approaches.

Table 19. Case Study 3: Description of Task 7.

Task 7	**Life Cycle Assessment of 5G Infrastructure**
Learning Hours	4 hours (1 lecture + 2 practical + 1 independent)
Learning Outcomes	• Conduct a simplified LCA; • Identify key environmental hotspots in 5G deployment.
Description	The task includes the following steps: 1. Compare two 5G deployment strategies (e.g., macro vs. small cells); 2. Use LCA methodology to estimate environmental impacts; 3. Propose optimisations based on findings.
Expected Outcomes	Comparative LCA summary with impact visualisations
Prerequisites	Basic understanding of LCA frameworks

Task 8, as detailed in Table 20, explores how circular economy strategies can be implemented in managing the end-of-life phase of 5G infrastructure.

Table 20. Case Study 3: Description of Task 8.

Task 8	**Circular Economy Strategy for 5G Network End-of-Life**
Learning Hours	4 hours (1 lecture + 2 practical + 1 independent)
Learning Outcomes	• Design a circular economy plan for telecom equipment; • Assess trade-offs between reuse, recycling, and policy impacts.

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Description	The task includes the following steps: 1. Study end-of-life options for 5G components (e.g., base stations, core servers); 2. Propose a lifecycle extension strategy; 3. Assess regulatory and financial feasibility of implementation.
Expected Outcomes	Circular economy roadmap with implementation analysis
Prerequisites	Awareness of telecom lifecycle and circular economy basics

4.3.5. Usage Guidelines and Examples for Case Study 3

Instructors may select only a subset of the above tasks or combine them, depending on curriculum design. Given the modular nature of this Case Study and its suitability for online delivery, group work is optional.

The evaluation for this Case Study is designed to be adaptable, recognising that different instructors may include a subset of tasks based on their specific course focus or time constraints. Assessment can be both formative and summative, and should consider the following criteria:

- **Relevance and depth of technical analysis**: Accurate application sustainability principles, e.g., energy profiling, green technology selection, and/or LCA methodology;
- **Evidence-based decision making**: Use of data, tools, or literature to justify strategic, regulatory, and/or technical decisions;
- **Integration of sustainability concepts**: Clear demonstration of how environmental, economic, and policy factors are balanced;
- **Communication and reporting**: Professional presentation of findings in structured reports or policy briefs;
- **Innovation and creativity**: Particularly in open-ended design tasks.

To support implementation, each task includes the following tentative evaluation criteria that instructors may adapt or extend:

- **Task 1**: Evaluate feasibility analysis, clarity of design proposal, justification of energy system, and quality of data interpretation;
- **Task 2**: Assess the effectiveness of energy reduction strategy, innovation in network configuration, and use of simulation tools;
- **Task 3**: Examine the completeness of the audit, the relevance of selected KPIs, and the critical interpretation of compliance issues;
- **Task 4**: Evaluate policy coherence, balance between environmental and economic goals, and clarity of proposed incentive mechanisms;
- **Task 5**: Review data consistency, LCA boundary definition, and presentation of environmental footprint;
- **Task 6**: Consider lifecycle thinking, originality in redesign, feasibility of material changes, and circularity improvement;
- **Task 7**: Evaluate modelling accuracy, use of tools like OpenLCA, clarity of assumptions, and communication of trade-offs;
- **Task 8**: Assess comprehensiveness, relevance of end-of-life strategies, and cross-stakeholder integration.

Additional Tasks. To support further adaptation and customization of the Case Study, optional tasks are proposed in Table 21. These are not included in the core learning pathway but may be relevant for instructors seeking to deepen engagement with

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emerging technologies, stakeholder complexity, or comparative analyses. They are useful in contexts where interdisciplinary emphasis or future-oriented digital skills are desired. In summary, these task ideas can help extend the Case Study for capstone projects, advanced electives, or interdisciplinary modules.

Table 21. Optional Tasks for Case Study 3.

Optional Task (OT)	Title	Description
OT #1	ML/AI for Energy Optimisation in 5G Networks	Students explore how ML/AI-based solutions can be used to predict, analyse, and optimise energy consumption of 5G network components.
OT #2	Stakeholder Engagement Simulation	A role-playing or negotiation task involving regulators, citizens, operators, and Non-Governmental Organizations (NGOs) to simulate planning a 5G deployment with sustainability constraints.
OT #3	Comparative Sustainability Assessment	Learners conduct a simplified comparative LCA or techno-economic evaluation of 5G versus alternative broadband technologies (e.g., WiFi6) in specific deployment scenarios.

4.3.6. Resources and Materials for Case Study 3

To complete the learning tasks in this Case Study, students are expected to consult a mix of technical, regulatory, and strategic resources. These materials support critical learning outcomes and reflect the interdisciplinary nature of sustainable 5G network design.

The following list gathers the technical, regulatory, and analytical resources that students will need to tackle the eight learning tasks. Instructors may further extend/modify this list based on their own assessment and library.

- EU Commission, "European Green Deal";
- EU Commission, "EU Directive on Energy Efficiency";
- National digital transformation and sustainability strategies. An example is provided for Spain: "Digital connectivity in Spain, Digital Spain 2025";
- ITU-T Recommendation, "ITU-T L.1310: Energy efficiency metrics and measurement for telecom equipment";
- 3GPP Documentation, "3GPP TR 32.972: Study on energy saving techniques for 5G networks";
- ETSI Documentation, "ETSI EN 303 645: Cybersecurity and operational considerations in telecom systems";
- GSMA Future Network Report, "GSMA Mobile Net Zero";
- U. D. Maiwada et al., "Energy Efficiency in 5G Systems: A Systematic Literature Review," International Journal of Knowledge-Based and Intelligent Engineering Solutions, vol. 28, no. 1, 2024;
- A. Ichimescu et al., "Energy Efficiency for 5G and Beyond 5G: Potential, Limitations and Future Directions," Sensors, vol. 24, 2024;
- A. Vijay, "Enhanced Spectrum and Energy Efficiency in 5G Networks Using MIMO MC-CDMA with Deep-Learning-Based Resource Optimisation," Journal of Electrical Engineering & Technology, 2025;
- Ericsson Report, "Breaking the Energy Curve: Scaling up 5G While Reducing Total Network Energy," 2022;

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- Nokia White Paper, "5G Energy Efficiency Revolution," 2024;
- GSMA Report, "Mobile Net Zero – State of the Industry on Climate Action 2025".

Suggested Simulation and Analysis Tools

- RETScreen (Energy project feasibility analysis);
- HOMER (Hybrid system design);
- ns-3 (Open-source 5G network simulator).

Suggested LCA and Circular Economy Tools

- Product Environmental Footprint (PEF) methodology;
- OpenLCA software and Ecoinvent database;
- Circular Design Toolkit (Ellen MacArthur Foundation).

Suggested Open Datasets and Planning Tools

- Global Solar Atlas and Global Wind Atlas (World Bank);
- PVGIS, EU JRC Photovoltaic Geographical Information System.

Suggested Readings and Multimedia Resources

- Sustainability Courses (FutureLearn);
- GSMA, "The Net Zero Transition: The impact of 5G-Advanced on energy efficiency in enterprise markets," 2025;
- MWC'24 Barcelona panel, "Can Telcos Harness ESG for Sustainable Growth?", 2024.

4.3.7. Mapping of Case Study 3 to 5G-DiGITs Courses

With respect to the courses developed within the 5G-DiGITs Project, the present Case Study is designed to support the learning framework of **"Energy Efficiency and Sustainability in Advanced 5G Technologies"** and **"Green Skills for Beyond 5G Technologies"** courses.

On the one hand, the learning outcomes of the Case Study map and extend the learning outcomes of both courses. On the other hand, both courses include Modules/Units relevant to the Case Study, as they are related to:

- **Energy efficiency and sustainability in the telecom industry**
    - "Energy Efficiency and Sustainability in Advanced 5G Technologies" – Module 3, Units 3.1 and 3.2;
    - "Green Skills for Beyond 5G Technologies" – Module 1, Units 1.1 and 1.2.
- **Regulatory frameworks, business models, and LCA**
    - "Energy Efficiency and Sustainability in Advanced 5G Technologies" – Module 4, Units 4.1 and 4.2;
    - "Green Skills for Beyond 5G Technologies" – Module 4, Units 4.1 and 4.2.

KSA items covered by the Case Study also map with the KSA covered by the above courses:

Knowledge items covered by the Case Study

- From "Energy Efficiency and Sustainability in Advanced 5G Technologies" course:
    - Energy Consumption in 5G Networks;
    - Renewable Energy Integration;
    - Environmental Impact of 5G;
    - Policy and Regulatory Framework.
- From "Green Skills for Beyond 5G Technologies" course:

    - Fundamental Principles of Green ICT and Sustainability;
    - Emerging Technologies for Sustainable Networks;
    - Regulations and International Standards;
    - Energy Impact of ICT Infrastructure;
    - LCA Principles and Tools;
    - Circular Economy Principles;
    - Sustainable Data Centres and Cloud Computing;
    - Green Optimisation and Operations;
    - Economic Models for circular ICT Systems.

Skill items covered by the Case Study

- From “Energy Efficiency and Sustainability in Advanced 5G Technologies” course:
    - Analyse 5G Energy Consumption Data;
    - Implement Energy Efficiency Measures in Networks;
    - Evaluate Renewable Energy Solutions for 5G;
    - Optimise Energy Usage in Real-World 5G Deployments;
    - Conduct Energy Audits for 5G Operators.
- From “Green Skills for Beyond 5G Technologies” course:
    - Analyse the Environmental Impact of ICT Networks;
    - Implement Energy-Saving Techniques;
    - Apply Circular Economy Strategies;
    - Design Sustainable Telecom Solutions;
    - Evaluate Compliance with Standards;
    - Monitor and Report Sustainability Metrics;
    - Integration of AI and Automation in Sustainable ICT;
    - Collaborative Practices for Sustainability.

Ability items covered by the Case Study

- From “Energy Efficiency and Sustainability in Advanced 5G Technologies” course:
    - Advocate for Green Telecom Policies;
    - Integrate Sustainability into 5G Project Planning;
    - Collaborate Across Disciplines for Sustainable Telecom Development.
- From “Green Skills for Beyond 5G Technologies” course:
    - Assess and Mitigate Environmental Impacts;
    - Align with Circular Economy Goals;
    - Apply Sustainability Principles in Multidisciplinary Projects;
    - Translate Policy Goals into Technical Strategies;
    - Critically Evaluate Design Decisions;
    - Lead Innovation in Sustainable ICT;
    - Justify Infrastructure Choices Using LCA and Policy.

The allocation of learning hours (30 hours) for the Case Study accounts for slightly more than 40% of the learning hours constituting a 5G-DiGITs course (60 hours, i.e., 2 ECTS). Therefore, when used in combination with one of the 5G-DiGITs courses, the Case Study can be used to replace parts (e.g., exercises, lab sessions, and presentations) of the target course, depending on how the instructor decides to leverage the provided material. Some tasks may also be removed in order to decrease the learning hours to 24 hours.

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4.4. **Case Study 4 –** Leveraging Digital Skills for Intelligent 5G Network Management in Smart Cities

4.4.1. General Information on Case Study 4

General information on Case Study 4 is provided in Table 22.

Table 22. General Information for Case Study 4.

Case Study	Leveraging Digital Skills for Intelligent 5G Network Management in Smart Cities
Learning Outcomes	• Acquire advanced digital skills for working with 5G networks; • Apply data analytics, visualization, and ML/AI techniques to 5G contexts; • Understand cybersecurity challenges and solutions in 5G networks; • Design and evaluate intelligent 5G network architectures using digital tools; • Explore ethical and privacy issues in data-driven telecom services; • Translate data into decisions through interactive visualization platforms; • Use ML/AI and cybersecurity techniques to enhance 5G network performance.
Total Learning Hours	**Lectures:** 8 hours **Practical Work:** 12 hours **Independent Study:** 10 hours **Total:** 30 hours
Prerequisites	• Basic understanding of 5G architectures and protocols; • Introductory knowledge of data analytics tools (e.g., Python, Excel, or R); • Familiarity with concepts of network security and M/AI (introductory level).

4.4.2. Introduction to Case Study 4

Smart cities are rapidly adopting 5G networks as the backbone for public services such as autonomous transport, remote health monitoring, air-quality sensing, and emergency communications. These applications demand URLLC and robust cyber-security safeguards, making intelligent network management a critical skillset for future telecom professionals.

In this Case Study, learners step into the role of digital analysts and engineers working with a national network operator and a municipal authority to design, secure, and optimise 5G-enabled urban services. They will analyse live and/or synthetic telecom datasets, configure network slicing to meet diverse SLAs, detect anomalies with ML/AI techniques, and recommend mitigation measures against emerging threats. The scenario reflects key priorities of the European Digital Decade and the drive for trustworthy, sovereign digital infrastructures. By blending technical design with data-driven decision-making, the Case Study offers a realistic sandbox in which students practice data analytics, ML/AI, and privacy-aware service engineering, all essential capabilities for 5G/B5G/6G ecosystems.

Learning objectives include:

- Apply data-driven optimisation to 5G systems;
- Deploy and interpret real-time dashboards for operational insights;
- Build and evaluate ML/AI models for anomaly detection;
- Conduct cyber-security risk analyses and propose counter-measures;
- Integrate ethical and legal considerations into service design.

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4.4.3. Detailed Description of Case Study 4

As 5G networks become the backbone of smart city services, operators and municipalities face growing demands to keep services intelligent, secure, and resilient. Use cases such as autonomous transport, real-time public health monitoring, and energy/traffic optimization rely on responsive and adaptable 5G network designs. At the same time, soaring data volumes, rising cyber-threats, and the push for explainable, data-driven decision-making require professionals with advanced digital skills. Dashboarding and ML/AI are thus key in 5G operations.

This Case Study is set in the context of a national network operator collaborating with a regional smart city authority to deploy and manage 5G-based services, ranging from remote health monitoring and environmental sensing to autonomous mobility and smart traffic control. Students assume the role of digital engineers and analysts within a team responsible for designing, monitoring, securing, and evaluating services powered by 5G infrastructures. The initiative is part of a national programme to demonstrate how intelligent, secure, and efficient 5G services can enhance public life in urban areas. The Case Study thus reflects EU priorities for digital transformation, trust, and technological sovereignty, providing a sandbox in which learners explore and design 5G-enabled services through realistic, interdisciplinary tasks.

Scope and Stakeholders. The scenario combines technical innovation, operational analytics, and cyber-security preparedness within a multidisciplinary framework. It invites learners to design and evaluate solutions based on collected data, ensuring that performance, security, and ethical considerations are balanced effectively. The scenario focuses on the design and oversight of a 5G-enabled smart city service platform, involving the following key stakeholders:

- National and regional telecom operators;
- Smart city authorities and urban planners;
- Digital service providers and ML/AI developers;
- Cybersecurity consultants and data protection officers;
- Citizens and end-users interacting with 5G-enabled services.

Challenges. Challenges addressed by the Case Study include:

- Managing multiple service and corresponding 5G network slices with diverse latency, bandwidth, and availability requirements;
- Visualising high-volume monitored data for real-time insights;
- Detecting anomalies and cyber-threats using ML/AI techniques;
- Aligning service design with ethical, privacy, and security requirements;
- Reporting findings in formats accessible to technical and non-technical stakeholders.

External References. To fully engage with this Case Study, students are expected to review:

- European Digital Strategy & Digital Decade targets;
- ENISA Guidelines on 5G cyber-security;
- ETSI specifications on 5G network slicing and orchestration;
- Network operator reports and open 5G datasets;
- Documentation related to data analysis, ML/AI application in mobile systems, and dashboarding tools (e.g., Python, R, Grafana).

4.4.4. Learning/Training Tasks of Case Study 4

The Case Study is organized into six tasks aligned with digital skills for 5G-enabled services. Learners may tackle the tasks sequentially or select those most relevant to their programme.

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Task 1, detailed in Table 23, introduces learners to digital platforms and tools used in managing 5G-enabled services. Students will explore data lifecycle in telecom systems and examine how visualization and analysis frameworks support operational decisions.

Table 23. Case Study 4: Description of Task 1.

Task 1	Exploring the Digital Tools Behind 5G Smart Services
Learning Hours	5 hours (1 lecture + 2 practical + 2 independent)
Learning Outcomes	• Understand the role of digital tools and data pipelines in 5G-enabled services; • Acquire familiarity with data visualization platforms and monitoring tools.
Description	The task includes the following steps: 1. Identify at least two smart city services; 2. Identify the data to collect and how they should be processed; 3. Explore visualisation platforms used to monitor service performance; 4. Produce a conceptual map showing how digital tools support service monitoring and delivery.
Expected Outcomes	Infographic and short presentation that map tools to service functionalities
Prerequisites	Familiarity with digital data workflows and an interest in smart city services

Task 2 (Table 24) helps students explore how dashboards support decision-making by allowing them to visualize and interpret performance data from 5G-enabled smart city services.

Table 24. Case Study 4: Description of Task 2.

Task 2	Designing Dashboards to Monitor 5G Network Performance
Learning Hours	5 hours (1 lecture + 2 practical + 2 independent)
Learning Outcomes	• Create interactive dashboards for real-time monitoring of 5G services; • Interpret 5G KPIs to support operational decision-making in smart city contexts.
Description	The task includes the following steps: 1. Select a 5G-enabled smart city application; 2. Identify the most relevant KPIs for that service; 3. Use a tool (e.g., Grafana, Power BI, Tableau) to create a user interface; 4. Provide a brief explanation of the visual choices and data interpretation.
Expected Outcomes	Interactive dashboard with a short explanatory report
Prerequisites	Basic understanding of KPIs, spreadsheet tools, and visualization concepts

Task 3, as described in Table 25, introduces students to the use of ML models to analyse large volumes of 5G data and uncover hidden insights about service usage and network behaviours.

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Table 25. Case Study 4: Description of Task 3.

Task 3	Using Machine Learning to Detect Traffic Patterns in 5G Networks
Learning Hours	5 hours (1.5 lecture + 2 practical + 1.5 independent)
Learning Outcomes	• Apply supervised or unsupervised ML techniques to analyse 5G network data; • Identify network usage profiles and performance anomalies using Python tools.
Description	The task includes the following steps: 1. Load and pre-process a dataset with 5G traffic information (logs or metrics); 2. Choose an appropriate ML model and train it; 3. Analyse the results and interpret clusters or anomalies of network behaviour; 4. Document the process and discuss potential applications.
Expected Outcomes	Notebook with model output and short analysis
Prerequisites	Familiarity with AI/ML software libraries (e.g., based on Python) and introductory ML concepts

Task 4 guides students through identifying cybersecurity threats in 5G services and proposing mitigation strategies using common threat modelling techniques (see Table 26).

Table 26. Case Study 4: Description of Task 4.

Task 4	Analysing Cybersecurity Risks in 5G Smart City Scenarios
Learning Hours	5 hours (1.5 lecture + 2 practical + 1.5 independent)
Learning Outcomes	• Perform a high-level threat and risk assessment for 5G-based services; • Propose mitigation strategies aligned with cybersecurity standards.
Description	The task includes the following steps: 1. Choose a 5G-based smart city service; 2. Identify potential cybersecurity threats and vulnerabilities; 3. Complete a risk assessment using a matrix or framework (e.g., STRIDE); 4. Suggest risk mitigation strategies for the most relevant threats.
Expected Outcomes	Risk matrix and summary policy brief
Prerequisites	Basic understanding of cybersecurity principles and 5G architectures

Task 5 challenges learners to design a network slicing architecture for multiple smart city services with different technical requirements (see Table 27).

Table 27. Case Study 4: Description of Task 5.

Task 5	Designing a 5G Network Slicing Strategy for Urban Applications
Learning Hours	5 hours (1 lecture + 2 practical + 2 independent)

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Learning Outcomes	• Design and evaluate a 5G slicing strategy for differentiated digital services; • Match service requirements with technical slicing configurations.
Description	The task includes the following steps: 1. Select three smart city services with different network needs; 2. Define key technical requirements for each one; 3. Design a slicing configuration that accommodates these services; 4. Justify your slicing strategy with a brief technical explanation.
Expected Outcomes	Diagram of slicing architecture and rationale report
Prerequisites	Basic knowledge of 5G slicing and network design principles

Task 6 helps students apply AI techniques to detect anomalies in 5G-enabled smart city operations and design a basic incident response workflow (see Table 28).

Table 28. Case Study 4: Description of Task 6.

Task 6	Using AI for Anomaly Detection and Response in 5G Networks
Learning Hours	5 hours (1 lecture + 2 practical + 2 independent)
Learning Outcomes	• Implement AI-based anomaly detection to identify faults/incidents in 5G data; • Design an incident response workflow for smart city network administrators.
Description	The task includes the following steps: 1. Analyse a dataset containing simulated 5G service performance or logs; 2. Apply an AI model to detect anomalies; 3. Create visual or textual indicators of detected issues; 4. Propose a simplified incident response plan for city-level deployment.
Expected Outcomes	Detection model output, dashboard or report, and response diagram
Prerequisites	Familiarity with AI/ML software libraries (e.g., based on Python), introductory AI knowledge, and familiarity with time-series and/or log data

4.4.5. Usage Guidelines and Examples for Case Study 4

All the above tasks are modular. Instructors may run them sequentially as a 30-hour mini-course, or select the ones to embed in existing modules. Each activity can be delivered online or in-person, and can switch between individual and team-based formats by adjusting deliverables (e.g., solo notebooks vs. group presentations).

Each task includes specific performance expectations related to technical accuracy, analytical depth, tool proficiency, and ability to communicate complex digital concepts clearly. As the Case Study may be implemented in diverse settings and integrated differently into the curriculum, the assessment methods are indicative and may be adapted by the instructor. General assessment dimensions should include:

- **Technical proficiency**: Effective use of tools for solving 5G-related problems;

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- **Problem-solving and innovation**: Creativity in approaching smart service design, optimisation, and troubleshooting;
- **Interpretation and visual communication**: Quality of dashboards, diagrams, and written reports that convey insights clearly;
- **Security awareness and compliance**: Demonstrated understanding of risks, mitigation strategies, and ethical frameworks;
- **Data-driven decision-making**: Sound use of analytics, ML/AI, and visualisation tools.

Additional Tasks. To support future expansion and adaptation of this Case Study, instructors may wish to consider integrating one or more of the additional tasks reported in Table 29. These proposals are designed to foster forward-thinking, multidisciplinary engagement and provide opportunities for learners to apply their digital skills in novel, industry-relevant contexts.

Table 29. Optional Tasks for Case Study 4.

Optional Task (OT)	Title	Description
OT #1	Ethics and Bias in ML/AI-Driven 5G Services	Students identify ethical concerns that may arise in ML/AI models deployed within smart city infrastructures. They analyse datasets for imbalance, reflect on algorithmic transparency, and propose mitigation strategies.
OT #2	Data Privacy by Design in Urban 5G Networks	Learners examine how personal data (e.g., health, mobility, location) is handled by smart city applications. They assess GDPR implications and propose privacy-preserving mechanisms in system design and data management.
OT #3	Digital Twin Simulation for Urban Service Planning	Students create a simplified digital twin of a 5G-enabled smart service (e.g., public lighting, traffic). Using basic simulation environments, they explore system behaviour under different usage scenarios and network conditions.
OT #4	Federated Learning for Edge Devices	Students experiment with federated learning to train ML/AI models across distributed 5G edge devices, evaluating energy savings and data privacy trade-offs.
OT #5	Cybersecurity Threat Modelling for 5G Applications	Learners identify and simulate cyber threat scenarios in 5G-enabled applications (e.g., healthcare, autonomous vehicles), proposing mitigation strategies and safeguards.
OT #6	Data Visualisation Dashboard for Smart City KPIs	Students build an interactive dashboard integrating data from smart city sensors (e.g., traffic, pollution, energy) for real-time analysis and public engagement.
OT #7	Cybersecurity Audit of a 5G Edge Deployment	Students assess the cybersecurity of a 5G network that uses edge computing. They identify key vulnerabilities, evaluate threat vectors, and propose realistic mitigation strategies. As an extension, they may simulate a basic intrusion or breach to validate defences.
OT #8	Real-Time Analytics for Smart Campus 5G Operations	Learners analyse streaming data from a simulated smart campus 5G deployment. They develop dashboards and alerts for monitoring service availability, balancing loads, and detecting operational anomalies in real time.

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4.4.6. Resources and Materials for Case Study 4

The following resources and tools are suggested to support the implementation of the Case Study and allow students to experiment with real-world platforms used in the field of 5G technologies and data analytics.

Technical standards and specifications

- 3GPP, "TS 23.501, System architecture for the 5G core";
- 3GPP, "TS 23.502, Procedures for the 5G core";
- 3GPP, "TR 32.972, Energy-saving techniques for 5G OAM";
- ETSI, "EN 303 645, Cyber-security for consumer IoT";
- ETSI, "ZSM 001, Zero-touch management requirements";
- ETSI, "ZSM 002, Zero-touch reference architecture";
- ITU-T, "Y.3111, Network management & slicing";
- ITU-T, "Y.3130, Fixed-mobile convergence in 5G".

Suggested Cyber-security and risk-management frameworks

- ENISA Threat Landscape for 5G Networks;
- MITRE ATT&CK Matrix;
- NIST SP 800-207 – Zero-Trust Architecture.

Suggested open-source tools and platforms

- Python (with Jupyter Notebooks): Software for data pre-processing and ML/AI modelling;
- Kibana / Grafana: Open-source dashboarding tools;
- Wireshark: Network-level packet inspection/analysis;
- Mininet-WiFi / GNS3 / Open5GS: Network emulation platforms (e.g., for testing 5G network slicing;
- Kaggle / Google Colab: Environments to access open datasets, test code, and collaborate on ML/AI and visualisation tasks in the cloud;
- MITRE ATT&CK: A framework to help students simulate realistic threat scenarios and mitigation strategies in 5G networks.

Suggested public datasets and sandboxes

- TU Darmstadt 5G-Core Networks Datasets;
- OpenCellID;
- Kaggle Telco Customer Churn;
- Kaggle Network Traffic Anomaly Detection.

Suggested multimedia tutorials & MOOCs

- Coursera MOOC: Business Considerations for 5G with Edge, IoT & AI;
- Coursera MOOC: 5G for Everyone;
- YouTube Playlist: Grafana for Telco Monitoring.

4.4.7. Mapping of Case Study 4 to 5G-DiGITs Courses

With respect to the courses developed within the 5G-DiGITs Project, the present Case Study is particularly designed to support the learning framework of the **"Digital Skills for Beyond 5G Technologies"** course.

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On the one hand, the learning outcomes of the Case Study map and extend the learning outcomes of the above course. On the other hand, the course includes Modules/Units relevant to the Case Study, as they are related to:

- **Advanced digital skills for working with 5G technologies**
    - Modules 1 to 3, Units 1.1 to 3.2;

KSA items covered by the Case Study also map with the KSA covered by the above course:

Knowledge items covered by the Case Study

- Fundamentals of 5G and Beyond 5G Technologies;
- Data Analytics and Visualisation in 5G;
- ML/AI Applications in 5G;
- Cybersecurity in 5G Networks;
- IoT and Edge Computing in 5G Ecosystems;
- Network Slicing and Virtualisation in 5G;
- Cloud Computing and 5G.

Skill items covered by the Case Study

- Data Visualisation for 5G Networks;
- Implementing ML/AI in 5G;
- Securing a 5G Network;
- Setting Up and Managing Virtualised 5G Environments;
- Configuring IoT Devices in 5G Networks;
- Troubleshooting 5G Network Issues;
- Cloud Integration for 5G Applications.

Ability items covered by the Case Study

- Designing a Secure and Scalable 5G Infrastructure;
- Optimising 5G Networks Using AI;
- Integrating IoT, AI, and Edge Computing in 5G;
- Evaluating Cybersecurity Threats in 5G;
- Analysing Industry-Specific 5G Applications.

The allocation of learning hours (30 hours) for the Case Study accounts for slightly more than 40% of the learning hours constituting a 5G-DiGITs course (60 hours, i.e., 2 ECTS). Therefore, when used in combination with one of the above courses, the Case Study can be used to replace parts (e.g., exercises, lab sessions, and presentations) of the target course, depending on how the instructor decides to leverage the provided material. Some tasks may also be removed in order to decrease the learning hours to 24 hours.

4.5. **Case Study 5 –** Optimizing Urban Mobility with Edge-Enabled 5G Solutions: A Minimum Viable Product Approach

4.5.1. General Information on Case Study 5

General information on Case Study 5 is provided in Table 30.

Table 30. General Information for Case Study 5.

Case Study	**Optimizing Urban Mobility with Edge-Enabled 5G Solutions**

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Learning Outcomes	• Explore user-centred design in developing smart city solutions; • Apply lean and iterative methods to create and validate Minimum Viable Products (MVPs) for connected mobility services; • Understand how edge computing enhances performance in urban mobility services using 5G networks; • Analyse scalability and go-to-market considerations for 5G-based applications.
Total Learning Hours	**Lectures:** 3 hours **Practical Work:** 11 hours **Independent Study:** 10 hours **Total:** 24 hours
Prerequisites	• Basic understanding of 5G systems and edge computing architectures; • Familiarity with MVP design and user research.

4.5.2. Introduction to Case Study 5

This Case Study introduces students to a fast-growing opportunity space: using 5G networks jointly with edge computing to design smarter urban mobility solutions. By focusing on a real-life problem (e.g., shared vehicle services or pedestrian safety), learners apply creative problem-solving and entrepreneurial thinking to design a Minimum Viable Product (MVP) solution. The Case Study mirrors early-stage innovation settings, where teams validate assumptions quickly, engage stakeholders meaningfully, and articulate a compelling value proposition. It emphasizes lean startup methodology, design thinking, and user-centric MVP design rather than deep technical development.

Learners will work individually or in small groups to identify specific pain points in an urban district, explore how 5G and edge computing could enable real-time responsiveness, and outline a lightweight MVP concept that addresses the issue. The process includes problem framing, solution sketching, and idea communication through a short pitch.

Learning objectives include:

- Identify and define a user-centric problem in an urban mobility scenario;
- Apply design thinking to generate solution ideas;
- Develop and articulate a clear MVP concept using lean tools;
- Understand the value of 5G and edge computing in time-critical urban services;
- Communicate business value and impact potential of MVP solutions.

4.5.3. Detailed Description of Case Study 5

Urban areas often suffer from disconnected transport modes, inefficient data usage, and lack of responsive services. New 5G and edge computing technologies promise faster decision-making and smoother integration of real-time services by processing data closer to the point of action (e.g., on a traffic light or scooter station instead of a central server). However, many solutions fail because they do not focus on actual user needs and co-creation with stakeholders.

This Case Study is set in the context of a mid-sized European city that is developing a new digital mobility solution to address growing urban congestion, public transport inefficiencies, and increased environmental concerns. City authorities and innovation stakeholders are exploring how 5G and edge computing can improve the way people move through high-density areas such as business districts, university areas, or tourist centers.

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Students take on the role of an entrepreneurial team tasked with designing a Minimum Viable Product (MVP) solution for a smart urban mobility service that uses edge-enabled 5G deployments. The focus is on user needs discovery, value proposition design, and rapid prototyping. Technical complexity is kept at a conceptual level, allowing participants to concentrate on problem-solution fit, stakeholder mapping, and early-stage business model development.

Scope and Stakeholders. The MVP design considers a limited pilot serving one specific district or use case, such as:

- Smart e-bike docking stations with real-time availability;
- Adaptive traffic lights reducing wait time for buses;
- Dynamic rerouting of shared e-scooters in crowded areas.

The scenario involves the following stakeholders:

- City transport and smart city departments;
- Public transit users, cyclists, and pedestrians;
- Local startups, edge network operators, and software vendors;
- Citizen user groups and city innovation labs.

Challenges. Challenges addressed by the Case Study include:

- Identify a specific user problem within urban mobility;
- Propose a simple, testable MVP solution that leverages 5G and edge computing without overengineering;
- Map early adopters and core stakeholders;
- Sketch basic user flows and interfaces;
- Prepare a short pitch with assumptions, metrics, and next steps.

External References. To fully engage with this Case Study, students should read, analyse, and review the documentation provided in Section 4.5.5.

4.5.4. Learning/Training Tasks of Case Study 5

The Case Study is organized in three tasks that guide learners through identifying urban mobility challenges, designing 5G/edge-enabled MVP solutions, and preparing a basic business plan. Tasks can be conducted sequentially or adapted independently depending on program structure. The full workload aligns with the 24-hour reference guideline for the 5G-DiGITs Project.

Task 1, detailed in Table 31, introduces learners to urban mobility challenges.

Table 31. Case Study 5: Description of Task 1.

Task 1	**Identifying Urban Mobility Challenges for 5G-Edge Solutions**
Learning Hours	8 hours (1 lecture + 4 practical + 3 independent)
Learning Outcomes	• Investigate real-world urban mobility issues suited for 5G/edge applications; • Conduct contextual analysis of traffic, safety, or service inefficiencies.
Description	The task includes the following steps: 1. Review key mobility challenges in EU cities (e.g. congestion, school zone safety, accessibility);

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	2. Select a specific service area (e.g. a busy transport hub or medical zone); 3. Define a clear problem statement with relevant pain points and user needs.
Expected Outcomes	3-page problem statement with rationale
Prerequisites	None

Task 2, detailed in Table 32, requires learners to design and validate an MVP solution.

Table 32. Case Study 5: Description of Task 2.

Task 2	**MVP Solution Design and User-Centric Validation**
Learning Hours	8 hours (1 lecture + 4 practical + 3 independent)
Learning Outcomes	• Translate the urban challenge identified in the previous task into an MVP solution design that leverages 5G and edge computing solutions; • Describe latency, data flow, and user privacy elements in the solution; • Apply user feedback techniques to validate the MVP solution design.
Description	The task includes the following steps: 1. Design an MVP solution using 5G and edge computing; 2. Map data flows and latency expectations based on user interaction; 3. Define what data is processed, where (edge/cloud), and why; 4. Run a mock user validation (interviews, peer review, etc.) and revise.
Expected Outcomes	System architecture diagram with 3-page explanatory note including user feedback
Prerequisites	Task 1

Task 3, detailed in Table 33, requires learners to implement a business model and a deployment plan for the solution identified in Task 2.

Table 33. Case Study 5: Description of Task 3.

Task 3	**Business Model and Deployment Plan**
Learning Hours	8 hours (1 lecture + 3 practical + 4 independent)
Learning Outcomes	• Define value proposition and business model; • Prepare a pilot deployment plan considering key stakeholders and constraints.
Description	The task includes the following steps: 1. Draft a Lean or Business Model Canvas for the MVP solution; 2. Identify key partners (e.g. transport authorities, tech vendors); 3. Outline a roadmap for pilot deployment including initial go-to-market considerations, risks, and KPIs.
Expected Outcomes	Completed Lean Canvas + a short 3-slide pitch + 1/2-page pilot deployment and scale-up plan

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Prerequisites	Task 2

4.5.5. Usage Guidelines and Examples for Case Study 5

The Case Study is designed with flexibility in mind to support different instructional formats, whether in-person, hybrid, or online. Educators may choose to deliver all three tasks sequentially or select specific ones depending on course goals and time availability. Tasks can be used for individual work, team collaboration, or as part of PBL workshops.

Assessment and Evaluation Strategy. The evaluation should be primarily formative, with a summative component if used in formal academic settings. Learners are expected to engage in practical, real-world problem solving, with emphasis placed on applying entrepreneurial methods and MVP development principles. Assessment criteria may include:

- **Clarity of problem identification**: Precision in framing an urban mobility issue with measurable goals;
- **Practicality and logic of MVP architecture**: Soundness of 5G and edge computing usage, including KPI management (e.g., latency) and privacy considerations;
- **User-centric thinking**: Integration of feedback loops and design for diverse user needs;
- **Business model coherence**: Clear value proposition, stakeholder fit, and scalability plan;
- **Presentation and communication**: Professional visuals, diagrams, and explanations;
- **Creativity and innovation**: Originality in approaching the scenario and selecting emerging technologies.

To facilitate the assessment, the following tentative evaluation criteria are proposed:

- **Task 1**: Evaluate the relevance of the selected mobility challenge, clarity of the problem statement, and appropriateness of indicators and contextual analysis;
- **Task 2**: Assess the logic of system architecture, understanding of 5G and edge computing benefits (latency, privacy, data flow), and integration of user feedback;
- **Task 3**: Evaluate the coherence of the business model and pitch, feasibility of the deployment roadmap, and alignment of KPIs and stakeholder mapping.

The above criteria aim to help instructors designing a clear grading system aligned with entrepreneurial and technical learning outcomes. Instructors may extend them to include:

- Presentation quality;
- Use of visual tools (e.g., canvas, diagrams);
- Teamwork and collaboration (if the Case Study is used in group settings).

4.5.6. Resources and Materials for Case Study 5

Students are expected to consult a mix of technical, entrepreneurial, and regulatory resources. These materials support the interdisciplinary goals of the Case Study, combining 5G and edge technologies, mobility innovation, and MVP-based development. The list below includes recommended technical standards, urban innovation frameworks, design tools, and entrepreneurial planning resources. Instructors may replace with different materials based on the educational context in which the Case Study is used.

Technical Reports and Standards

- ETSI MEC 003: Multi-access Edge Computing – Framework and Reference Architecture;
- 3GPP TR 22.886: Study on Communication for Automation in Vertical Domains;
- GSMA Edge Cloud White Paper;

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- IEEE P1931.1: Standard for Edge/Fog Computing Reference Architecture**.

Smart Mobility and Urban Innovation Policies

- Urban Mobility Framework – European Commission;
- EU Smart Cities Marketplace;
- EIT Urban Mobility Strategic Agenda 2021–2027;
- National Transport Master Plan – Malta (replace with local version if applicable) ;
- OECD – The Innovation Systems of Smart Cities (2022).

Academic and Industry White Papers

- McKinsey – Smart Cities: Digital Solutions for a More Livable Future;
- ETSI White Paper (2019) — Enabling Multi-access Edge Computing in IoT .

Suggested Entrepreneurial Tools and MVP Resources

- Lean Startup Toolkit – Strategyzer;
- Business Model Canvas – Osterwalder & Pigneur;
- EIT Urban Mobility Marketplace.

Suggested MVP Design & Testing Tools

- Figma: UI/UX design for web and mobile prototypes;
- Miro: Collaborative whiteboarding and customer journey mapping;
- Canva: MVP pitch decks, flyers, and UI prototypes;
- Thunkable / Glide Apps: No-code app builders for early MVPs.

Suggested User Testing and Feedback Tools

- Typeform: Interactive surveys and feedback collection;
- Useberry: Test prototypes built in Figma, Adobe XD, etc.;
- Lookback.io: Live MVP feedback and recording sessions.

Suggested Urban Tech and 5G-Mobility Simulation (Optional Advanced Tools)

- FlowOS: EIT Urban Mobility partner tool for logistics MVPs;
- MATSim: Open-source transport simulation toolkit;
- ns-3: 5G network simulator.

Suggested Readings and Multimedia

- "FutureLearn – Design Thinking for Sustainable Cities". Online course introducing sustainable urban solutions through the lens of design thinking;
- "EIT Urban Mobility Academy". Materials on mobility, innovation, and entrepreneurship;
- Podcast: "The Smart Community Podcast (Smart City Chronicles)". Interviews with innovators in the smart cities and mobility space;
- TED Talk: "Creating Smarter Cities Through Connectivity and Data". Carlo Ratti's TED Talk on using data and connectivity to design better urban environments.

4.5.7. Mapping of Case Study 5 to 5G-DiGITs Courses

This Case Study directly supports the development of practical entrepreneurial and innovation skills in early-stage 5G venture creation. It fits especially well with courses focused on ideation, user research, MVP-based development, and open innovation collaboration. With respect to the courses developed within the 5G-DiGITs Project, the Case Study is designed to support the learning framework of **"Entrepreneurship and Innovation in Advanced 5G Technologies"** and **"Entrepreneurial Skills for Beyond 5G Technologies"** courses.

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On the one hand, the learning outcomes of the Case Study map and extend the learning outcomes of both courses. On the other hand, the courses include Modules/Units relevant to the Case Study, as they are related to:

- **Innovation in the 5G/B5G landscape**
  - "Entrepreneurship and Innovation in Advanced 5G Technologies" – Module 1, Unit 1.2;
  - "Entrepreneurial Skills for Beyond 5G Technologies" – Module 1, Unit 1.1;
  - "Entrepreneurial Skills for Beyond 5G Technologies" – Module 1, Unit 1.2.
- **Building and funding a 5G Startup:**
  - "Entrepreneurial Skills for Beyond 5G Technologies" – Module 2, Unit 2.1;
  - "Entrepreneurial Skills for Beyond 5G Technologies" – Module 2, Unit 2.2.

KSA items covered by the Case Study also map with the KSA covered by the above courses:

Knowledge items covered by the Case Study

- From "Entrepreneurship and Innovation in Advanced 5G Technologies" course:
  - Turning Ideas into Products;
  - Innovation and Opportunity Mapping;
  - Market Analysis and Customer Discovery.
  - Business Models.
- From "Entrepreneurial Skills for Beyond 5G Technologies" course:
  - Innovation Tools and Frameworks;
  - 5G Market Dynamics;
  - Stakeholder Ecosystems.

Skill items covered by the Case Study

- From "Entrepreneurship and Innovation in Advanced 5G Technologies" course:
  - Ideation tools;
  - Market research methodology;
  - Customer validation;
  - Business Model tools;
  - Go-To-Market Planning;
  - Entrepreneurial Pitching.
- From "Entrepreneurial Skills for Beyond 5G Technologies" course:
  - Ideation and Creativity;
  - Cross-Disciplinary Collaboration;
  - Leadership and Delegation.

Ability items covered by the Case Study

- From "Entrepreneurship and Innovation in Advanced 5G Technologies" course:
  - Navigate Innovation Ecosystems;
  - Iterate Based on Feedback;
  - Design and Defend a Startup Plan.
- From "Entrepreneurial Skills for Beyond 5G Technologies" course:
  - Turn ideas into validated solutions;
  - Operate in agile venture teams.

The allocation of learning hours (24 hours) for the Case Study is designed to account for up to 40% of the learning hours constituting a 5G-DiGITs course (60

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hours, i.e., 2 ECTS). Therefore, when used in combination with one of the above courses, the Case Study can be used to either extend the learning hours or to replace parts (e.g., exercises, lab sessions, and presentations) of the target course, depending on how the instructor decides to leverage the provided material.

4.6. **Case Study 6 –** Strategic Intellectual Property and Tech Transfer in 5G: Startup Case Studies

4.6.1. General Information on Case Study 6

General information on Case Study 6 is provided in Table 34.

Table 34. General Information for Case Study 6.

Case Study	Strategic Intellectual Property and Tech Transfer in 5G: Startup Case Studies
Learning Outcomes	• Understand the role of Intellectual Property (IP) in technology-based ventures; • Evaluate different forms of IP and their applicability in 5G-related ventures; • Explore the intersection of IP strategy, standardization, and global competition; • Analyze commercialization and licensing models for 5G patents.
Total Learning Hours	**Lectures:** 3 hours **Practical Work:** 11 hours **Independent Study:** 10 hours **Total:** 24 hours
Prerequisites	• Basic understanding of 5G system architecture; • Basic understanding of patent systems and business strategy frameworks.

4.6.2. Introduction to Case Study 6

This Case Study introduces students to the strategic use of Intellectual Property (IP) in the fast-evolving 5G ecosystem. With 5G technologies generating thousands of patents worldwide, startups need to understand how to protect and monetize their innovations to stay competitive.

Through practical team-based tasks, students will step into the shoes of a new 5G venture and design an IP strategy that supports growth, avoids legal risks, and creates value through licensing or partnerships. They will also explore how global market dynamics, regulation, and litigation risks affect IP decisions.

Learning objectives include:

- Understand the role of IP in the development and commercialization of 5G technologies;
- Differentiate between various forms of IP protection (e.g., patents, trade secrets) and determine their strategic application in startup contexts;
- Design an initial IP and tech transfer roadmap for a fictional 5G startup, considering commercialization and competitive positioning;
- Identify and evaluate IP risks and litigation threats in global markets relevant to 5G;
- Simulate a basic licensing negotiation, considering standard essential patents (SEPs), Fair, Reasonable, and Non-Discriminatory (FRAND) terms, and cross-border IP dynamics;
- Collaborate across disciplines (tech, legal, business) to integrate IP strategy into broader go-to-market planning.

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4.6.3. Detailed Description of Case Study 6

As 5G patents become central to market dominance, startups must act strategically when it comes to protecting, transferring, and monetizing their innovations, by quickly adopting IP strategies aligned with SEPs, licensing frameworks (e.g., FRAND), and cross-border compliance. Simultaneously, research-based startups and Technology Transfer Offices (TTOs) of universities involved in research face increasing pressure to deliver value through effective IP management.

This Case Study is situated in the context of a high-tech startup entering the competitive 5G telecommunications landscape. Students will take on the role of an innovation advisory team supporting WaveCore, a fictional early-stage startup developing edge-enabled 5G base station modules with AI-assisted energy optimization. The company must navigate IP filings, licensing options, and tech transfer strategies while positioning itself for expansion and partnerships. Rather than focusing on legal theory, the Case Study emphasizes strategic IP planning, stakeholder engagement, and scenario-based problem-solving for real-world applications.

Scope and Stakeholders. Students will evaluate the strategic options for IP protection and tech transfer for WaveCore's core technologies. The Case Study is constrained to two priority markets: the EU and East Asia. In this context, WaveCore's key stakeholders include:

- Founders and engineering team;
- University tech transfer office (IP co-owner);
- Industry standardization bodies (e.g., 3GPP);
- Potential corporate licensors (equipment manufacturers or telcos);
- Public funders and early-stage investors;
- Potential initial customers and end-users;
- Emerging competitors (indirect stakeholders in shaping IP strategy).

The team must also consider partners in R&D consortia and standard-setting forums who influence patent essentiality and IP pooling.

Challenges. WaveCore's main challenge is typical of EU-based startups emerging from research consortia and aiming to scale internationally. The startup holds a provisional patent and plans to join standardization efforts, but must also secure funding and prepare to negotiate licensing agreements with multinational players. Specific challenges addressed by the Case Study include:

- Select the most appropriate IP protection pathway (e.g., patenting vs. trade secret) for different elements of WaveCore's innovation;
- Map IP-related risks across regions including litigation exposure, export restrictions, and licensing barriers;
- Evaluate licensing and tech transfer routes (e.g., direct licensing, IP pooling, spin-off structuring);
- Simulate a negotiation with a multinational telco interested in licensing WaveCore's energy optimization algorithm;
- Deliver a short roadmap and risk map balancing technical, legal, and commercial considerations.

External References. To fully engage with this Case Study, students should read, analyse, and review the documentation provided in Section 4.6.5.

4.6.4. Learning/Training Tasks of Case Study 6

The Case Study is structured into two tasks to help learners navigate the complexities of IP strategies and tech transfer for early-stage 5G ventures. The full

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workload is 24 hours divided into contact sessions, independent analysis, and collaborative work, following the reference guideline for the 5G-DiGITs Project.

Task 1 requires learners to design an IP protection and Tech Transfer strategy (Table 35).

Table 35. Case Study 6: Description of Task 1.

Task 1	Designing an IP Protection and Tech Transfer Strategy
Learning Hours	12 hours (2 lecture + 5 practical + 5 independent)
Learning Outcomes	• Understand the types of IP (patents, trade secrets, copyright) relevant to 5G-based startups; • Compare protection strategies across jurisdictions (EU, US, East Asia); • Develop a roadmap linking IP to commercialization goals.
Description	The task includes the following steps: 1. Identify core IP assets of the startup (based on fictional startup profile); 2. Decide which elements to patent, keep secret, or license; 3. Create an IP & tech transfer roadmap considering co-owned research outcomes and investor expectations.
Expected Outcomes	Strategic IP Memo (4 pages) + IP Asset Map
Prerequisites	Basic understanding of IP and business model elements

Task 2 requires learners to simulate and address an IP risk scenario (Table 36).

Table 36. Case Study 6: Description of Task 2.

Task 2	Licensing and IP Risk Scenario Simulation
Learning Hours	12 hours (2 lecture + 5 practical + 5 independent)
Learning Outcomes	• Identify international IP risk factors and legal exposure; • Understand key concepts in licensing negotiations and FRAND principles; • Simulate strategic decision-making in IP disputes.
Description	The task includes the following steps: 1. Analyze two fictional case examples of IP disputes or SEP negotiations; 2. Map global IP risk factors (e.g., litigation hotspots, export bans) for the startup; 3. Conduct a role-play licensing negotiation with a potential partner.
Expected Outcomes	Licensing Risk Map (poster format) + Negotiation Summary Report (1-2 pages)
Prerequisites	Task 1

4.6.5. Usage Guidelines and Examples for Case Study 6

This Case Study is designed to support flexible delivery across diverse learning environments, whether taught in a classroom, hybrid format, or online. It fits well within IP strategy, innovation

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management, or entrepreneurship modules and can be conducted through team-based simulations, individual assignments, or as a short course sprint.

Tasks are modular and can be delivered sequentially or independently, depending on course design. The material supports experiential learning through realistic simulations and decision-making scenarios aligned with 5G innovation.

Assessment and Evaluation Strategy. Assessment should combine formative and summative approaches. Learners are expected to demonstrate critical thinking, apply real-world reasoning, and reflect on strategic trade-offs in IP and licensing. Assessment criteria may include:

- **Strategic clarity**: Alignment of IP choices with business/commercial objectives;
- **Contextual analysis**: Consideration of legal, geographic, and technical factors in IP protection;
- **Risk awareness**: Identification of international IP risks and proposed mitigation;
- **Negotiation skills**: Depth of preparation and realism in simulation or licensing scenarios;
- **Communication**: Clarity and structure of memos, maps, and summary reports;
- **Innovation and critical thinking**: Originality of strategy and decision-making under constraints.

The following grading suggestions support flexible evaluation:

- **Task 1**: Evaluate the coherence of asset mapping, the logic behind protection decisions, and clarity in the proposed IP roadmap;
- **Task 2**: Assess understanding of IP risk environments, the relevance of risk mitigation strategies, and engagement in the licensing role-play scenario;

Additional assessment options include:

- Use of IP mapping tools and licensing visuals;
- Peer evaluation (if conducted in groups);
- Reflection brief on decision-making trade-offs.

4.6.6. Resources and Materials for Case Study 6

To complete this Case Study, learners will access a curated blend of IP, standardization, negotiation, and innovation strategy materials. These resources reflect real-world IP challenges in emerging tech sectors like 5G, edge computing, ML/AI, and deep tech ventures, with a particular emphasis on SEPs, patent licensing, and IP strategy for startups. The materials are structured to support PBL, role-playing simulations, and strategic decision-making.

Technical and IP Intelligence Resources

- WIPO Patent Landscape Report for 5G (2022). An in-depth global analysis of 5G-related patent filings, ownership trends, and technology clusters;
- EPO Case Study on SEPs and FRAND: It explores the legal and business dimensions of SEPs and FRAND licensing frameworks;
- Huawei Annual Intellectual Property Reports (2019-2023): It illustrates how a major telecom company manages IP assets, licensing income, and patent strategy;
- Lens.org and EPO Espacenet**:** Open-access patent search tools to explore patent families, legal status, and citations. Ideal for prior art research and patent landscaping.

Entrepreneurial and Strategic IP Planning Tools

- IP Strategist's Playbook (WIPO): It provides practical guidance for Small and Medium-sized Enterprises (SMEs) and startups on how to align IP with business goals, FTO analysis, and market positioning.

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- European IP Helpdesk Guides: It covers IP due diligence, tech transfer, licensing contracts, and commercial exploitation.
- IAM Magazine Case Studies: High-level business cases on monetizing patents, patent pools, and licensing strategy.

Licensing and Negotiation Simulations

- “Licensing Negotiation Role-Play Templates”. Customizable templates for student role-play (e.g., SEP holder vs. AI startup). Based on real negotiation models from EPO, AUTM, and Stanford TLP programs;
- “EU Technology Transfer Guidelines (DG RTD)”. Practical references on exclusive vs. non-exclusive licensing, royalty models, and research collaborations;
- “FRAND Royalty Rate Dispute Cases”. Summaries of key court cases (e.g., Huawei vs. ZTE, Ericsson vs. Apple) to illustrate legal tactics and strategic positioning.

4.6.7. Mapping of Case Study 6 to 5G-DiGITs Courses

With respect to the courses developed within the 5G-DiGITs Project, the Case Study is designed to support the learning framework of the **“Entrepreneurship and Innovation in Advanced 5G Technologies”** course.

On the one hand, the learning outcomes of the Case Study map and extend the learning outcomes of the course. On the other hand, the course includes Modules/Units relevant to the Case Study, as they are related to:

- **IP, Compliance & Competitive Positioning in 5G Ventures**
  - Module 3, Unit 3.1;
- **Compliance, Ethics, and Responsible Scaling**
  - Module 3, Unit 3.2;

KSA items covered by the Case Study also map with the KSA covered by the above course:

Knowledge items covered by the Case Study

- IP & Tech Transfer;
- Knowledge Valorisation Routes;
- Regulatory and Ethical Strategy.

Skill items covered by the Case Study

- IP Strategy & Competitive Positioning.

Ability items covered by the Case Study

- Apply IP & Regulatory Strategy;
- Design IP-aware Go-To-Market Paths.

The allocation of learning hours (24 hours) for the Case Study accounts for up to 40% of the learning hours constituting a 5G-DiGITs course (60 hours, i.e., 2 ECTS). Therefore, when used in combination with one of the above courses, the Case Study can be used to either extend the learning hours or to replace parts (e.g., exercises, lab sessions, and presentations) of the target course, depending on how the instructor decides to leverage the provided material.

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4.7. **Case Study 7 –** Advancing Precision Agriculture through 5G-Enabled Smart Farming: A Design-Driven Innovation Framework

4.7.1. General Information on Case Study 7

General information on Case Study 7 is provided in Table 37.

Table 37. General Information for Case Study 7.

Case Study	Strategic Intellectual Property and Tech Transfer in 5G: Startup Case Studies
Learning Outcomes	• Apply creative thinking tools (e.g. Design Thinking, Lean Canvas) to identify and validate 5G use cases in smart farming; • Understand how 5G capabilities (low latency, edge computing) can create value in traditional sectors; • Conduct user research and stakeholder interviews; • Translate feedback into actionable product and business model iterations.
Total Learning Hours	**Lectures:** 3 hours **Practical Work:** 10 hours **Independent Study:** 11 hours **Total:** 24 hours
Prerequisites	• Basic understanding of 5G concepts; • Awareness of key design; • Exposure to business modeling tools.

4.7.2. Introduction to Case Study 7

This Case Study immerses students in the transformative potential of 5G technologies for modern agriculture. As European farms face mounting challenges—labor shortages, climate variability, and economic pressures—precision farming emerges as a key enabler of sustainable and resilient food systems.

Students will take on the role of a startup team collaborating with telecom providers, agricultural experts, and equipment manufacturers to develop an MVP that integrates 5G connectivity, edge computing, and IoT sensors. Through hands-on activities, students will engage in co-creation workshops, design sprints, and stakeholder interviews to validate user needs and iterate rapidly on smart farming prototypes.

The Case Study encourages students to leverage 5G capabilities to drive value in crop management, water conservation, and soil health—while navigating the complexities of farmer adoption, regional differences, and business model scalability.

Learning objectives include:

- Understand the role of 5G in transforming agricultural operations, including sensor integration, autonomous machinery, and real-time analytics;
- Apply design thinking and user research to co-create precision farming solutions that reflect regional contexts and stakeholder needs;
- Develop and validate an MVP and business model tailored to the agricultural sector, incorporating user feedback, sustainability goals, and technology constraints;
- Explore the challenges of digital adoption in rural ecosystems, including interoperability, infrastructure gaps, and behavioural barriers;

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- Pitch a smart farming solution that balances innovation, practicality, and market potential—framed within the broader context of agricultural policy and sustainability.

4.7.3. Detailed Description of Case Study 7

Technological innovation is becoming essential to securing food resilience. Enabled by 5G's real-time data capabilities, smart farming offers new possibilities for optimizing operations, reducing environmental impact, and revitalizing rural economies.

This Case Study situates students in the context of AgriCore, a fictional early-stage startup aiming to deploy a precision agriculture platform using 5G-enabled edge computing, autonomous equipment, and real-time analytics. The company has partnered with a telecom operator and regional farming cooperatives to pilot its MVP in a rural European setting.

Rather than concentrating on technical specs alone, the case challenges students to engage in design-driven innovation—integrating user research, iterative development, and stakeholder analysis to create a solution that is both viable and context-sensitive. Teams will validate their MVP with end users, iterate based on feedback, and pitch their concept through a business model lens informed by market realities and agricultural policy frameworks.

Scope and Stakeholders. Students will define the strategic direction for AgriCore's MVP and go-to-market approach, focused on a chosen rural test site (e.g. in Southern Italy or Eastern Poland). Key stakeholders include:

- Local farmers and agricultural cooperatives (primary users and data providers)
- The founding team (engineering + business leads)
- Telecom infrastructure partner (connectivity and edge capabilities)
- Agricultural policymakers and EU rural development agencies
- Potential investors and agritech equipment providers
- Sustainability advocates and environmental monitoring groups
- Public funders and early-stage investors.

Students must also consider cross-sector dynamics such as regional adoption barriers, telecom-agriculture collaboration models, and incentive structures tied to digital transformation funding.

Challenges. The MVP is a sensor-driven crop analytics tool powered by 5G connectivity and edge-enabled data processing. The startup must validate its solution with users, demonstrate economic value, and build a credible business model for scaling across geographies. Core challenges explored include:

- Conducting contextual research to identify regional farming pain points and climate-related challenges
- Designing a user-centric MVP with clear functionality and value assumptions
- Simulating farmer interviews and co-creation workshops to validate the concept and adapt quickly
- Building a Lean Canvas model tailored to the realities of smart agriculture innovation
- Delivering a stakeholder pitch that balances technical feasibility, user desirability, and business viability
- Mapping adoption barriers, such as connectivity gaps, resistance to change, and trust in digital tools

External References. To fully engage with this Case Study, students should read, analyse, and review the documentation provided in Section 4.7.5.

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4.7.4. Learning/Training Tasks of Case Study 7

This Case Study is structured into three tasks designed to guide learners through the development, validation, and strategic positioning of a 5G-enabled smart farming solution. It simulates a pilot initiative where a startup partners with a telecom provider, farmers, and other stakeholders to co-create a precision agriculture MVP tailored to the needs of a European rural region. The full workload is 24 hours, distributed across contact sessions, independent exploration, team collaboration (if applicable), and writing tasks, which follow the reference guideline for the 5G-DiGITs Project.

Task 1 focuses on understanding smart farming and mapping a region (Table 38).

Table 38. Case Study 7: Description of Task 1.

Task 1	Understanding Smart Farming and Mapping a Regional Context
Learning Hours	7 hours (1 lecture + 3 practical + 3 independent)
Learning Outcomes	• Conduct contextual research on regional farming challenges; • Compare solution needs across geographies; • Understand the key components of a 5G-based smart farming solution.
Description	The task includes the following steps: 1. Select a rural region (e.g. in Southern Italy or Eastern Poland); 2. Research typical farming practices and limitations in the region; 3. Identify a solution to address one of the identified challenges.
Expected Outcomes	Presentation slide deck (2–3 slides) on local needs and the solution to the challenge
Prerequisites	None

Task 2 requires learners to implement design thinking and validation tools (Table 39).

Table 39. Case Study 7: Description of Task 2.

Task 2	Design Thinking, Validation and Iteration
Learning Hours	9 hours (1 lecture + 4 practical + 4 independent)
Learning Outcomes	• Apply design thinking to design an MVP based on the identified challenge; • Visualize product functionality and user journey.
Description	The task includes the following steps: 1. Create MVP concept(s) tailored to the regional context; 2. Define key assumptions about the MVP's value; 3. Run role-play interviews or online simulations; 4. Update MVP concept based on validation results.
Expected Outcomes	2-page summary of key insights regarding design thinking, validation and iteration

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Prerequisites	Task 1

Task 3 challenges learners to design a robust business model and craft a compelling pitch tailored for key stakeholders (Table 40).

Table 40. Case Study 7: Description of Task 3.

Task 3	Business Model and Pitching
Learning Hours	8 hours (1 lecture + 3 practical + 4 independent)
Learning Outcomes	• Build a Lean Canvas business model; • Communicate the solution effectively.
Description	The task includes the following steps: 1. Complete a Lean Canvas for the MVP; 2. Prepare a 5-minute pitch for stakeholders.
Expected Outcomes	Lean Canvas + video or live pitch
Prerequisites	Task 2

4.7.5. Usage Guidelines and Examples for Case Study 7

This Case Study is designed to support flexible delivery in diverse formats—on-campus, hybrid, or remote. It fits well into modules focused on digital innovation, agritech entrepreneurship, sustainability transitions, or rural development. Learners navigate a realistic simulation where a startup prototypes a 5G-enabled precision agriculture solution in partnership with farmers and telecom stakeholders.

Tasks are modular and can be implemented sequentially or independently. For shorter formats, Tasks 2–3 work well in a design sprint. The case may be completed individually or as a group project. For team-based formats, instructors may assign innovation roles such as UX lead, systems engineer, or agronomist.

The material emphasizes experiential learning and decision-making in emerging technology settings. It is well suited to hackathons, summer schools, or innovation labs. Templates (e.g. Lean Canvas, stakeholder maps) and feedback sessions should be provided during tasks to support prototyping.

Assessment and Evaluation Strategy. Evaluation should combine formative and summative approaches, measuring learners' ability to connect stakeholder needs with technical solutions and business feasibility. Assessments may include:

- **Problem-solution fit:** Relevance and clarity of the farming challenge being addressed;
- **Stakeholder understanding:** Depth of insight into user needs and regional farming dynamics;
- **Business logic:** Viability of business model elements (value proposition, scalability, partnerships);

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- **Pitch quality:** Clarity and persuasiveness in presenting the MVP to farming and telecom stakeholders;
- **Design rationale:** Documentation of iterations and validation steps during MVP development;
- **Team collaboration:** Quality of group contributions (if applicable), role-playing, and communication.

Additional assessment options include:

- Use of mapping tools, farmer personas, or MVP wireframes;
- Peer review (in group formats);
- Reflection brief on trade-offs in solution design (e.g. tech cost vs. farmer usability).

4.7.6. Resources and Materials for Case Study 7

To complete this Case Study, learners can access the following material:

- "The Lean Startup" by Eric Ries;
- "Design Thinking for Strategic Innovation" by Idris Mootee
- Lean Canvas templates
- EU 5G in agriculture white papers
- Optional: farmer interview videos or sample datasets

4.7.7. Mapping of Case Study 7 to 5G-DiGITs Courses

With respect to the courses developed within the 5G-DiGITs Project, the Case Study is designed to support the learning framework of both **"Entrepreneurship and Innovation in Advanced 5G Technologies"** and **"Entrepreneurial Skills for Beyond 5G Technologies"** courses.

On the one hand, the learning outcomes of the Case Study map and extend the learning outcomes of the courses. On the other hand, the courses include Modules/Units relevant to the Case Study, as they are related to:

- **Innovation in the 5G/B5G Landscape**
- **Building and Funding a 5G Startup**
  - "Entrepreneurial Skills for Beyond 5G Technologies" – Modules 1 and 2, Units 1.1, 1.2, 2.1, and 2.2
  - "Entrepreneurship and Innovation in Advanced 5G Technologies" – Module 1, Unit 1.2

KSA items covered by the Case Study also map with the KSA covered by the above courses:

Knowledge items covered by the Case Study

- From "Entrepreneurship and Innovation in Advanced 5G Technologies" course:
  - Turning Ideas into Products;
  - Innovation and Opportunity Mapping;
  - Market Analysis and Customer Discovery.
  - Business Models.
- From "Entrepreneurial Skills for Beyond 5G Technologies" course:
  - Innovation Tools and Frameworks;
  - 5G Market Dynamics;
  - Stakeholder Ecosystems.

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Skill items covered by the Case Study

- From “Entrepreneurship and Innovation in Advanced 5G Technologies” course:
    - Ideation tools.
    - Market research methodology.
    - Customer validation.
    - Business Model Tools.
    - Go-To-Market Planning.
    - Entrepreneurial Pitching.
- From “Entrepreneurial Skills for Beyond 5G Technologies” course:
    - Ideation and Creativity;
    - Cross-Disciplinary Collaboration;
    - Leadership and Delegation.

Ability items covered by the Case Study

- From “Entrepreneurship and Innovation in Advanced 5G Technologies” course:
    - Navigate Innovation Ecosystems.
    - Iterate Based on Feedback.
    - Design and Defend a Startup Plan.
- From “Entrepreneurial Skills for Beyond 5G Technologies” course:
    - Turn ideas into validated solutions;
    - Operate in agile venture teams.

The Case Study has been allocated 24 learning hours, representing up to 40% of the total workload of a standard 5G-DiGITs course (60 hours / 2 ECTS). When integrated with either of the above courses, it can be employed flexibly—either to extend the overall learning experience or to substitute specific components such as exercises, lab sessions, or presentations. Instructors may adapt its implementation based on course design and preferred pedagogical approach.

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5. Conclusions and Future Steps

The work carried out so far under Task T2.3 has resulted in the successful integration of the PBL methodology in the 5G-DiGITs curriculum/courses being developed in WP2.

As detailed in the present Deliverable, a key accomplishment of this task has been the design of seven PBL Case Studies that flexibly support the educational frameworks of the eight courses being developed under Task T2.2. These Case Studies thus provide a key PBL-oriented extension of the 5G-DiGITs curriculum and play a key role in the overall 5G-DiGITS educational strategy.

At the time of writing, the next Steps for Task T2.3 are under preparation and include the organization of two webinars targeting HEI and VET educators/trainers, where the 5G-DiGITs strategy for implementing the PBL methodology will be presented and discussed, in order to provide guidelines to educators/trainers willing to use the PBL methodology in their own courses, while also collecting feedback for further refinement of the 5G-DiGITs action plan.

In conclusion, T2.3 has successfully delivered on its first milestone, i.e., the integration of PBL approaches via the identification and design of real-world problems and case studies, opening the way for the next phase of the Project, including the activities of the incoming Task T2.4, where the 5G-DiGITs curriculum testing and refinement will take place.

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