5G smarT mObility, media and e-health for toURists and citizenS

Deliverable D8.5
Final report on innovation management, dissemination, standards and exploitation plans

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List of Acronyms and Abbreviations

2D	2-Dimensional
3D	3-Dimensional
3GPP	Third Generation Partnership Project
4G	Fourth Generation (of Mobile Network)
5G	Fifth Generation (of Mobile Network)
5G PPP	5G Infrastructure Public Private Partnership
AI	Artificial Intelligence
AIA	Athens International Airport
AR	Augmented Reality
ASAP	As Soon As Possible
ATE	Augmented Tourism Experience
BNO	Broadcast Network Operator
BTS	Base Transceiver Station
CAPEX	Capital Expenditure
CARS	Computer Assisted Radiology and Surgery
CDN	Content Delivery Network
CHU	Centre Hospitalier Universitaire (French)
COVID	Coronavirus Disease
C-RAN	Cloud-RAN / Centralized-RAN
CSP	Communication Service Provider
DAS	Distributed Antenna System
DICOM	Digital Imaging and Communications in Medicine
DVB	Digital Video Broadcasting
E2E	End to End
eMBB	Enhanced Mobile Broadband
ESC	Eurovision Song Contest
ESG	Environmental, Social and Governance
ETSI	European Telecommunications Standards Institute
ETSI ENI	ETSI Experiential Networked Intelligence
EUCNC	European Conference on Networks and Communications
FDD	Feature Driven Development
FTA	Free To Air
FtableGAM	Galleria Civica d'Arte Moderna e Contemporanea
FTM	Fondazione Torino Musei
GP	General Practitioner
GPS	Global Positioning System
GSMA	GSM Association
HEVC	High Efficiency Video Coding
HPHT	High Power High Tower
IBC	International Broadcasting Convention
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
LPLT	Low Power Low Tower
MaaS	Mobility as a Service
ML	Machine Learning
mMTC	massive Machine Type Communications
MNO	Mobile Network Operator
MNO	Mobile Network Operator
MR	Mixed Reality
NB-IoT	Narrow Band – Internet of Things
NGMN	Next Generation Mobile Networks
OPEX	Operational Expenditure
ORF	Österreichischer Rundfunk (Austrian Broadcasting Corporation)
PCHA	Personal Connected Health Alliance
PRs	Press Releases
QoS	Quality of Service
R&D	Research & Development
RGB-D	Red Blue Green and Depth
SC	Small Cells
SDO	Standard Development Organisations
SNPN	Standalone Non-Public Network
SWR	Südwestrundfunk (Southwest Broadcasting)
TCO	Total Cost of Ownership

TMO	Technologies, Markets & Organisations
TMOG	Technologies, Markets & Organisations and Governance
TRL	Technology Readiness Level
TSN	Time-Sensitive Networking
UC	Use Cases
UHD	Ultra-High Definition
URLLC	Ultra-Reliable Low-Latency Communication
V2X	Vehicle-to-X
VR	Virtual Reality
WebRTC	Web Real-Time Communication
WG	Working Group
WP	Work Package
XR	eXtended Reality

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Executive Summary

Bringing use cases to a level of maturity such that they can be experienced by future potential users and beneficiaries has been a critical objective of the 5G-TOURS project. The emergence of COVID-19 has undoubtedly created substantial challenges for the principal industrial sectors of 5G-TOURS, with Transport, Health and Tourism all experiencing major impacts either due to their criticality to keep society ticking over (such as Health) or due to Government health measures substantially curtailing their Operations (Tourism and Airports). Nevertheless, even with these challenges, and perhaps because of these challenges, imaginative approaches have been taken to overcome with substantial outcomes being secured by 5G-TOURS.

For the first two years of the project a close working relationship with 5G-EVE established the **underpinning trials infrastructure asset**. The infrastructure was available for the trials not only in lab environments but also in realistic deployments to enable **tangible and realistic experiences for the public**. The view of 5G-TOURS is that these place-based trials engagements and infrastructure investments proved to **be critical in the diffusion of innovations into the industrial sectors**.

The risk of substantial and perhaps critical impact on the ability of the 5G-TOURS trials to reach the targeted users has been high due to COVID-19. However, through flexibility of scheduling of events and appropriate use of both face to face and virtual engagement mechanisms these risks have been overcome. The spirit of open innovation has led to highly valuable feedback being received from trials participants: **substantial user experience and acceptance data has been gathered.** Both positive and some that may be perceived as negative feedback has been received from trials participants. At this stage of the development of the 5G-TOURS innovations it is essential to receive both positive and negative feedback to increase the likelihood of success when the innovations are refined and bought to market.

Standards impact and dissemination

All quantitative targets for dissemination have been met, and in some case substantially exceeded. The quantitative exceeding of targets in the Standards domain led to the refinement of the 5G-TOURS approach to the assessment of quality of the Standards contributions. Even with these additional levels of quality assessment the project has exceeded expectations.

We highlight the successful convergence of telecoms and broadcast technical platform views which has assisted in substantial outcomes in refining approaches to the use of such approaches in networks. The substantive contributions to standards in this area is notable. In 5G-TOURS the principal beneficiary sector of this convergence theme has been Tourism; however, other sectors will benefit from these converged capabilities in networks, devices, applications, and services. The launch of the 5G-MAG forum during the life of this project with substantive input from project partners evidences the importance of the knowledge gained during this project and the contributions to the Standards.

As COVID-19 restrictions lifted 5G-TOURS took the opportunity to be highly engaged with two important and internationally influential face to face events; Mobile World Congress and EuCNC. Both events provided opportunities to communicate with industry and the wider research community. A common observation that was received by those that engaged with 5G-TOURS experts on the stands at these events was the positive impression regarding the **level of public engagement** the project was targeting; not only for the demonstration of technologies but also for the 5G-TOURS assessment of the willingness of users to adopt novel approaches to improve their experiences in the Health, Tourism and Transport sectors.

A framework for the assessment of innovations and refinement of exploitation thinking

Work Package 8 leads business validation and exploitation considerations for 5G-TOURS. In this final work package report we provide a multifaceted critical review of the **value propositions of the innovations.** The business environment for each of the sectors is becoming extremely challenging. Global recessionary forces, energy costs, continuing COVID-19 impact on willingness to travel etc. create an extremely uncertain context within which to apply standard benefit and cost assessments.

The multifaceted business view is framed by four business aspect consideration establishing the TMOG assessment framework within which each of the different perspectives of the sectors can be considered, and then an

assessment of the 5G-TOURS innovations can be carried out. Such an approach provides a toolkit or mechanism for appraisal by the Innovation Managers.

The process of critically reviewing the innovations within their sectors assisted 5G-TOURS project partners in the refinement of views on their exploitation opportunities and how they intend to create and capture value from their participation in 5G-TOURS by leveraging the potential of the innovations.

An assessment of Innovations

A longlist of 19 candidate innovations has been identified and each assessed over the duration of the project from two key perspectives: a supply-side perspective and a business viability perspective. For each industry sector the supply-side perspective identifies key features of the innovation that are of the highest interest as they emerged from the trials and technology development perspective. The commercial viability perspective highlights, through the application of the TMOG framework, the innovations where demand appetite may be the highest. This assessment is intended to reflect a certain, hypothetical, viewpoint of a generic industry buyer on the demand side. TMOG highlights the following two innovations in each sector:

- **For the Airports Sector** TMOG brings to the fore the potential of solutions that support navigation technologies for passenger guidance for the purposes of safety and crowd management, and multiple UHD video feeds from 5G enabled ground-based moving vehicles offers the ability potential to provide much more detailed data, in real-time, on vehicle status which can be used to improve the efficiency of ground-based vehicle operations;
- **For the Health Sector** TMOG brings to the fore Remote health monitoring and emergency situation notification capabilities and Teleguidance for diagnostics and intervention support;
- **For the Tourism Sector** TMOG brings to the fore the value of augmentation of the experience of the user which clearly resonated with the trials users as well as featuring well in vertical / business users' interest, as well as high quality video distribution which converges mobile and broadcast infrastructure.

Highlights of exploitation aspirations

The focus of the investment in 5G-TOURS towards deployment and trials of use cases tilts the technology readiness of the project towards commercial exploitation and thus the standards contributions align with that motivation. The 5G-TOURS project partners who joined together shared a common interest in the sectors but with diverse capabilities ranging from equipment to application to business analyst. Views of each project partner on their paths to exploitation were firmed up in Deliverable 8.2 at the conclusion of year2. In the final year, project partners have advanced their aspirations on particular opportunities and where appropriate within this document project partners exploitation views have been interspersed within the innovations to illustrate areas of exploitation beyond the end of this project and where appropriate evidencing a refinement of views since Deliverable 8.2.

1 Introduction

This deliverable is the final record of outcomes from the activities that have been carried out in Work Package 8 (WP8) of 5G-TOURS. Implicit in the mission of WP8, business validation and exploitation, is to be outward looking and steer impact in pre-market and market opportunities domains. A significant proportion of the duration of the 5G-TOURS project has been overshadowed by the global health crisis of COVID-19. Nevertheless, the essential objective of touching society, with users experiencing the use cases and innovations that have been developed has been secured and the knowledge gained through that success shall be bought to the reader's attention. The Business validation and exploitation objectives of WP8 are structured around four key process areas.

- **Task8.1** focusses the Business context and validation analysis for the project. Business analyst thinking in this task has developed an understanding of the business context in each of the three sectors. This has been achieved through strategic market studies in the vertical sectors, exploring evolving value chains and commercial models and qualifying their relevance to the emergence of 5G in the sectors. An important aspect of the analysis has been the interaction with the innovation managers, economic value analysis of WP2 and drawing on aspects of WP7 user experience assessments. Earlier reports have refined the understanding of potentially relevant business models and analysis capabilities that could be required to validate investment opportunities. This final report articulates a framework that has emerged that assists in the critical review of innovations and opportunities. The framework is designed to be generic enough to be relevant to all three sectors whilst allowing customisation based on a characterisation of the sector within which innovations will emerge.
- **Task8.2** co-ordinates Exploitation and Innovation Management focussed activities. Whilst the 13 use cases of 5G-TOURS have underpinned the development of the technology and trials demonstrators, the innovation managers have developed a view on the sector and how to articulate the innovations of the project. Each sector is different in the nature and technology sophistication of potential solution buyers. Businesses operating in the sectors have sector specific priorities and ways in which they view innovations. This leads to a refinement and sector specific assessment of the innovations, the conclusion of which are captured in this report. Each project partner has had the opportunity to assess the views of the innovation managers with their expertise in the sector and to refine their view on their exploitation strategy. The business context of Task8.1 and the interdependence with WP4, WP5, WP6 where use cases trials are delivered converge into this Task under the watchful eye of the three sector specialist Innovation Managers.
- **Task8.3** co-ordinates the Standardisation activities of the 5G-TOURS partners. Telecom's technology Standards bodies such as 3GPP and ETSI have proved to be the principal beneficiaries of the contributions from partners. However, other Standard Development Organisations (SDOs) and standards influencing forum have emerged and 5G-TOURS consortium members have become founding members of these organisations. 5G-MAG which embraces the broadcast convergence with mobile domains has exemplified the success of 5G-TOURS members in influencing the creation of an industrially focussed group and providing Board level leadership. Open-source communities have also benefitted from the release of reference code from the project. The Standards contributions have been motivated by the 5G-TOURS consortium motivation to advance to use case trials and market readiness.
- **Task8.4** co-ordinates Industrial Communication and Dissemination for the project. In this deliverable we report on the final outcomes of these activities. There can be no question that COVID-19 has impacted this aspect of the project. Nevertheless, all objectives have been met and, in some areas, significantly exceeded. The final stage of the project has been characterised by a concerted effort to increase the project presence in face-to-face opportunities meeting with European Commission representatives on stands as well as other projects. Collaboration with other EC projects for workshops has assisted in raising the profile of the project – the health sector related activities in particular have benefited from this approach.

1.1 Structure of this report

This deliverable is structured around the industrial sectors that have underpinned the business context of 5G-TOURS and the innovations that fit within that business context:

- **Chapter 2**: Provides a framework which defines the scope of deliberations that business analysts in 5G-TOURS have detected the buyers of innovations are deliberating upon as part of their 5G innovations buy/no-buy decision making processes. Realistically post-COVID and with global recessionary forces now in play deliberations have been complex and multivariate qualitative and quantitative judgements and assessments.
- **Chapter 3**: The transport sector view has been refined to focus on the airport. The supply and demand side pressures and challenges are significant in this sector, the assessment of the innovations and relevant exploitation planning view of the partners is considered here.
- **Chapter 4**: The health sector innovation and exploitation view is again shaped by the reality of a substantial service demand increase due to the COVID-19 impact. Innovations are assessed in that context as well as in the context of the priority innovation view in the pre-COVID19 era. Exploitation views are aligned with these innovations' views.
- **Chapter 5**: In a refinement of the project sector views the Tourism and Media sectors are considered. The technology architecture supply side view in the convergence of broadcast and telecoms infrastructure potentially delivers a converged sector view on innovations and exploitation plans.
- **Chapter 6**: Substantial Standardisation outcomes of the project are reported alongside the wider dissemination of academic as well as industrially oriented messaging from the project. The outcomes are reported against the original objective of the project alongside insights in terms of how the approach to dissemination channels has had to evolve in response to the COVID-19 impact.
- **Chapter 7**: Conclusions are then provided to draw upon the business and innovation merits of the project. As 5G-TOURS was a three-year project it was inevitable that new opportunities for collaboration and demonstration and engagement with users have emerged; due to time and resource constrains not all unplanned for opportunities can be seized and immediately acted upon. Therefore, we also provide a view and insight for those that follow on behind the pioneering work of 5G-TOURS as the market for 5G innovations in three economically critical sectors start to crystalize.

1.2 List of all innovations developed in the project

Table 1 summarises all the potential innovations identified in the project from its beginning; the ID number is a unique reference to the various innovations. A key objective of the project was to develop innovations that led to commercial exploitation. When applying that view, we have found that some of the innovation ideas have emerged as having greater potential based on how use case demonstrations have been received and commercial context is evaluated. In Chapters 3, 4 and 5 the most relevant innovations to these considerations are described.

Table 1. 5G-TOURS Innovations Master Table.

ID	Innovation Title	Vertical	Linked UC(s)
#01	*Tele guidance for diagnostics and intervention support through 5G mobile transmission of real time ultrasound images, video and audio streaming and smart glasses use*	Health	UC7
#02	*Autonomous 5G operated robotic system for telepresence and museum guide* (note*)	Tourism & Media	UC3

#03	*Large scale IoT deployment using 5G mobile Networks standards for identifying car park availability and driver guidance in large car parking environments.*	Airport	UC10
#04	*5G based indoor navigation technology for passenger guidance using 5G enabled devices*	Airport	UC13
#05	*Multiple Ultra High-Definition Video feed transmission from 5G based enabled ground moving vehicles*	Airport	UC11
#06	*A Novel 2D Ultrasound Probe Calibration Framework using an RGB-D Camera and a 3D-Printed Marker*	Health	UC6-9
#07	*Augmented Tourism experience*	Tourism & Media	UC1
#08	*Telepresence*	Tourism & Media	UC2, UC3
#09	*Robot assisted museum guide*	Tourism & Media	UC3
#10	*High quality video services distribution*	Tourism & Media	UC4
#11	*Remote and distributed video production*	Tourism & Media	UC5
#12	*Remote health monitoring and emergency situation notification*	Health	UC6
#13	*Teleguidance for diagnostics and intervention support*	Health	UC7
#14	*Wireless operating room*	Health	UC8
#15	*Optimal ambulance routing*	Health	UC9
#16	*Smart Parking Management*	Airport	UC10
#17	*Video enhanced ground-based vehicles*	Airport	UC11
#18	*Airport Evacuation*	Airport	UC12
#19	*AR/VR Students Bus Excursion*	Airport	UC13

Note* The innovation #02 *Autonomous 5G operated robotic system for telepresence and museum guide* has been successively subdivided in Innovation #08 *Telepresence* and Innovation #09 *Robot assisted museum guide* as the evolution of Innovation #02 arises two separate innovations better and easier to describe separately.

2 A Framework for Appraising Innovation Potential (Business)

2.1 Introduction and Motivation

This section presents a methodology that has been developed under 5G-TOURS, which allows for the appraisal of the project's innovative outcomes from a business viability perspective.

A core objective of 5G-TOURS is: **"*To get the European 5G Vision of "5G empowering vertical industries" closer to deployment with innovative digital use cases involving cross industry partnerships*"**. As such, 5G-TOURS expects that 5G technologies will create business opportunities for the ***main players: operators, manufacturers and industry verticals***. Some elements of the value chain will remain faithful to the traditional business models that underpin mobile networks, but other parts will undergo very significant changes. In particular, the involvement of vertical industries is expected to lead to entirely new business models with new players (the verticals), which will play a central role in the new 5G ecosystem.

5G-TOURS seeks to evaluate the business viability of 5G innovations and ecosystems in the selected industry verticals with a view to identifying those that are likely to be most successful at creating and delivering value within Europe. To a degree, the success of innovations will be measured by their uptake and adoption by the verticals and actors within their respective value chains. However, a major challenge for actors who are not used to dealing with the usual supplier ecosystems (OEMs, infra providers, operators, integrators etc), is how to independently assess the value of prospective investments in innovative technologies and solutions.

The widespread exploitation of 5G-TOURS innovations will depend greatly on the ability of leaders within the vertical industries to understand the potential impact of 5G solutions on their business, on their stakeholders and increasingly, on the wider society.

In previous reports we have considered the likely commercial return (D8.3) and socio-economic value (D2.3) of the 5G-TOURS innovations within the different evaluations case settings of the project, i.e., the city, the airport, and the hospital. These are important dimensions when considering the potential impact of new technologies and solutions, however they do not give a complete picture in themselves. Other factors that might influence investment are how impactful innovations may be, their scalability, ease of adoption, maturity and more. Collectively these factors help to qualify what we call the ***solution - ecosystem fit***, i.e., the degree to which the supply-side and demand-side ecosystems are aligned, with each other as well as with society, that results in the best prospects for successful technology exploitation.

We have set out to create a framework that allows for executives and decision makers within the various ecosystems to evaluate the 5G-TOURS innovations in a way that will allow them to prioritise and portion their investments coherently. The concept of value and impact may be viewed from many different perspectives reflecting the different views and agendas of the various actors and a key principle from the outset was to implement an agnostic structure that can be adapted to suit any particular technology, or actor, in a way that fosters a greater understanding across the value chain.

2.2 Developing the Analysis

In D8.1 we reviewed the Business Model Canvas (BMC) as a tool for understanding an organisation's "money earning logic" and as a means of analysing certain aspects of the business process and determining the value proposition for each vertical.

It was noted that the BMC is primarily aimed at informing the supply-side ecosystem and is specific to a particular organisation selling a certain offering (product or service). It aims to capture the immediate supply chain (direct suppliers and customers) and to quickly understand the financial structure (inflows and outflows). To use the BMC effectively requires that many of the parameters are known and this can be challenging for nascent technologies and weakly defined markets.

We also found that the BMC was less useful in capturing the requirements of the demand side ecosystem, particularly where it consists of multiple stakeholders whose interests in 5G may not be aligned. 5G also presents a number of architectural options, which adds to the complexity of the analysis.

An increasing number of permutations quickly renders the BMC clumsy and unmanageable so in D8.2 we introduced the "Enterprise Pathfinder Framework" as a means to navigate the array of use cases, evaluation settings and business models included under the umbrella of 5G-TOURS. The framework draws on a on a number of business models, but also incorporates elements of corporate strategy, individual sector objectives and value delivery within the vertical markets and the wider society.

In D8.3 we zoomed in on commercial exploitation as a first step to understand business viability and providing an "optioneering" capability for buyers of 5G technologies to assess different solutions and architectures. Our analysis took the output from D2.3 on commercial and economic benefits of the 5G-TOURS innovations and married it with a breakdown of the costs required to implement and support 5G services under various deployment scenarios.

Moving forward we wanted to build on the earlier work and provide a more holistic view of business viability that goes beyond an assessment of the ***potential*** capabilities of the technology and seeks to inform decisions makers in the value chain about the likelihood of any investment delivering positive, meaningful outcomes.

Markets for 5G mobile service adoption by vertical industries are immature and introducing advanced new technologies and capabilities such as those afforded by 5G creates an "unsettled space" where the possibilities are vast. Many fruitful relationships are yet to be established and it is far from clear who will lay claim the to the potential value or how.

Here we present a ***practical interpretation*** of a model that has been developed at Oxford University to explore the innovation space in nascent markets where products might lack definition, where industry structures may be unclear and where the logic for market actions may be haphazard. It is intended to provide a snapshot of the landscape and inform decision-makers as to the innovation – ecosystem fit in a way that allows them to prioritise investment at an early stage.

2.3 Oxford University Integrated TMO Framework

2.3.1 Introduction

The Oxford University Integrated TMO (**T**echnologies, **M**arkets & **O**rganisations) Framework was developed at the university's Saïd Business School as part of the content for its Strategy & Innovation courses[1].

The approach recognises the huge variety of scale and scope that exists within the innovation space and in particular across these three dimensions (Figure 1). It seeks to encourage leaders to consider the interdependent relationships between "technology dynamics, nascent markets, and organization capabilities" and draws on a variety of tried and tested models that help to explore what the landscape of innovation looks like for them. This empowers managers to develop robust strategies that support successful innovation and deliver greater value for their organisations, their partners and their stakeholders.

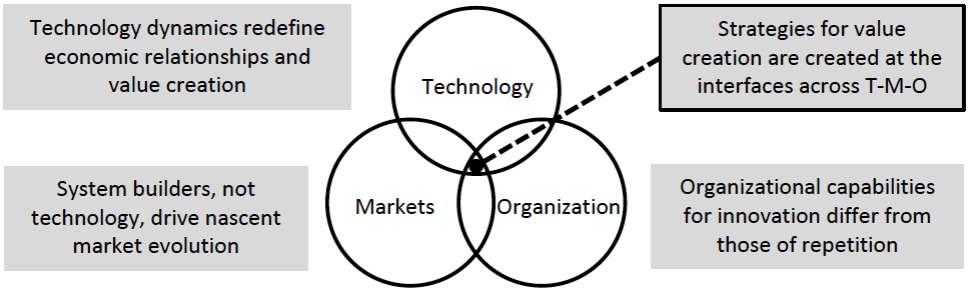

Figure 1. Oxford TMO Framework.

[1] Ventresca, M., and V. Seidel. The T-M-O Framework: Strategic Innovation across Technology, Markets, and Organization. University of Oxford, 2020.

2.3.2 TMO-Governance

5G-TOURS is heavily focused on innovation as leveraged by the enhanced technological capabilities offered by 5G. At the same time the project recognises that value is created not by technology in itself but in the dynamic interplay between technological development, market formation and organisational capability. Innovation in processes and relationship building can be just as important in creating successful products and services.

Furthermore, we also recognise that innovation travels along trajectories whose pace and direction can be motivated by numerous objectives and purposes. It is important therefore, that private enterprise and public organisations realise the impact of their operations and aim to deliver far more value against sustainability targets and align themselves better with recognised ESG metrics.

The European Commission's stated aims include achieving sustainable development and social progress and protecting and improving the quality of the environment. The project has therefore chosen to expand the TMO framework to include "Governance", which allows for innovations to be rated on the basis of their impact on the environment and on society (Figure 2). It is also intended to reflect the integrity, principles and motivations of the organisations and actors involved in the delivery and exploitation of the innovations, which is an increasingly important part of the investment decision making process.

In the next sections we describe how we have developed the TMOG framework into something practical by considering a number of attributes that can be used to measure innovations against each of the main dimensions. The idea is that the model can and will be customised by individuals, organisations and consortia to suit their specific needs and those of their stakeholders. In the remainder of the report, we will illustrate how the framework might be used from the perspective of a generic buyer in each of the vertical industries and on that basis which of the 5G-TOURS innovations would be most attractive to that particular market.

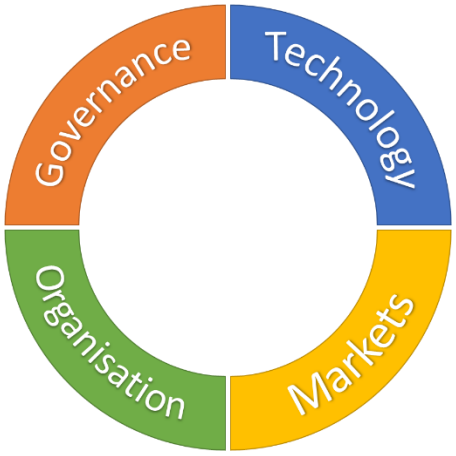

Figure 2. 5G-TOURS TMOG Outline.

2.4 Technology

Technological innovation typically builds on what exists or what has gone before and tends to be incremental rather than revolutionary. There can be periods of rapid development where significant advances are made over a short period of time and similarly there may be times when progress seems worryingly slow. Success is not guaranteed, and the journey is often characterised by numerous failed attempts and dead ends as various options are tried and tested along the way.

For business leaders and managers such uncertainty is manifest as financial risk and decision makers will normally seek to reduce such risk as far as possible to improve their chances of generating a positive return on any investment[2]. Two critical factors that can have a bearing on the risk profile of a technology trans-formation

[2] Different actors have different appetite for risk noting that steps taken to de-risk a project or investment might incur such expense as to render the enterprise unviable.

project are the maturity of the technology(ies) and their effect. In 5G-TOURS we have chosen to measure the innovations in terms of their readiness and impact to reflect the risk-reward profile of the specific product or service.

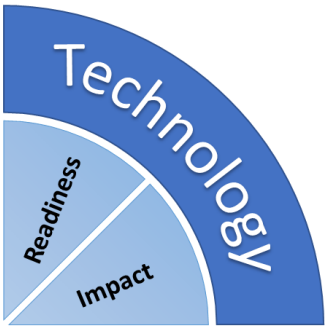

Figure 3. 5G-TOURS TMOG Outline – Technology.

2.4.1 Technology Readiness

Technology readiness is a measure of technical maturity and was presented in D8.3. To recap, the TRL scale was developed at NASA during the 1970s and adopted in EU in 2010 [11]. It has been adapted for 5G-TOURS and aims to capture the maturity of a project's solutions simply, with a single score.

Technology Readiness Levels are an accepted method used to assess solution maturity, making a clear distinction between research ideas (TRL 0 – 3), innovation prototypes (TRL 4 – 5) and more established technologies, with proven capabilities, closer to commercial launch (TRLs 6 to 9).

The methodology is designed to help leaders and decision makers implement their innovation strategy based on an understanding of the technical merit of innovations, solutions and projects. Scores reflect the level of risk that innovations can deliver on their promise by indicating levels of robustness, accumulated knowledge, and practical experience.

Figure 4. Technology Readiness Level Framework (Cloud Watch Hub, 2020).

2.4.2 Technology Impact

In this latest period, we have extended the concept of TRL to consider the potential **impact** of a particular technology. The intention is to provide a measure of technical originality and the potential for disruption to established products and solutions.

In assessing the 5G-TOURS innovations we consider the level of performance improvement relative to the current art. Where solutions deliver entirely new capabilities or functionalities, the innovation will score highly. We also judge innovations on the basis of whether outcomes can be delivered by existing or alternative technologies and the ease by which that is possible.

Innovations that deliver a set of unique outcomes only realised using the technologies in question are assigned a high score. However, if the same or similar outcomes can be achieved via legacy solutions, with little modification or additional development, then the innovation will be assigned a lower score.

2.5 Markets

As much as invention drives technological progress, we must also recognise the role of markets in capturing the value of emerging technology and powering the innovation engine through re-investment.

Technology evolves to fulfil unmet needs in existing markets (demand pull) or to fuel the growth of new markets (technology push), but demand is often immature and poorly defined so there can be decades between invention to commercialisation and then sales take-off (if it happens at all).

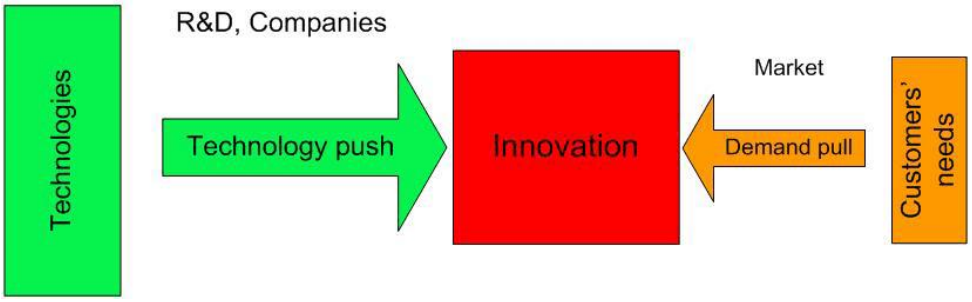

Figure 5. Technology - Customers' Demand – Innovation.

Who will capture the value that emerges depending on many variables. In the previous section we spoke about the imitability of outcomes using other solutions, but we might also want to think about who has control over the complimentary assets i.e., the other solutions, resources and infrastructure we may come to rely on for our innovation to be successful.

Competitor organisations, intermediaries, and institutions (e.g., government) can be influenced, if they are known, but rarely controlled. We have therefore limited the scope of our assessment of market potential to simplify the analysis and have focused on elements where we have a greater degree of confidence.

The two critical factors concerning markets that can help to determine the risk profile of an innovative product, service or project are the maturity of the market(s) and their potential return. In 5G-TOURS we have chosen to measure the innovations in terms of the market readiness and commercial value to reflect the risk-reward profile of the specified innovation.

Figure 6. 5G-TOURS TMOG Outline – Markets.

2.5.1 Market Readiness

As with Technology readiness, Market readiness was presented in D8.3. Market readiness is an estimate of the "potential for commercialisation of the technology offering and provide a context from by which it can be assessed". It aims to capture the level of traction and adoption in the market with customers and stakeholders and as with the TRL framework is similarly graded according to a 10-point scale (Figure 7).

Four stages are defined as follows: a MRL describes the level of commercial traction and can also help in defining dissemination of less mature results. 0-3 correspond to IDEATION; 4-5 to TESTING; 6-7 to TRACTION and 8-9 to SCALING. Innovations that are commercially untested, or have no analogous solutions in existing markets, will receive a low score with higher scores reserved for those innovations that are commercially proven with predictable growth.

The MRL model is intended to consolidate the internal[3] view on the latent market demand and scalability potential of innovations. As an indicator of market-fit they reflect the amount of work required to bring innovations to market and therefore represent the degree of risk that innovations can be commercially successful at the particular time of enquiry.

Figure 7. MRL Model.

2.5.2 Commercial Value

In this latest period, we have extended the concept of MRL to consider the prospective financial impact of a particular innovation. The intention is to provide an estimate of financial benefit for the investor's organisation. The investor might be on the supply side, directly financing R&D and looking to make a profit from direct sales. Or they may be on the demand side, purchasing innovative technologies to improve their own line of business if they consider solutions can increase profitability (lower costs, increase revenues).

[3] This can be internal to the department, organisation, consortium etc

In D8.3 we considered the profitability of some of the 5G-TOURS innovations by looking at the cost to implement the supporting 5G infrastructure. D2.3 provided input on the commercial and socio-economic potential[4]. This analysis feeds directly into the commercial value dimension of TMOG model. However, unlike the MRL assessment, which has a well-defined scale, commercial value is judged relative to other innovations under consideration e.g., in the same sector.

We also include a subjective assessment of availability or control of complimentary assets, and imitability or appropriability of the market opportunity. The idea is to provide guidance on the degree to which the investor's organisation is in control of the value chain and the extent to which they can influence the market.

Innovations that demonstrate no obvious financial benefit (commercially or operationally) or are easily reproduced by others (high imitability) are assess as lower potential. Where they are readily monetizable and cash-generating, with scalable commercial returns, or are difficult for the rest of the market to emulate, the assessment will be higher. Clearly the highly assessed innovations will appeal far more to financers of innovation.

2.6 Organisation

Organisational capabilities and relationships are equally as important to successful innovation as the technology and market dynamics. Enterprises that exhibit sustained success in innovation typically have clear systems and procedures that support their R&D efforts. Having a culture of innovation and enquiry is also an asset as is a willingness to embrace change and challenge accepted norms.

However, the value of organisational capability can be magnified significantly by cultivating experience and expertise across organisational boundaries e.g., between departments, between partners, with other stakeholders and even with competitors if it means everyone wins. The collaborative efforts around telecommunications standardisation are one such example of an entire industry coming together to create greater value.

In the 5G-TOURS TMOG framework we have aimed to capture organisational capabilities using two distinct metrics, namely organisational effectiveness and organisational readiness, which assesses the competence of the organisation, and the wider ecosystem, to explore new opportunities and to exploit them.

Figure 8. 5G-TOURS TMOG Outline – Organization.

2.6.1 Organisational Effectiveness

In 5G-TOURS we define Organisational effectiveness as the ability of actors to manage the development of innovative solutions and deliver innovative projects. The intention is that the metric shall reflect the strength and agility of organisations or ecosystems through their internal and external relationships.

Successful innovation is typically built on organisational stability, resilience and mutual understanding. These can help to support dynamic environments where experimentation and enquiry is actively encouraged. Such

[4] Here we are concerned with the commercial value opportunity of the innovations. Socio-economic value as a metric is covered under the section on Governance.

characteristics can, however, be eroded by sources of organisational inertia that will hinder the ability to innovate with purpose. Pointless complexity[5], latency, bureaucracy etc are often a consequence of bloated hierarchies, functional duplication and operational misalignment. Unless there is strong leadership in evidence, the risk posed by these factors typically increases as the number and diversity of stakeholders increase.

Owing to the difficulty in quantifying intangible traits, it is suggested to adopt a relative approach to assessing innovation projects. Projects involving partners with a strong culture of supporting innovation and change will be assessed highly compared to others where the foundations for innovation are weaker or alignment of purpose is unclear.

2.6.2 Organisational Readiness

Closely related to organisational effectiveness is organisational or operational readiness. Readiness is intended to measure the current abilities of organisations to deliver (or receive) innovation solutions to (from) the wider ecosystem. We wish to understand the maturity of ecosystem networks and capture the experience of the supply chain in delivering innovations of a similar nature. An organisation may be excellent at innovating but lack the skills or experience relevant to certain industries or technologies.

Projects will be assessed highly where they include ecosystem actors that have relevant skills and experience or established processes and proven working relationships with each other. Where there is less evidence of any proficiency with comparable innovations then projects will be assessed lower.

2.7 Governance

As previously mentioned, the Oxford TMO framework has been extended under 5G-TOURS to include governance as a measure of the social and environmental **purpose** of the innovation projects and their stakeholders. Governance is a vast and growing area of research covering the full set of social and physical conditions in which people live and work, including socioeconomic, demographic, environmental and cultural factors.

In 5G-TOURS we are mainly concerned with the impact of the actions and outcomes associated with the innovations and their ecosystem actors. Examples include, but are not limited to

- Environmental impact & positive action on
    - Energy
    - Water
    - Air quality
    - CO_2 emissions
    - Biodiversity
    - Waste
- Social impact & positive action on
    - Employee wellness
    - Equal opportunities and rights
    - Education and welfare
    - Poverty
    - Community support
- Corporate Management & Responsibility

[5] Some complexity can be good https://hbr.org/2020/01/taming-complexity

- Diversity of human resources
- Health and safety
- Executive compensation
- Accountability
- Regulation

Some sectors have come under more scrutiny than others concerning so-called **ESG metrics**, particularly extractive industries like oil production and mining. However, social and environmental pressures and in particular the effects of climate change, are bringing more businesses into focus, including those in the technology sector. In order to make sense of this wide-ranging landscape we have decide to focus on two main aspects, namely ESG credentials and Socio-economic value.

Figure 9. 5G-TOURS TMOG Outline – Governance.

2.7.1 ESG Credentials

In 5G-TOURS we have adopted a somewhat broad-spectrum view of governance by judging the extent to which sustainability and responsibility is embedded-in the missions, objectives, values and standards of the actors. We also consider the orientation of the wider market and industry sectors looking at the collective positions and attitudes on the factors mentioned above.

Investors are increasingly seeking evidence of positive behaviours, ethical cultures and proven records of purposeful action. Where there is alignment between actors and stakeholders their effect is amplified. Pro-jects with a clear ESG trajectory, strong alignment and evidence-based authenticity will be assessed more highly than those with incoherent or weakly aligned intentions.

2.7.2 Socio-economic Value

Socio-economic value is a more quantitative measure of the direct benefit of 5G-TOURS innovations to local communities, society and the environment. It is based on the work of D2.3, which provided results on the socio-economic and ecological potential of the various projects in terms of their wider financial impact whether through cost savings or increased prosperity and wellbeing. It is difficult to quantify many sources of socio-economic value, so we also consider qualitative outcomes in our comparative assessment.

Projects are assessed favourably where socio-economic and environmental outcomes are highly quantifiable, readily scalable and extend far beyond the immediate ecosystem. Where benefits are less clear, with no obvious quantitative nor qualitative impact then they will be assessed lower.

2.8 Ecosystem Priorities

The complete 5G-TOURS TMOG framework is depicted in Figure 10 below. This framework draws heavily from the Oxford University model but is quite different in its objectives and its execution. The Oxford model is geared towards sensemaking of nascent innovations in opaque markets and organisations. What has been developed here is a practical framework for the analysis and assessment of 5G-TOURS innovations and projects, which by their nature are a little more mature. The Oxford model seeks to integrate several existing models and

create a more holistic picture to better direct strategic planning with respect to a **particular** theme. In 5G-TOURS we wanted to create a similarly holistic framework, but one that allows a comparison **between** projects.

Figure 10. 5G-TOURS TMOG Outline.

Our more specific purpose was to take the view of a generic 'buyer' of 5G solutions in the various vertical industries represented in the project. However, the result is something which we believe would be useful beyond 5G-TOURS and may be taken and adapted by individual organisations, consortia or ecosystems etc to suit their own purpose, particularly when deciding where to commit funds for new technology projects. To be used to maximum benefit it is important to be clear and transparent across all stakeholders about what is and isn't included in any adapted version of the framework, particularly when it comes to the burgeoning subject of Governance.

Each Industry sector, ecosystem, actor will have their own set of individual or collective priorities. Therefore, within 5G-TOURS we have adapted the model to reflect that each vertical industry may have different emphasis on the various dimensions, which is reflected in how much **weight** they might place on them.

A neutral assessment of all 5G-TOURS innovations would require a means to directly compare the characteristics of different industries, which could be drastically different, making such an assessment difficult to formulate and defend. It was therefore decided to treat each industry sector independently, taking the perspective of a buyer of innovative solutions on the demand side of the respective ecosystem.

We have considered the relative priorities and requirements of each sector in our assessment of the innovations and developed a set of weightings for each industry vertical, covering each of the model dimensions. The resulting weightings were then applied to the individual innovations in the formulation of their overall sector assessment.

2.8.1 Health Sector

The weightings that have been assumed for the 5G-TOURS health sector is illustrated in Figure 11 below.

Figure 11. TMOG spider diagram for Health Sector.

We have emphasised the strong focus on health outcomes, which translates to greater emphasis on technology impact and socio-economic value. The health sector has a track record of innovating and is often happy to get involved at an early stage to help direct development efforts, therefore technology readiness is a lower priority. However, there needs to be a clear market and with a very low appetite for financial risk the market readiness needs to be at an advanced stage. Organisations acting in the space tend to be highly sophisticated, but some parts of the ecosystem are perhaps lacking experience in the mass deployment of digital innovations and solutions, although that is starting to change.

2.8.2 Transport Sector

The spider diagram of TMOG weightings for the 5G-TOURS transport sector is shown in Figure 12.

Figure 12. TMOG spider diagram for Transport Sector.

Within the transport sector and for airports in particular, there is a strong track-record of technology adoption that suggesting a high degree of organisational readiness to embrace innovation and change. As with the medical sector, there is a willingness to engage with technologies at an early stage and to invest in their development, hence the lower weightings.

Technologies do not need to be particularly impactful as long as there are marginal benefits that can scale across organisations and provide a positive return. Commercial value (including operational efficiency) is therefore an important consideration.

As an industry, transport is acutely aware of its aware of its environmental responsibility and social impact, therefore it is important for organisations and enterprises to be seen to act responsibly. However, profit margins are tight and many businesses, and therefore buyers, are primarily focused on commercial returns.

2.8.3 Tourism Industry

For the 5G-TOURS tourism sector we have assumed that the emphasis on each branch of the TMOG model corresponds to the diagram in Figure 13.

The tourism sector is very competitive, whether that is different attractions competing for customers in the same territory or organisations coming together to compete with other cities and countries around the world. Consequently, the tourism sector will enthusiastically embrace any innovations that has mass appeal and provide a clear advantage over competitors. For that reason, we assume that innovations need to be reasonably advanced in their development with particular emphasis on technical and commercial maturity (readiness).

Where innovations are able to deliver wider value across society, particularly within public funded organisations such as many museums, then buyers are likely to be prepared to sacrifice commercial value for meaningful socio-economic impact. At the same time, the tourism sector is considered to be less focused on ESG strategies as it is heavily reliant on transport to bring visitors and move them around, and in many quarters, there is a reliance on casual or low-paid labour.

Although organisations tend to be smaller, independent and more agile, when it comes to technology adoption and innovation, the sector is assumed to be largely reliant on others to lead.

Figure 13. TMOG spider diagram for Tourism Sector.

2.9 Conclusion

In this section we have presented a framework to facilitate the assessment of 5G-TOURS innovations according to their viability from an enterprise perspective. The framework is influenced by the Oxford University TMO model and has been adapted to create a practical tool to better inform business leaders and decision makers decide when and where to commit resources for the development and implementation of innovative solutions.

The 5G-TOURS TMOG model adds the extra dimension of governance to reflect an increasing awareness amongst business, government and society about the need for responsible and sustainable enterprise. Whereas the Oxford University model aspires to make sense of embryonic technologies and markets, the 5G-TOURS

framework is better suited to solutions that are closer to being commercialised. However, it is felt that the model is flexible enough to be adapted for a wide range of scenarios and actors.

In the sections that follow we describe the results of applying the framework to the various 5G-TOURS innovations within each of the industry sectors. It is not intended to expose the detailed analysis since the assessments are largely subjective and therefore open to debate. The assessment of the innovations are intended to reflect a certain, hypothetical, viewpoint of a generic industry buyer. We present those that are judged to be the most viable in each of the industry sectors, although only time will tell whether the actual uptake of each innovation matches the expectation.

3 Airport Sector Business Models, Deployment and Operations

The innovations in the Transport/Airport related work package (WP6) are related to passenger experience, passenger safety and operational situational awareness enabled by 5G and these are based on four different scenarios. These innovations are developed in the context of concrete use cases (UC):

- UC10 – Smart airport parking management

Drivers will be informed in real-time about the parking facility status as well as finding a free parking spot and be routed to it based on the parking facility status, other concurrent requests aiming to minimize the unnecessary driving that leads to increased fuel costs, and emissions. Parking facility staff will be able to monitor the condition of the facility in real time as well as view the occupancy trends. This can lead to the optimal management of the parking facility as well as the ability to schedule maintenance proactively through the platform's real-time notifications.

- UC11 – Video-enhanced ground-based moving vehicles

The end users (follow-me car driver and the control centre personnel) will increase their situation awareness, have better and more interactive collaboration among themselves and pre-emptively address irregular or harmful conditions that might happen.

- UC12 – Emergency evacuation

The end-user (evacuee) will be guided towards the nearest exit via an intuitive interface rather than a set of instructions that maybe confusing for the users under stress. Also, the location accuracy that will be provided from the network will provide the users precise location and way finding information and guidance. Moreover, the use cases will take into consideration the terminal design and the exit routes capacity in terms of evacuees in order to identify the most optimal route for the passengers to exit to safety.

- UC13 – Excursion on an AR/VR-enhanced bus

This UC aims at demonstrating the value of the 5G technology for groups of people travelling (e.g., on a bus) to visit a site of interest, enabling the provision of good quality digital experiences to the travellers both during the transportation to and from the destination and during the visit. Although it has been implemented as part of the Athens testbed, from a business viability perspective it is considered that the most impactful context is as a tourism application. Consumption of the service mostly takes place away from the airport and relies on wide-area infrastructure. Infrastructure requirements and costs are therefore analysed for providing coverage along major road corridors as part of the city setting. To paint a more meaningful picture of the innovations from an eco-system and value chain perspective, the 4P's framework (Product, Process, Position and Paradigm) is used to assess how technology meets both medical needs and provide business value for each partner along the value chain.

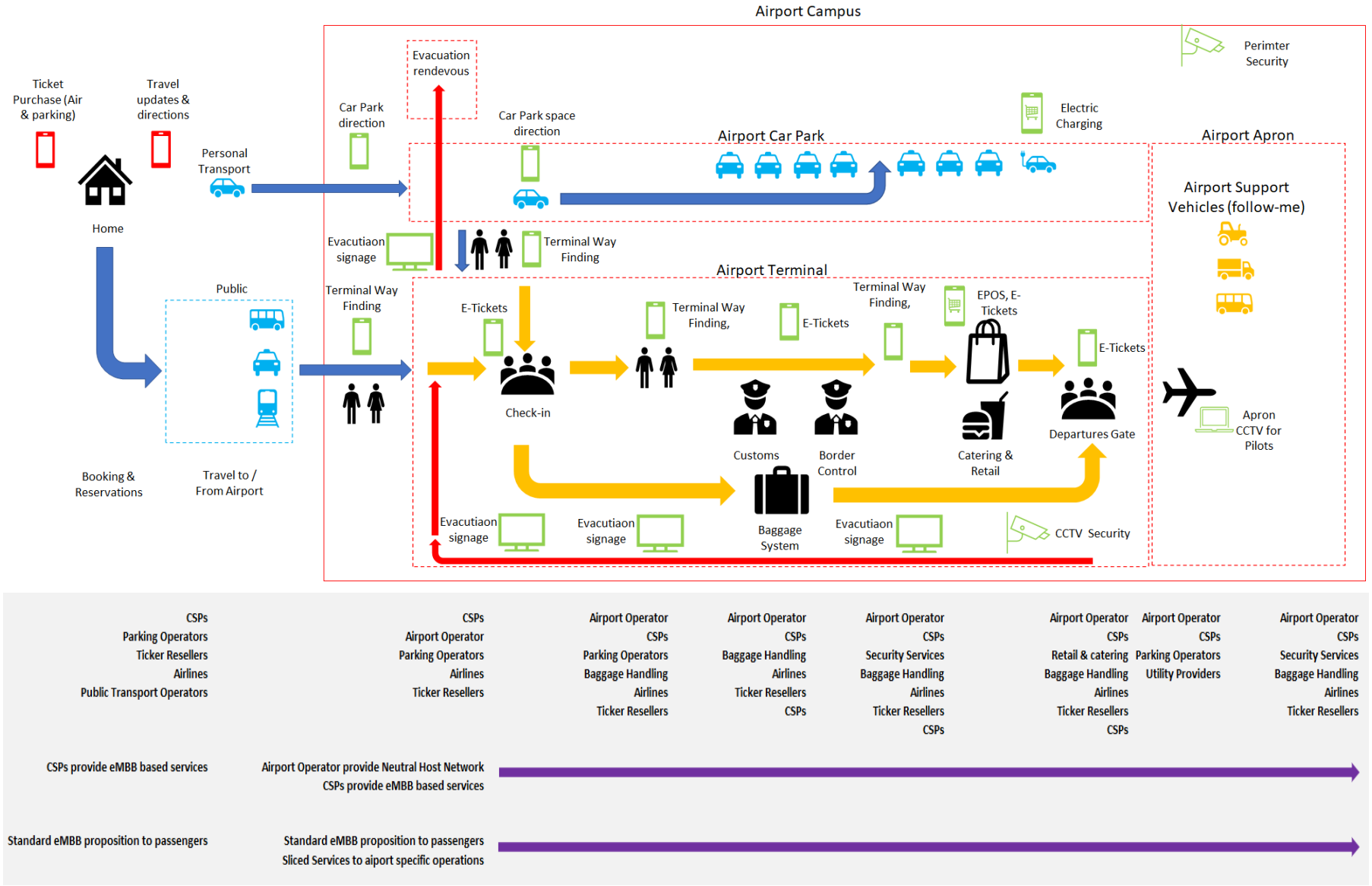

Figure 14. Airport User Journey.

The Neutral Host Business Model is a recognized model for the Airport environment. This is primarily due to the requirement to host all national CSP's to serve all passengers and operational staff in the airport, irrespective of which CSP they subscribe to. Security and disruption considerations mean that it's better to have a shared infrastructure solution and a single responsible party, rather than multiple MNO solutions and multiple teams vying for access. In addition to public mobile services, a Neutral Host solution can also accommodate targeted Airport / Vertical specific services as demonstrated by the range of UCs. Where business requirements dictate, such vertical-specific services can be supported on a Private 5G Network but sharing elements of the same Neutral Host infrastructure as the CSPs.

An overview of the innovation characteristics of each of the use cases in WP6 – Transport & aviation industry is provided in the following paragraphs.

Table 2. Transport/aviation use cases and their innovation characteristics in 5G-TOURS.

Innovation Unique ID	Innovation Title	Linked UC(s)
03	Large scale IoT deployment using 5G mobile Networks standards for identifying car park availability and driver guidance in large car parking environments.	UC10
04	5G based indoor navigation technology for passenger guidance using 5G enabled devices	UC12
05	Multiple Ultra High-Definition Video feed transmission from 5G based enabled ground moving vehicles	UC11
16	Smart Parking Management	UC10
17	Video enhanced ground-based vehicles	UC11
18	Airport Evacuation	UC12
19	AR/VR Students Bus Excursion	UC13

For each of these use cases one or more innovations have been identified that are described in more detail in the next sections.

3.1 Innovation #03 *Large scale IoT deployment using 5G mobile Networks standards for identifying car park availability and driver guidance in large car parking environments*

3.1.1 Summary of the innovation

This innovation makes use of the mMTC (massive Machine Type Communications) and NB-IoT (Narrow Band – Internet of Things) to research the installation of potentially thousands of proximity sensors at every car park position of massive car parks such as those at airports, stadiums, shopping centres etc. The sensors will detect, determine and indicate if the parking spot is occupied or not, collect information from all positions that they sensors are installed and transmit their status over a 5G network to a management portal.

The system will handle the driver's request to identify the best parking position, taking into consideration the driver's location and preferences and calculate the optimal route for the driver to reach the assigned parking position. A mobile application provides this information to the driver while the system is receiving the preferences and location information of the driver from the mobile app.

Drivers will have the ability to request to see the availability of available parking positions beforehand and be guided to empty car park spaces in an efficient and environmentally friendly manner.

3.1.2 Innovation value

Drivers will be informed in real-time about the parking facility status as well as finding a free parking spot and be routed to it based on the parking facility status, other concurrent requests aiming to minimize the unnecessary driving that leads to increased fuel costs, and emissions. Parking facility staff will be able to monitor the condition of the facility in real time as well as view the occupancy trends. This can lead to the optimal management of the parking facility as well as the ability to schedule maintenance proactively through the platform's real-time notifications.

The additional value of this innovation is that allows the visitors and passengers of the airport that arrive with their own car, to have more control of their journey to the airport both in terms of effort and time required to reach the airport terminal. Keeping passengers and visitors informed about every step of their – the parking process steps on this case – diminishes the stress and the anxiety of the passenger in finding a parking post, reduces the risk of the and provides the sense control. A stress-free passenger that arrives at the airport terminal on time is more likely that will have the time and the sentimental propensity to proceed to impulsive purchases at the airport terminal contributing considerable to the non-aeronautical revenues of the airport.

3.1.3 Exploitation

This innovation affects one of the most lucrative and important revenue streams at airports. Car Parks comprise an important part of the airport's turnover that can amount to 10%-15% or even higher - depending on several parameters the location of the airport, the proximity to the cities etc. Furthermore, the innovation can have the propensity to change the charging model for the car parking positions from a static one to a dynamic one and introduce concepts as revenue/yield management for parking spaces that are high in demand such as the ones that are close to footbridges or bus stops that are used to reach the airport terminals.

The airport will work closely with car park operators to introduce the new capabilities that the new smart parking features introduce and fine-tune the exploitation strategy of airport car parks accordingly. The introduction of a revenue/yield management model for the parking places that are high in demand can introduce an increase of revenues of up to 30%. The investments required are the 5G based IoT sensors that will be placed at every parking spot, the management platform and the mobile application.

Additionally, in the case of the revenue/yield management model where drivers will be pre-assigned the parking spot that they bought or actioned in advance that parking operators must introduce mechanisms that will save the parking spot until the assignee driver arrives. This means an additional cost for automated parking barriers, displays and/or digital signage will need to be also taken into consideration.

Finally, as the neutral host model has been foreseen as the most prominent model for the smart parking, the assignment of a dedicated mMTC network slice must be coordinated with the operator of the neutral host 5G mobile network.

3.2 Innovation #04 *5G based indoor navigation technology for passenger guidance using 5G enabled devices*

3.2.1 Summary of the innovation

This innovation makes use of the 5G features for enabling the identification of the location of passengers and how they progress with their journey - in a massive scale - in large and complex structures such as an airport terminal. The 5G Mobile features will be complimented with specific software that will map the floorplans of the building structure and will provide specific features such as journey characteristics such as origin and destination, way finding and navigation instructions to the passengers.

Large building structures such as airport terminals are complex structures with multiple floors and large number of rooms where thousands of passengers are using them at any given time. In this context this innovation is addressing both passenger experience aspects through the efficient and effortless navigation of passengers within the airport terminal but also passenger safety aspects during an emergency evacuation.

3.2.2 Innovation value

The location based and indoor navigation technologies have been widely studied and successfully commercialized in many applications such as mobile phones and unmanned systems. In particular, indoor guidance technology is becoming increasingly important with the emergence of new sensors, positioning data analysis and Artificial Intelligence (AI) technology, as well as the increase of public interest and social potential.

Proximity, location based and way finding services, assisted by AR/VR ones, will help passengers to autonomously navigate within even the most complex and unfamiliar venues. During this process the passengers can receive status information regarding their flights and how they can efficiently optimize their journeys according to their preference such as shopping, dining, visiting a business lounge or having an online collaboration with colleagues.

Furthermore, the platforms responsible for the above services can interface with other platforms and allow for personized marketing campaigns and commercial initiatives maximizing business revenues and minimizing customer engagement costs for retailers. Finally, through the proximity, location based and way finding services, passengers can report their status and location to airport operators and airline personnel so that they can efficiently plan and monitor their processes (e.g., queuing for security checks, aircraft boarding, pax flow management etc.). Similarly, passenger – in case of laws and regulations for pandemical situation requesting – can transmit their vital health indications to health authorities, in an effort to further enhance passenger trust and their fitness for travel in order to protect general public and contribute towards the impediment of COVID-19 virus spreading.

Location based and indoor navigation technologies can serve safety and benefit special groups such as the elderly, children, and the disabled. Meanwhile, these technologies can help the widespread usage of Mobility as a Service (MaaS).

3.2.3 Exploitation

Location based and indoor navigation technologies will be part of the Airports offering to passengers through the airport mobile app. In that way the passengers will already have preloaded the application to their smart devices and in the case of an emergency evacuation the application will already have been preloaded and will immediately be able to provide the required location based and indoor navigation information and guidance services that will lead the passengers to safety thorough the most efficient and capacity capable escape route.

During non-emergency periods the app can be used by the airport concessionaires for the location of prospective customers and entice them with proximity based or personalized offers through a digital airport marketplace platform.

Finally, the airport can further exploit the location based and indoor navigation technologies to compliment digital assistants with advanced guidance capabilities for passengers that request flight and airport related information and directions related to certain areas of the airports such as check-ins and gates pertinent to the flights that passengers are interested in.

3.3 Innovation #05 *Multiple Ultra High-Definition Video feed transmission from 5G based enabled ground moving vehicles*

3.3.1 Summary of the innovation

This innovation makes use of the transmission speeds and bandwidth capacity of the 5G mobile network to broadcast Ultra High-Definition video feeds from ground-based vehicles equipped with High-Definition resolution video cameras. The follow-me ones that operate within the airport apron and attend critical events and accidents at the respective area. The feeds will be aggregated to a media streaming server and transmitted to the operational centers of the airport and airport stakeholders such as police, firefighting services, civil protection etc. with the aim to achieve a common situational awareness. This will assist the decision-making process and the coordination of the first responders in case of an incident.

3.3.2 Innovation value

The Operational centres of the Airport stakeholders – including the one of the Airport Operator – coordinate a large number of activities and oversee most of the processes at the airport's apron. It is very important for these operational centres to have a detailed operational overview and status (situational awareness), in a timely manner. Aspects such as flight turnaround process of aircrafts, mobilisation of ground handling equipment and personnel, preparedness of the apron to safely cater for aircrafts are only a few of the aspects that operational centres are responsible for.

In the case of an incident at the apron though, the dynamics and the number of perturbations of the different actors required to help mitigate the incident, increase exponentially. Incident handling procedures dictate that all involved stakeholders including government authorities such as police, fire fighting, medical and civil protection services etc., must quickly respond and orchestrate their actions to mitigate the incident.

The value of the multiple High-Definition Video feed transmission from 5G based enabled ground moving vehicles that are attending the scene of the incident, is that it provides detailed information regarding the extent and the impact of the incident which can be further used to calculate the impact to airport operations and the estimated recovery time. Furthermore, these video feeds can be transmitted to multipole operations centres assisting further the coordination of the stakeholders and expediting their decision making and coordination.

3.3.3 Exploitation

The exploitation for this innovation is to include these multiple High-Definition Video feed transmission from 5G based enabled ground moving vehicles services in a greater airport operational concept and framework. This innovation has the potential to reassess the existing emergency plans and crisis management procedures especially in the event that the coordination of multiple stakeholders is needed.

3.4 Innovation #16 *Smart Parking Management*

3.4.1 Summary of the innovation

Smart parking management allow drivers some unique capabilities and advantages especially in massive, high demand and roughout carparks such as the ones that can be found at major international airports. Smart parking management informs drivers in real-time about the parking status the available parking spots as well as view the occupancy and utilization in real time. This can lead to the optimal management of the parking facility as well as scheduled and unscheduled maintenance and unavailability periods.

The smart parking management solution is complemented by a mobile app that is used for the interaction and the notification of the platform with the drivers. It displays parking occupancy information, way finding instructions, interactive maps that updated in real-time and information regarding the stats of car parks as well as financial information in the cases of car parks utilizing diversified or dynamic charging schemes.

3.4.2 Innovation value

This can lead to the optimal management of the parking facility as well as schedule maintenance proactively through the platform's real-time notifications. Smart parking management systems provide multiple benefits to operators of massive car parking areas such as airport operators. In more detail they provide:

- User Experience – A smart parking solution gives passengers the control to plan and organise their journey, the duration and the cost of stay in advance. Keeping drivers informed through their mobile app alleviates any anxiety or stress and provides visibility and control of the journey to the airport to the drivers.
- Assigned parking – Users select the best spot available according to their preferences, saving time, resources and effort. This is important for high throughput parking's where spaces change status very often, such as short-term parking from Airports or Shopping centres.

- Reduction of traffic – Traffic congestion decreases as fewer cars are required to drive around in search of an open parking space.
- Environmental impact – A smart parking solution will significantly decrease driving time, thus lowering the amount of vehicle emissions and ultimately reducing the global environmental impact.

3.4.3 Exploitation

New revenue streams are possible with smart parking technology. Airports can enable tiered payment options dependent on parking space location such as proximity to terminals, footbridges etc. Additionally, the smart parking management solution can provide a revenue management and yield management capabilities to airports, similar with the ones that airlines are using to auction the passenger seats at their flights. This means that popular parking spots could be auctioned to the highest bidder and provide an additional revenue stream to the airports.

Finally, a loyalty and reward programs can be integrated to the smart parking management solution encourage repeat users and allow for upselling and cross selling opportunities with other products and services that the airport is offering such as access to business lounges, priority security screening etc.

3.5 Innovation #17 *Video enhanced ground-based vehicles*

3.5.1 Summary of the innovation

The innovation characteristics are similar to innovation #05 and is based on the video transmission of video feeds from airport operational vehicles that are responsible for the monitoring or the airport and aircraft operations on the apron and attending at incidents and emergencies.

The feeds are transmitted to the Airport Operations Center (AOC) and are aggregated to a media streaming server and transmitted to the operational centers of the airport and airport stakeholders.

3.5.2 Innovation value

The airport operational centers will increase their situational awareness and have better and more interactive collaboration with other stakeholders that will have access to these video streaming feeds. This will allow for expedited and coordinated decision making and response that will help mitigate any irregularities, incidents and emergencies.

The innovation value is similar to innovation #05 at par. 3.3.2.

3.5.3 Exploitation

The exploitation of the Video enhanced ground-based vehicles takes place in the context of the responsibility of the airport to provide a safe and secure operating environment for aircrafts, passengers, personnel and equipment. According to European Union Safety Agency (EASA) regulations Airports must define and implement a safety management system that safeguards the aircraft operations at Airport. The exploitation of Video enhanced ground-based vehicles innovation will take place in the context of the safety management system as an enabler for promoting safety and security.

3.6 Innovation TMOG Assessment

5G-TOURS innovations applicable to the airport sector were assessed according to the TMOG framework described in chapter 2. We applied the sector ratings of section 2.8.3to reflect the preferences of a buyer a generic buyer of 5G products and services in the airport sector The outcome was that innovations #4 and #5 were considered as presenting the best opportunity to leverage 5G infrastructure investment and deliver the best overall returns against TMOG criteria at the time of writing.

3.6.1 Assessment of Innovation #04 Business Viability

Innovation #4 concerning 5G based indoor navigation technologies for passenger guidance scored highly on technology impact, commercial value and organisational effectiveness.

From a technology perspective, whilst innovation #4 may not yet be at the level of commercial deployment it was felt that in terms of the technology impact, the innovation has the potential to instigate a seismic shift in the ability to deliver highly accurate and reliable in building positioning information compared to that of existing alternatives. Such capabilities could be instrumental in delivering an extensive range of new products and services, which can be highly disruptive to the way airports are currently run and organised, going far beyond the way-finding application demonstrated by 5G-TOURS.

The Innovation also scored highly against commercial value as it was felt that the ability to offer new products and services offers tremendous scope to commercialise and monetise passenger information and data, as well as helping to improve airport operational efficiency and in doing so, reduce costs.

Retail outlets, restaurants and cafes for example would be willing to pay a premium to access customer information in real-time and push their own products and offers direct to passengers as they approach their enterprise location within the airport.

Innovation #04 also assessed highly against organisational effectiveness. It was felt that the ecosystem of stakeholders and actors working in and around the airport environment would be well motivated to make innovation #4 a success. Airports are complex environments and technology plays a large part in ensuring operational effectiveness, hence many of the stakeholders are experienced in implementing new and complex technologies and would be able to impart a great deal of knowledge and expertise in delivering complex technical solutions.

In addition, indoor localization in airports has social benefits such as reducing the evacuation time during an emergency event.

Away from the airport environment and thinking about transport in general, the potential for in-building location and navigation services is high. It was felt like the technology demonstrated it by innovation #4 is highly portable into other sectors and environments particularly retail and hospitality and entertainment. The platforms responsible for location-based services can interface with other platforms and allow for personalised marketing campaigns and commercial initiatives maximising business revenues and minimising customer engagement and acquisition costs for retailers.

The current global market for location-based services is driven by high demand across various sectors including agriculture, energy, defence and transportation. However, the market is dominated by outdoor solutions and services, which are largely reliant on satellite positioning systems such as GPS and its alternatives. The market for **in-building** location-based services has long been anticipated but until now remains largely untapped. If the promise of innovation #4 can be fulfilled, then the market for indoor solutions and services can grow exponentially.

Of course, there are other technological solutions that offer to deliver indoor location information such as the use of radio beacons, or using cameras, however a standalone 5G solution will bring the weight of the 5G ecosystem to bear. In particular, having the capability built into handsets and therefore readily available to customers, will make the technology more likely to be widely adopted by consumers and enterprises alike.

The emphasis on passenger (user) experience can be a real game changer for those enterprises that adopt the technology early and it was felt that where a choice exists, and all else being equal, passengers would certainly choose to use facilities where indoor navigation is enabled, and location-based services are possible. The Innovation offers the potential to improve passenger and customer safety and security. This in itself can also be a major game changer in terms of widespread adoption and uptake of the technology, with similar applications beyond the airport environment and into other settings such as hospitals, museums, factories, offices, hotels etc

In-building positioning has provided a tough challenge over the years and the lack of any widely adopted and scalable solution in today's world suggests that the market remains relatively untapped and therefore somewhat nascent. However, given the success in demonstrating the capabilities in 5G-TOURS it seems only a matter of time before the innovation is more widely adopted with the potential to create immense value across the EU.

3.6.2 Assessment of Innovation #05 Business Viability

Innovation #5 also scored highly on technology impact commercial value and organisational effectiveness. It was felt that although Innovation #5 was at an earlier stage of technical and market development it nevertheless offers the potential for significant disruption to current airport operations offering marked improvements in efficiency, safety and security.

From a technical perspective the ability to have multiple UHD video feeds from 5G enabled ground-based moving vehicles offers the ability potential to provide much more detailed data, in real-time, on vehicle status which can be used to improve the efficiency of ground-based vehicle operations.

UHD video requires a great deal of network resources (demand) and coupled with the challenge of mobility it would be difficult to deliver by any comparable technology and would typically require a dedicated, bespoke solution. The fact that 5G offers a wider array of features and services means that 5G infrastructure can deliver the necessary resources and yet also support a wide range of other, complimentary services.

At the same time, the investment in 5G infrastructure to support UHD video equipped ground-based vehicles needs to ensure that the demand is met and that the resulting service exhibits high quality and high resilience by virtue of the fact that airport operations are dependent on the reliable movement of ground-based vehicles. From that perspective the commercial value associated with the innovation was judged to be somewhat less than that offered by innovation #4, which is more readily monetised. However, the capacity for improvement in operational efficiency across the airport in terms of reduced delays and reduced disruption has the potential to realise a significant amount of value for the airport.

For the same reasons as innovation #4 it was felt that the stakeholders involved in the airport setting are typically well-equipped, highly skilled and very experienced and delivering technical innovations into this industrial setting. Consequently innovation #5 was rated equally highly on organisational effectiveness.

The aviation sector with its obvious dependency on fossil fuels means that from an ESG perspective any innovations that can prove improve efficiency will be highly valued. The research carried out in D2.3 regarding the overall socioeconomic value of innovation #5 was inconclusive therefore it is difficult to say whether the improvements in efficiency would in itself be sufficient to justify investment in the innovation, and from a governance perspective the assessment was neutral.

Finally, just as with innovation #4 it was also felt that looking beyond the airport environment, innovation #5 has a potential to disrupt the transport sector in other settings. Video equipped vehicles are likely to be a feature of standalone automation, which threatens to be a major source of growth in the transport sector (including airport operations) in the medium term. Such portability across the sector will also be key to the successful uptake and long-term business viability of innovation #5.

3.7 Cost of deploying indoor DAS vs. small cells in an airport environment

People spend most of their time in an indoor environment, such as their home, office, or other large buildings such as shopping malls, stadia, and airports. This is where most of the data are generated and consumed, and access to data services is of paramount importance for offering an excellent user experience.

Connectivity at home is predominately achieved using Wi-Fi, for which the user is responsible. At larger buildings, wireless connectivity for data services is more challenging, with the responsibility lying predominately with the venue owner.

There are different ways and architectures for realising wireless connectivity in such environments, each of which are characterised by strengths and weaknesses. Two of the most popular solutions are distributed antenna system (DAS) and small cells (SC).

3.7.1 Distributed antenna system (DAS)

The distributed antenna system follows a C-RAN approach, where the intelligence of the radio network is separated by the radiating elements. All the baseband functionality of the network is located in the equipment room(s), whose number and size depends on the needs, layout and total area of the indoor venue. The equipment room(s) include equipment from the network operators (BTS) – for each technology and band that the network supports - as well as access to the optical fibre for the backhaul. This equipment generates the signal which is transferred through coaxial and/or fibre cables to the remote units and the antennas to be transmitted.

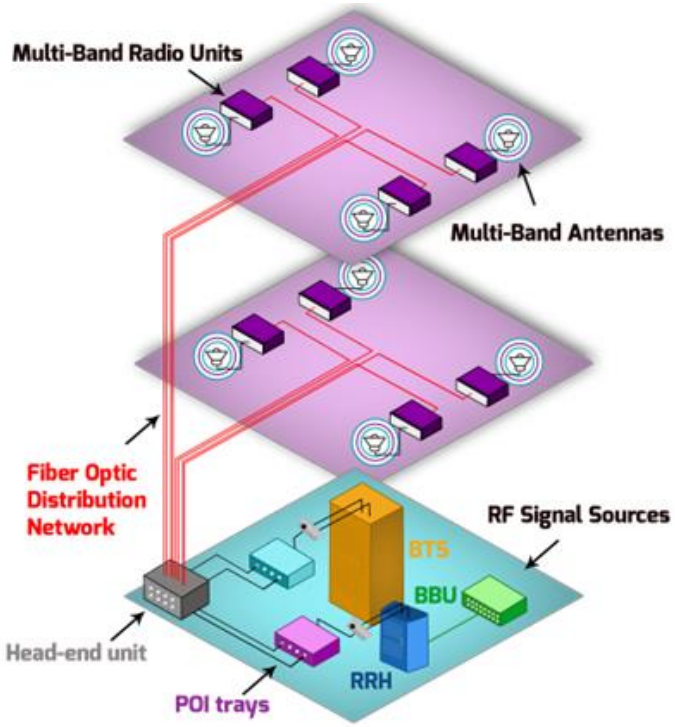

Figure 15. An example of an active DAS implementation [Source: signalbooster.com].

With a proper planning, DAS systems can potentially offer a consistent received signal coverage. In addition, DAS systems offer a network flexibility to a certain extent, as adding capacity to the network can be achieved relatively easy by updating/upgrading the equipment room with the additional capability, and zoning of the antennas, without the installation of extra antennas in the common areas, disturbing the operation of the indoor venue.

On the other hand, they require a substantial initial capital expenditure, as the passive network infrastructure (antennas) should be deployed in the beginning of the project, with a view of the future needs of the venue, as adding antennas to the network afterwards may require a substantial cost and investment.

3.7.2 Small cells

Small cells are low-powered radio access nodes, which can be viewed as miniature macrocells. Small cells perform all the communication tasks (scheduling of resources, transceiver functions, power amplification, D/A and A/D conversions) and they are usually integrated with the antenna. They are primarily used to increase capacity in hotspot areas or offer coverage in indoor environments and complement the macrocell network. Backhaul connection to the small cells is achieved by optical fibre or carrier grade ethernet.

Small cells are relatively easy to install (in indoor deployments), even though more advanced implementations may include a controller to assist with handover and baseband functions and reduce overhead.

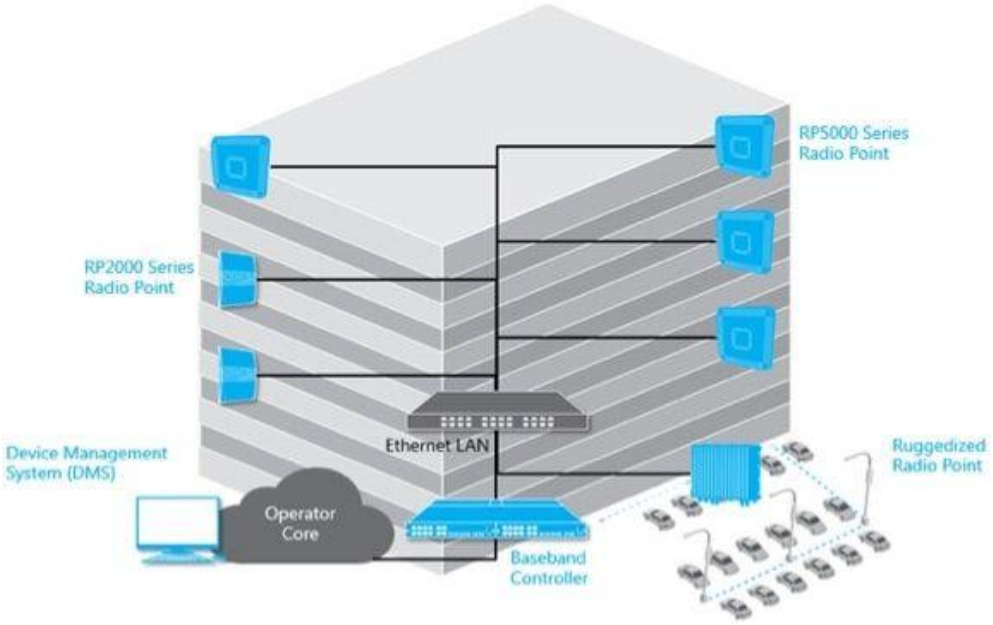

Figure 16. Small cell network on a building with baseband controller [Source: CommScope/ONECELL].

On the other hand, small cells are limited on the number of operators and bands that they can support, due to the limited size of the equipment itself, which may affect multi-operator implementations on indoor venues. Adding more bands may require the installation of more small cells, increasing thus the deployment cost.

3.8 Example – Athens's airport

Athens's international airport, Eleftherios Venizelos, is a relatively new airport, built in 2001, ready for the 2004 Summer Olympics in Athens, Greece. It is a modern airport with two terminals, the main terminal and the satellite terminal, which can be accessed by an underground corridor to the south of the main terminal.

Figure 17. Aerial photograph of Athens's airport.

The main terminal carries the majority of the traffic, in terms of passenger footfall. It has three levels – one for arrivals, one for departures, and one level is the food court – and all the airport's check-in desks are located there, as well as the belt conveyors for luggage.

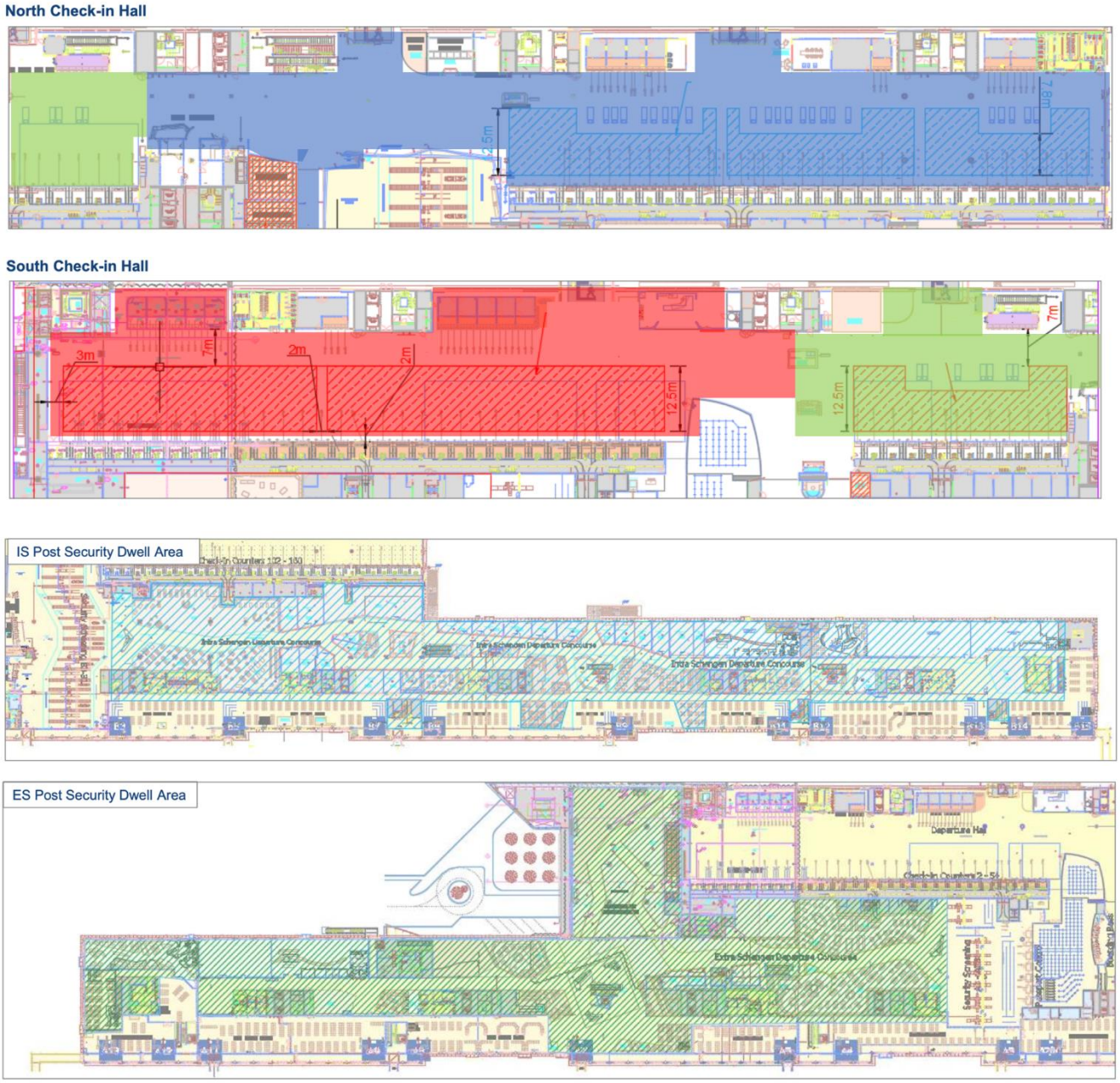

Figure 18. View of some of the areas in Athens's airport.

The total area of the airport available to the passengers is approximately 69,000 m^2, while the peak population is approximately 15000 passengers. In Table 3, we present the breakdown of the different zones in Athens's airport, where we have aggregated areas of similar use.

Table 3. List of the different zones and peak populations in Athens's airport.

	Size of zones	Peak population
Departure Hall	14,050 sq. m	2,040
Security Screening Area	900 sq. m	450
Emigration Area	765 sq. m	383

Post Security Dwelling Areas	14,946 sq. m	2,218
Gate Lounges	15,122 sq. m	5,800
Emigration Area Arrival	1,600 sq. m	650
Baggage Reclaim Areas	2,337 sq. m	780
Landside Arrivals Area	3,150 sq. m	626
Satellite Terminal Building	12,500 sq. m	1,875
Underground Walkway	3,200 sq. m	320

3.8.1 Modelling approach – brief overview

Real Wireless has developed an indoor costing tool to estimate and compare the costs for deploying two different wireless infrastructure systems; one based on DAS and one based on Small Cells. The tool estimates the number of antennas, base stations and other equipment required for covering the indoor venue – the airport in this example - with a sufficient signal level and wireless resources for the intended service and translates them into the level of investment required.

The tool considers the frequency bands and bandwidths available to the system design, the target use cases in terms of throughput requirements and service penetration, as well as the area of the indoor venue and footfall to compute the number of antennas, sectors and small cells – among other components – and their corresponding predicted cost.

The tool can also consider future growth levels by incorporating annual growth figures for service throughput, service penetration and footfall, to emulate future service needs and airport expansion.

3.8.2 Demand and use cases

The main driver for the wireless services in an airport is broadband connectivity (eMBB), primarily for video streaming, social media updates, gaming, and general web browsing – leisure activities for the airport visitors while they await their departure or luggage to be brought in.

We have estimated this service to require 4 Mbps downlink on average and that 20% of the passengers/users at the airport use this service simultaneously at the beginning of the simulation period.

We have also considered a 5% year-on-year growth of the service demand as well as a 5% annual penetration increase. That means, that users' behaviour changes as the time goes by, accessing more data demanding applications (higher resolution videos, more graphic processing games), but also, the number of users accessing simultaneously the network increases, as more people spend time on their devices, to mirror the current trend (by comparing people's behaviour now and ten years ago).

For the DAS system, we have assumed that the system is designed for 3 operators, operating on a 5G band (3700 MHz), with 50 MHz bandwidth available to each operator.

3.8.3 Results

The results below show the difference in terms of cost of DAS and Small cell in several areas of the airport. The costs shown are applicable only for the selected scenarios and system configurations, however the conclusions may change according to the system configuration, scenarios, users' demand and technologies.

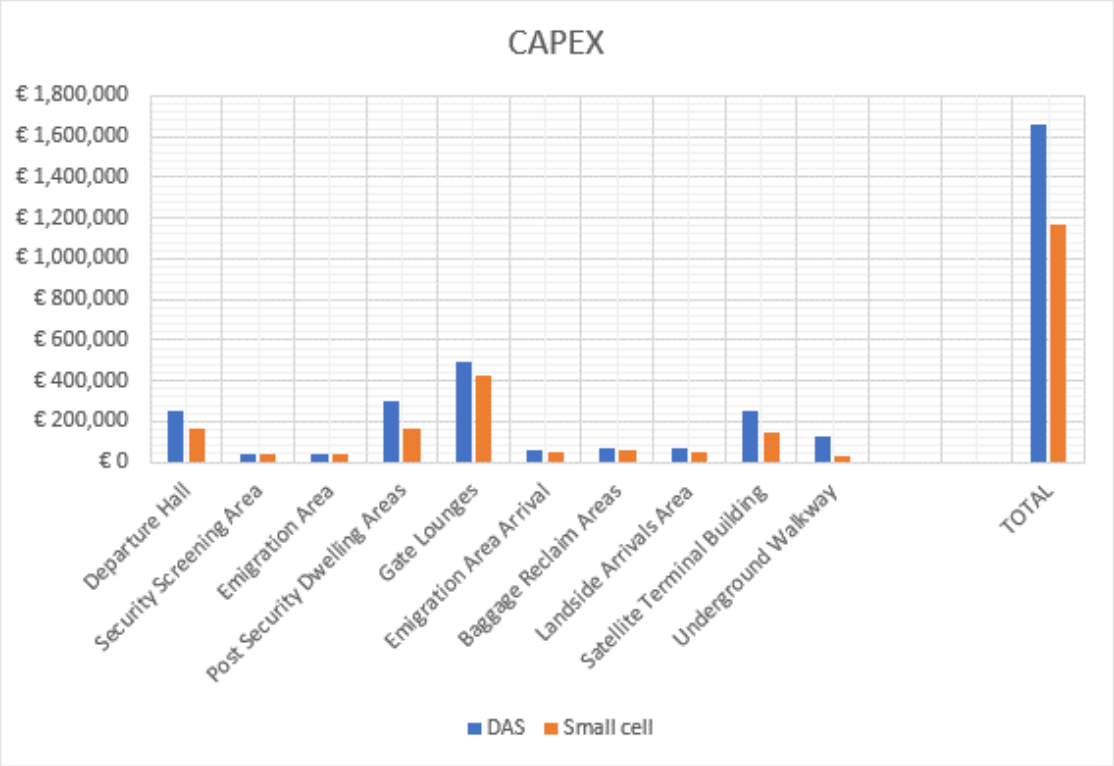

Figure 19. CAPEX of DAS vs. small cell configurations.

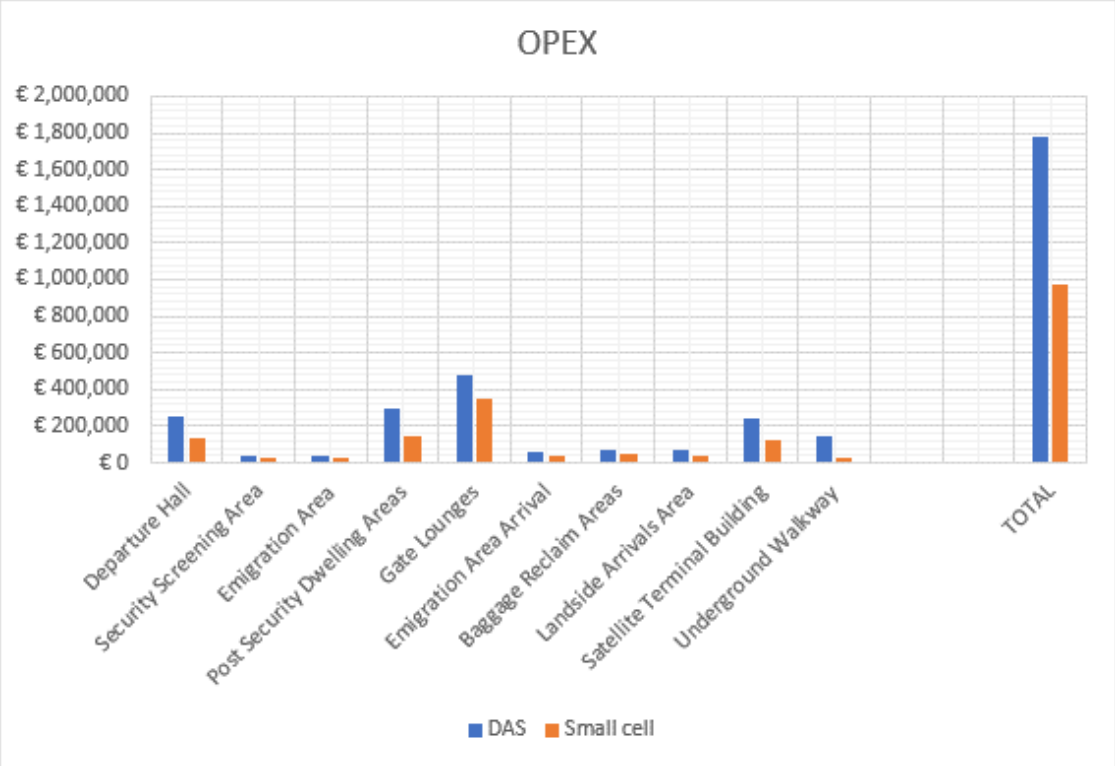

Figure 20. OPEX of DAS vs. small cell configurations.

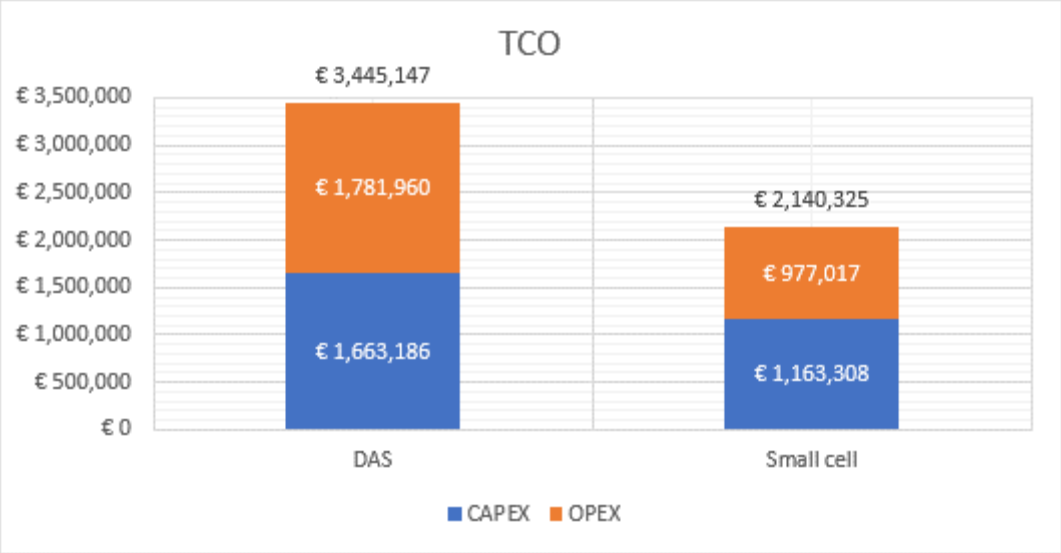

Figure 21. TCO of DAS vs. small cells for a study period of 10 years.

In conclusion, DAS costs are higher compared to small cell ones since we are dealing with one band in this scenario. We expect that by adding more bands and technologies that DAS costs increases at a lower rate compared to small cells deployments. DAS configurations are relatively more flexible hence they are relatively easier and cheaper to upgrade to a new technology or add new bands. On the other hand, small cells are often configured to one band or one technology.

4 Health Sector Business Models, Deployment and Operations

The innovations in the healthcare related work package (WP5) are related to continuous health monitoring & intervention support enabled by 5G and these are based on an overall scenario where a chronic patient suddenly becomes ill when being on a touristic trip. These innovations are developed in the context of concrete use cases (UC):

- UC 6: Remote health monitoring and emergency situation notification
- UC 9: Optimal ambulance routing to get medical help ASAP to the incident
- UC 7: Tele guiding of ambulance staff by remote medical expert
- UC 8: Advanced surgical intervention enabled by 5G connected medical scanners in OR

To paint a more meaningful picture of the innovations from an eco-system and value chain perspective, the 4P's framework (Product, Process, Position and Paradigm) is used to assess how technology meets both medical needs and provide business value for each partner along the value chain.

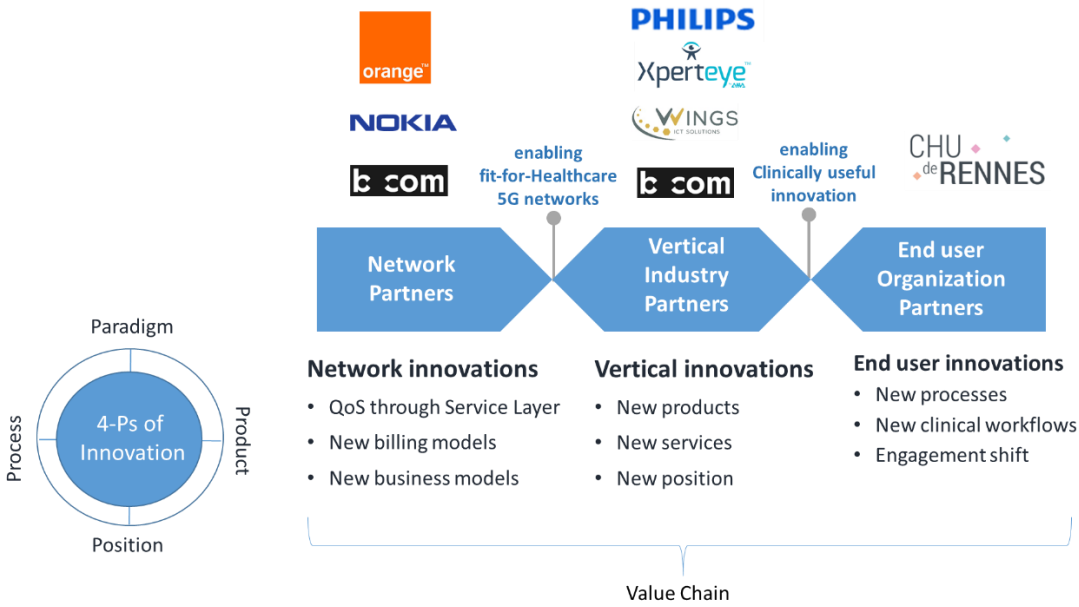

Figure 22. Healthcare innovation value chain in 5G-TOURS.

The value chain runs from network partners, such as communication service providers and network equipment manufacturers, up to end user organizations, such as the hospital addressed in work package 5 (WP5) of 5G-TOURS. In the middle are the vertical industry partners. In 5G-TOURS, these are medical equipment R&D companies (Philips), ICT solution providers (WINGS), remote video service providers (AMA – XpertEye) and Research institutes such as BCOM (who also are working on network technology).

Innovation is done by each of the stakeholders in the various domains that they are active in, and innovations can take different forms but are very much interrelated. The 4P's of Innovation is a model for that, describing innovation in terms of product, process, position, and paradigm. Paradigm indicates a whole new way of thinking, which is enabled by this new eco system and value chain of stake holders. This becomes possible by close cooperation between eco system partners. Among others, understanding each other's needs and defining new E2E business & operational models together. This includes new vertical solutions (products & services) based on new network technology. As such, there is ongoing push & pull of requirements and technology options between eco-system stakeholders along the value chain in 5G-TOURS.

An overview of the innovation characteristics of each of the use cases in WP5 is provided in Table 4.

Table 4. Health use cases and their innovation characteristics in 5G-TOURS.

Innovation feature	**UC6:** **Remote health monitoring and emergency situation notification**	**UC7:** **Teleguided ultrasound**	**UC8:** **Wireless OR**	**UC9:** **Optimal Ambulance Routing**
Type	New service, significantly improved process	Significantly improved process	Significantly improved process	New service, significantly improved process
Benefits	Early release from hospital possible. Early detect health deterioration. Timely response possible	Anywhere anytime best medical care Expert only contacted when needed Less trained doctors can do exams	Reduction of wiring clutter; reduction of physical connections and associated pull-out incidents Easier config and prep of OR Better sterility, easier cleaning	Prepare in advance the care of the patient with medical team and suitable equipment Provide quicker medical assistance and transfer patient to hospital Lower stress of ambulance driver
5G technology enabling features	Low battery energy consumption Large coverage, even underground Large number of devices per km^2 High reliability	Reliable network connectivity Guaranteed QoS also in crowded areas Low latency for eye – hand coordination Seamless connection setup (WebRTC)	High speed connectivity for live X-Rays & ultrasound Extreme low latency for RT medical image fusion TSN image streams synchronization	Guaranteed quality data & video communication along trajectory. V2X 5G communication for clearance. Accurate positioning info
Bottlenecks	Regulations, skills, standards,	Regulations, skills, standards, finance, CSP business models, 5G roll-out	Regulations, workflow, skills, standards, finance, CSP business models	Regulations, standards, finance

For each of these use cases one or more innovations have been identified that are described in more detail in the next sections.

4.1 Innovation #01 *Tele guidance for diagnostics and intervention support through 5G mobile transmission of real time ultrasound images, video and audio streaming and smart glasses use*

4.1.1 Summary of the innovation

The goal of the innovation is to improve the communication between care givers in the ambulance / near the patient, the medical regulator (dispatch), remote experts and emergency department staff to save the life of more patients than before. This should improve the outcome for and wellbeing of patients on the short and longer term, reduce the workload and stress of all care providers while improving their effectiveness, and last but not least, reduce the overall cost of care on the short and longer term so that patients can participate fully in society again after a quick recovery.

The innovation provides live video and live streaming of ultrasound images, in addition to voice communication, leveraging the capability of new 5G cellular networks to give the high-quality video and reliable medical feeds to the emergency care regulators for best decision making.

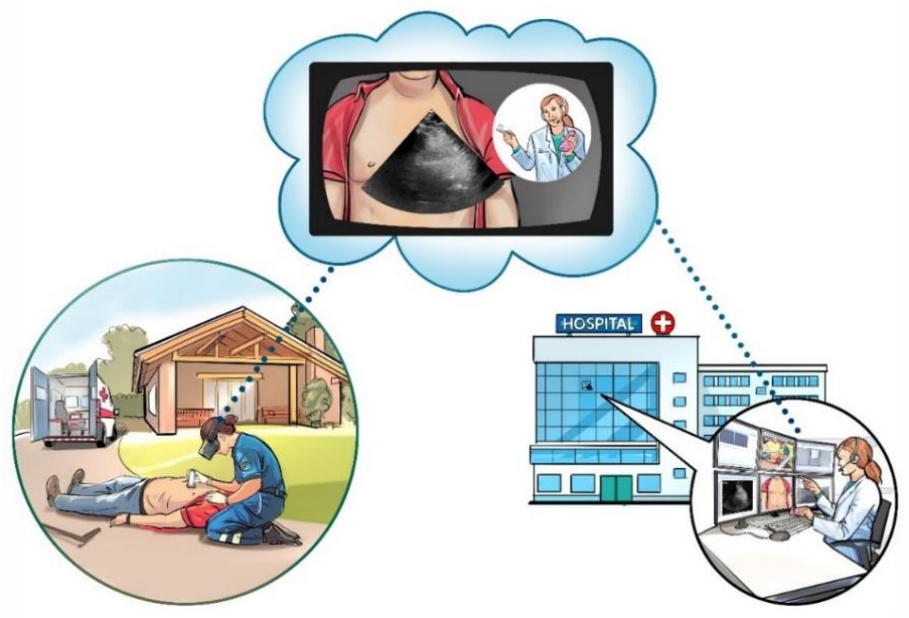

Figure 23. Tele-guided diagnostics and intervention support.

The innovation enables the ambulance crew to share their views with the remote regulator via the XpertEye [12] smart glasses solution provided by AMA. This solution offers an immersive experience to distant users via a real time video transmission. Another key element offered by XpertEye solution is a conference mode that eases sharing of the emergency between several remote medical experts for best decision making.

Furthermore, this innovation will enable the ambulance crew to use teleguided ultrasound. Ultrasound is a highly versatile diagnostic tool "to look inside the patient" in such emergency situations and has the advantage, using ultrasounds, to be non-invasive and non-irradiating. It enables rapid and quantitative examination of a variety of organs, including the heart, lungs and abdomen, using different types of ultrasound imaging techniques.

The innovation is built on WebRTC real-time communication, for audio, video and data communications. This enables seamless connection establishment, real-time image transmission (video, ultrasound) and reliable transfer of image metadata.

4.1.2 Innovation value

In the healthcare context, the sources of value we assessed are grounded in the quadruple aims of healthcare (Figure 24), i.e.: improving patient experience; enhancing population health; reducing the cost of care, improving the clinical experience and the wellbeing of providers.

Figure 24. Quadruple aim of healthcare.

With respect to this innovation (tele-guided diagnostics and intervention support), the following improvements are realized for each aim:

1. **Improved patient experience**:
   The innovation enables the best care for the patient, because remote experts can guide the local doctor/paramedic in doing the right diagnosis and best intervention as quickly as possible, including the application of pain killers and tranquilizers.
2. **Better health outcomes**:
   The innovation enables faster intervention, potentially saving the life of the patient or at least preventing further deterioration. For, the best medical expertise will be available through remote communication of medical information and ultrasound images. Such an expert will be able to guide a paramedic already in the ambulance, preventing any further waste of time due to transportation to a suitable hospital.
3. **Lower cost of care**:
   The innovation reduces the cost of care is several ways:
   (1) No need for experts to physically travel to the patient, saving precious time of the expert;
   (2) Better chances for full and more quick recovery of the patient due to early intervention guided by medical experts.
4. **Improved staff experience**:
   Medical staff is able to make the best decisions for patients. The medical and paramedic team in the ambulance have less stress when they are assisted by a remote expert in difficult and urgent cases. The hospital experts know exactly patient's condition when it arrives at the hospital and can prepare in advance in terms of teams and equipment, thus reducing the patient's chance loss in terms of mortality and morbidity, thereby reducing stress.

In terms of novelty of the invention, the following elements are important to mention:

1. Use of web-based communication standards for easy connection establishment, as well as audio, video and data communications: WebRTC;
2. Real-time bi-directional communication of high-quality video and audio;
3. Real-time transmission of ultrasound images and reliable transmission of ultrasound image metadata.

4.1.3 Exploitation

Philips has developed two products for audio video communication in combination with ultrasound image sharing. There is one portable solution for healthcare professionals based on a (5G) Smartphone/Tablet that runs the Philips Lumify App and connects to a Lumify ultrasound transducer. Remote communication of live ultrasound images and audio/video to a remote expert is provided through the Reacts real-time communication services. See [7] and [8]. This solution can be used anywhere at the point of care, including at the emergency department, at the patient's home and from an ambulance.

The second solution, called Collaboration Live (Philips Collaboration Live | Philips Healthcare https://www.usa.philips.com/healthcare/resources/landing/collaboration-live), is integrated into a professional ultrasound machine like the Philips EPIQ (EPIQ 7 Ultrasound Machine | Philips Ultrasound https://www.usa.philips.com/healthcare/product/HC795200R/epiq-7-ultrasound-system-for-radiology). It provides audio/video communication with a remote expert who is running the Reacts application on a standard computer. This solution also includes the sharing of live ultrasound images as well as remote control of the ultrasound machine by the remote expert. The digital ultrasound transmission solution developed in 5G-TOURS [5] will be further evaluated for possible application in AI driven diagnostics and decision support.

4.2 Innovation #06 *A Novel 2D Ultrasound Probe Calibration Framework using an RGB-D Camera and a 3D-Printed Marker*

4.2.1 Summary of the innovation

The innovation is about improving image guided cardiovascular interventions by offering advanced multimodality medical imaging consisting of real-time fusion of X-Ray fluoroscopy and ultrasound image feeds. The ultrasound image stream is superimposed on the X-Ray fluoroscopy image, using advanced segmentation and matching algorithms with an Augmented Reality application that generates a guidance image displayed on a monitor.

The merged ultrasound – fluoroscopy image provides real-time advice, particularly for delicate procedures: introduction and follow-up of a catheter, treatment of a vascular leak, haemorrhage, RF ablation, treatment of arrythmia. To be able to align geometrically the images coming from the ultrasound and X-Ray, a registration has to be performed. To do that, it is firstly mandatory to perfectly know the position of the ultrasound probe. Several solutions are already available for that, such as:

- Optical localization solution such as NDI Polaris based on small lighted spheres trackers;
- Magnetic localisation solution such as NDI Aurora based on magnetic sensor trackers;
- RGB-D camera providing point cloud enabling to find and track known objects.

Figure 25. NDI Polaris, NDI Aurora and RGB-D camera.

The use of magnetic sensor trackers can be problematic in case of X-Ray acquisition. In the operating room, the presence of multiple electronic devices can interfere with the magnetic sensors and alter the precision of the tracking. The use of NDI Polaris could be an option, but the price of this device is much more important than the one of standard RGB-D cameras. Since localization algorithms using depth camera are available at BCOM, it has been decided to use this technology. The probe to be tracked is relatively small and can be heavily occluded by hand (Figure 26).

Figure 26. Ultrasound probe to be tracked.

Figure 27. First test of localization of US probe using depth camera and marker.

The poses calculated by the localization system are then transported as DICOM-RTV metadata so that the AR application can realign the images coming from the ultrasound and X-Ray. To display the ultrasound image in the same plane as the fluoroscopy image, the transformation between the two coordinate systems has to be known. To simplify the procedure, it was considered that the camera and the C-Arm would not move during the interventional procedure. In addition, two calibration steps need to be defined, one for the ultrasound and one for the X-Ray. Main ideas for these calibrations are presented below.

Since the position of the RGB-D camera is fixed, the spatial coordinate system in Figure 28 is defined by the camera, with its origin at the optical centre and the x, y and z axes following the geometry of the camera. The ultrasound calibration aims to align the ultrasound images with the spatial coordinate system information. This can be realized by chaining two transformations: 1) the first one maps the pixel coordinates to the local probe coordinates (TUS-Probe) and 2) the second one from the probe system to the space (TProbe-CAM). Since the probe is tracked by the RGB-D camera, the relationship between the probe and the space is known. The goal becomes now to estimate the transformation TUS-Probe, of which the parameters can be estimated using a standard N-wire phantom. The X-Ray calibration aims to compute a transformation matrix that maps the spatial information to the fluoroscopy images. Since both the camera and the C-arm have fixed positions, this transformation has constant parameters. Those parameters are estimated using a phantom with metal landmarks, via a dedicated calibration procedure.

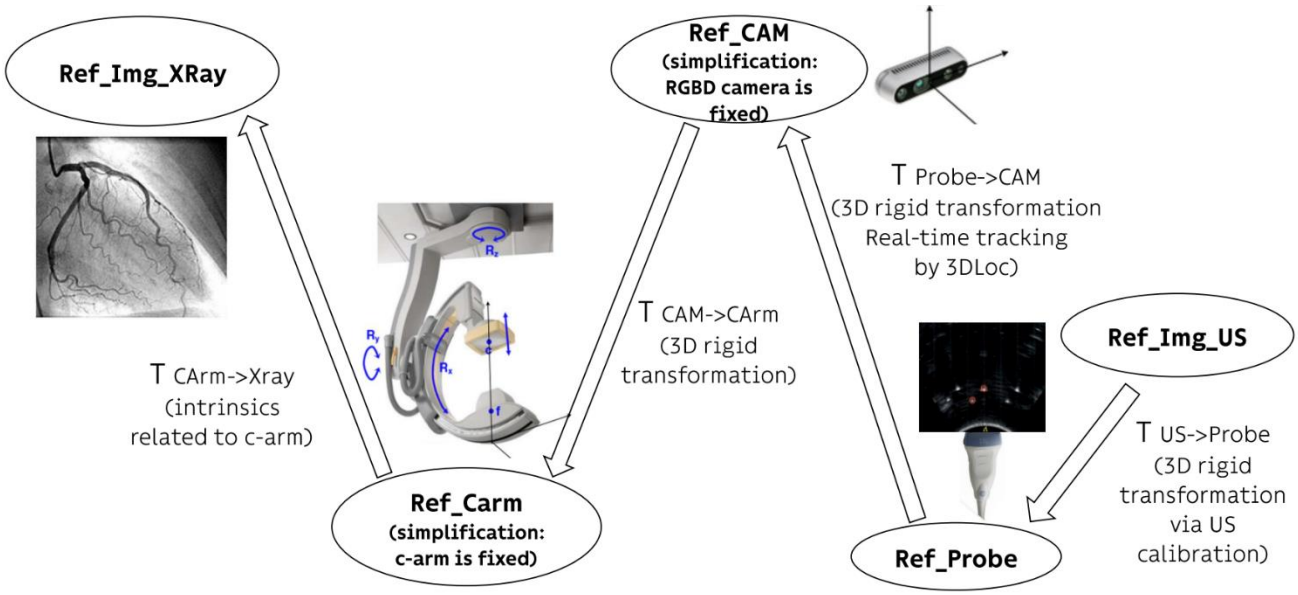

Figure 28. Multiple references involved.

The transformation $T_{US\text{-}Prob}$ can be retrieved using a dedicated calibration workflow that has been set up for the project (Figure 29). Basically, we use a 3D printed phantom with holes and place metal wires to form a N inside it. Then, we start an ultrasound acquisition and localize the dots formed by the wires in the US image. Knowing

the positions of the wires and the position of the probe thanks to the 3D marker, we are finally able to retrieve the calibration parameters.

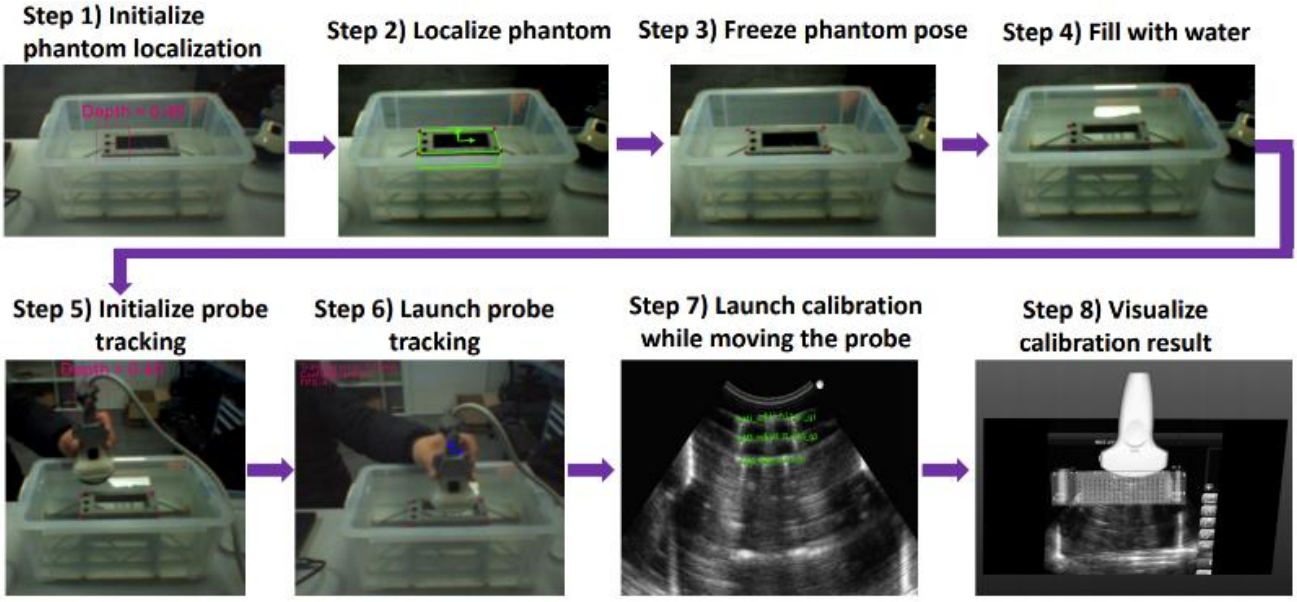

Figure 29.Ultrasound calibration procedure.

To estimate the parameters from the XRay, we printed another phantom with metal balls. Indeed, metal is highly visible in X-Ray images and enables to easily detect and segment objects. Acquisitions have been performed in July 2021 in the TheraImage room to adjust the size of the phantom and to adapt the calibration parameters. As for the ultrasound, the metal balls are segmented automatically in the X-Ray image and using the localization of the phantom and the position of the balls, we can extract the X-Ray calibration matrix.

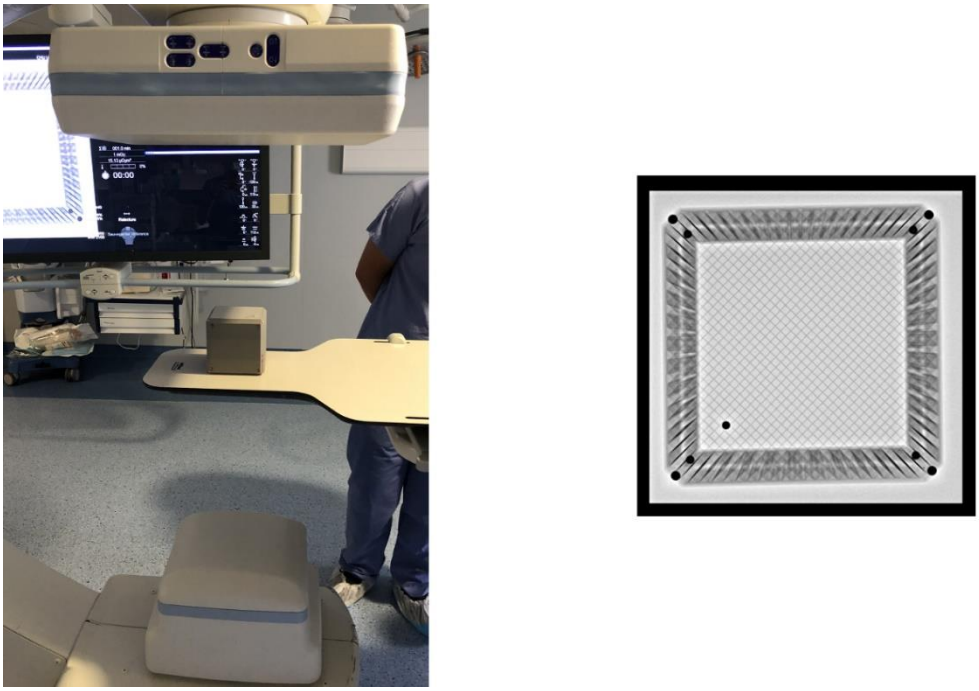

Figure 30. X-Ray phantom acquisition.

Next, the matrices coming from these two calibration procedures are combined to display the ultrasound image in the same plane as the fluoroscopy image.

4.2.2 Innovation Value

In terms of the quadruple aim of healthcare, the innovation realizes the following improvements:

1. **Improved patient experience**:
   The innovation enables minimally invasive surgery, because the ultrasound feed shows the exact position of a needle or catheter in real-time on the 3D X-Ray fluoroscopy images. Next, X-Ray fluoroscopy does need to be done continuously during the procedure, because the registration of fluoroscopy with ultrasound images will enable the display of the associated/registered 3D fluoroscopy images that are previously acquired. This will lower the radiation dose for the patient.
2. **Better health outcomes**:
   The innovation enables the best care for the patient, because the intervention can be done more precisely with the aid of real-time ultrasound showing the exact position of a needle or catheter in real-time. This will reduce diagnostic and treatment errors, surgery time (consequent anesthesia) and post-surgical complications.
3. **Lower cost of care**:
   The innovation reduces the cost of care because the specialist needs significantly less time to perform cardiovascular procedures when supported by the advanced real-time imaging tools provided by this invention. In addition, less experienced specialists will be able to perform the procedure, thus allowing a better allocation of medical resources according to the degrees of complexity of the interventions, saving time and money while maintaining a high level of safety for the patient.
4. **Improved staff experience**:
   The innovation provides advanced means to specialist to perform procedures more precisely, more quickly and more safely, reducing their overall stress levels and improving their wellbeing. Also, exposure of the specialists to X-Ray radiation can be minimized with this invention.

In terms of novelty of the invention, the following elements are important to mention:

1. Use of 3D (RGB + Depth) cameras as a low-cost solution for tracking of the ultrasound probe;
2. Use of advanced algorithms to determine the pose of the probe based on 3D markers;
3. Overlay of a synthetic ultrasound image beam in the video stream that shows the ultrasound probe (Figure 27);
4. Superimposition/replacement of the live ultrasound image stream on/ instead of the synthetic overlay. Also, when the probe is placed on a body, such superimposition is possible, seemingly showing at the same time the probe, the body and the inside of the body (inside the ultrasound beam area) at the location where the probe is placed;
5. Registration of 3D X-Ray fluoroscopy with real-time ultrasound via the calibration method described above.

4.2.3 Exploitation

Thanks to 5GTours, BCOM has improved its 3D tracking solution, by making it more robust and resilient, and will strive to find new use cases, either medical or industrial, and to bring this solution to the market.

The project also helped to reinforce BCOM's DICOM-RTV implementation. Discussions are in progress with different companies to make them adopt this standard and integrate BCOM's framework to redesign the future of the operating room.

4.3 Innovation #12 *Remote health monitoring and emergency situation notification*

4.3.1 Summary of the invention

This innovation addresses solutions for remote health monitoring of people, especially when already diagnosed with a critical disease still compatible with home care (e.g., some form of cardiovascular disease, hyper-tension,

diabetes, etc.). The main features offered by this innovation involve: (a) remote health monitoring services, (b) quick, reliable notifications to nearby ambulances, medical professionals, and family members in case of a health incident or a health emergency prediction. The innovation leverages wearable de-vices tracking a tourist's vital signs and having them aggregated inside an IoT-based platform named STARLIT (Solutions for digital health and wellness based on Artificial Intelligence and IoT) [13], see Figure 31 below. STARLIT offers a dashboard for medical professionals enabling them to monitor the vital signs and health status of several patients at a time. It also provides the option of setting up a video call with a certain patient. Alarms are raised notifying of current or potential future issues.

The current coronavirus (COVID-19) pandemic has increased the incentives for efficient remote health monitoring. The pandemic has on the one hand led to a reduction of on-site referrals for routine care due to the risk of contamination in clinical settings; on the other hand, it has caused an increase in the need to continuously monitor the status of non-critically ill patients (either quarantined at home or at dedicated venues such as hotels or suffering from chronic issues that cannot be checked up on as regularly). Remote health monitoring requires foremostly clinician acceptance which depends, among others, on the service being perceived as efficient. While this depends on various factors, at least from a technological perspective, 5G offering high-speed, ultra-reliable low-latency communication is instrumental for efficiency of remote health monitoring, allowing it to become a reality. In this current context, the trial and validation activities in the scope of this use case within 5G-TOURS are more important than ever.

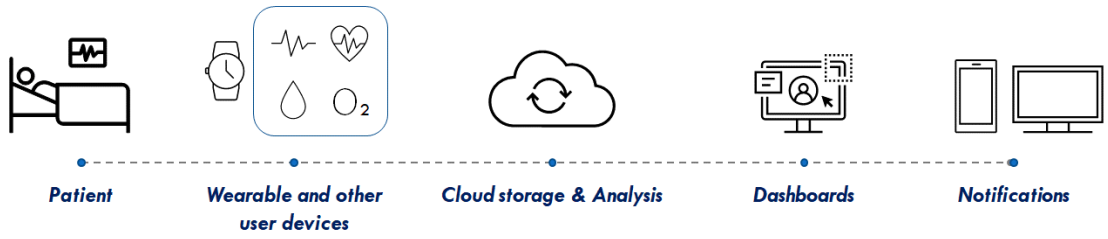

Figure 31. Remote health monitoring and emergency situation notification overview.

4.3.2 Innovation value

The innovation has enormous potential to improve on current healthcare practices. In terms of the quadruple aim, the following advantages can be noticed.

1. **Improved patient experience**:
   The innovation enables chronically ill patients and frail elderly to regain their freedom of movement, because their health condition can be monitored anytime, wherever they are. Also, post-surgery patients can go home earlier because their health can be monitored continuously, so no risk of unnoticed health deterioration. Next, no frequent visits to the hospital are needed anymore.
2. **Better health outcomes**:
   The innovation assures that the health condition of patients is monitored continuously, day or night. Any deterioration is detected in time, so timely intervention will be possible.
3. **Lower cost of care**:
   The innovation reduces the cost of care, especially for post-surgery patients, because patient do not need to stay at the hospital for many days after surgery, because their health can be monitored anywhere anytime.
4. **Improved staff experience**:
   The innovation provides advanced means reduce the working load for the medical staff and allow them to take the right decisions. In particular, patient health data is continuously uploaded to the cloud where advanced algorithms analyze this data and only notify medical staff in case of an emergency or otherwise notify family members if a worsening condition is expected. Medical staff is freed from unnecessary frequent appointments with patients.

In terms of novelty of the invention, the following elements are important to mention:

1. A large variety of measurement devices can be used, either connected through 4G, 5G, Wi-Fi or Bluetooth (relayed by smartphone);
2. Advanced cloud solution for uploading storage of measurement data;
3. Advanced analytics to assess patient data and identify potential upcoming issues, e.g., blood pressure, blood glucose levels forecasting, etc;
4. Advanced dashboards to present patient data and show important parameters of a patient's condition.

4.3.3 Exploitation

WINGS develops digital solutions (software and hardware) for various vertical sectors. Through the solutions developed in the context of 5G-TOURS, WINGS can mature its health-related solutions and enhance them with new services and consequently expand its portfolio and becoming more efficient in its offerings. The solutions developed in 5G-TOURS have enhanced the WINGS STARLIT suite for digital health and wellbeing with the enhancement of the dashboard, the integration of several diverse devices and the addition of functionality patient status assessment and health issues identification. The WINGS STARLIT suite targets public and private hospitals, clinics, healthcare professionals and healthcare businesses. In all cases the Greek market is the first target, with the European market being pursued in parallel. There are various ongoing efforts and activities for commercial exploitation aimed at municipalities and stakeholders in the health/wellness domain.

4.4 Innovation #14 *Wireless operating room*

4.4.1 Summary of the innovation

This innovation is aiming to demonstrate the advantages and impact of 5G inside the operating room. It will address very low latency requirements for high resolution video streams, resulting in high bitrate data streams to be transferred. The innovation considers a situation where a patient must undergo a cardiac intervention procedure based on live, simultaneous X-Ray and ultrasound imaging.

The video of the ultrasound probe is transferred as wireless video over IP, thanks to the recent DICOM-RTV standard, enabling synchronized real-time communication of video and associated metadata. The data stream from the X-RAY is synchronized, registered and fused with ultrasound stream to create an improved real-time view of the area of interest to provide advanced visual feedback to the doctors who are performing the intervention.

In addition, doctors are wearing XpertEye smart glasses to share their view with remote colleagues for learning purposes and for getting intervention support. The stream of the smart glasses, connected to a 5G smartphone ASUS, compatible with 5G NSA mode in the n257 band, is transmitted through the 5G network inside the operating room to a remote doctor in Athens, thanks to a secured VPN.

Specific modules were designed to perform the emission and reception of these streams. The video signal retrieved from the ultrasound is 1080p60 (1920*1080 at 60Hz), which leads to 3 Gbps to be transferred. This is currently not possible over a 5G network, especially in uplink, so this signal needs to be compressed by the DICOM-RTV-Tx (Transmitter) module. The video signal coming from the X-Ray is also 1080p60. Knowing that the X-Ray is already heavily connected inside the operating room and not transportable, there was no real point of transferring its signal over 5G. Moreover, we need to keep this video signal uncompressed because it is used as a reference to merge the signals. At reception side, a dedicated AR platform was setup. This platform receives the two incoming streams, performs the different calculation and video processing and sends the resulting view over a 5G downlink. Knowing the downlink bandwidth is also not able to transfer a 1080p60 video signal, the augmented reality output has been reduced to 720p20. The AR platform embeds a video decoding board to decompress the signal coming from the ultrasound with the minimum possible latency. One DICOM-RTV-Tx (Transmitter) is located in the operating room, close to the medical equipment, and the second one is settled in the technical room with the AR platform, just next to the TherAimage room. To receive the results of

the AR platform, a DICOM-RTV-Rx (Receiver) is placed in the OR next to a secondary monitor and to display the fusion of the two images.

4.4.2 Innovation value

The innovation has enormous potential to improve on current healthcare practices. In terms of the quadruple aim, the following advantages can be noticed.

1. **Improved patient experience**:
   The innovation enables the removal of cables in the operating room, presenting an opportunity to realize a more pleasant environment for the patient, which is an important factor in patient wellbeing.
2. **Better health outcomes**:
   The innovation enables the best care for the patient, because the intervention can be done more precisely with the aid of real-time ultrasound. The system can be configured more quickly, saving precious time, because there are less cables to connect, which also reduces errors when setting up the system.
3. **Lower cost of care**:
   The innovation reduces the cost of care because the specialist needs significantly less time to perform cardiovascular procedures. Also, less time is spent on configuring the system and connecting different medical devices because of the wireless connectivity. The sterility of wireless equipment is easier to guarantee and maintain.
4. **Improved staff experience**:
   The innovation provides advanced means to specialist to perform procedures more precisely, more quickly and more safely, reducing their overall stress levels and improving their wellbeing.
   The wireless connectivity removes the number of cables running around the room, reducing the risk of stumbling over a cable and improving the freedom of ultrasound probe manipulation and freedom of movement for the doctor.

In terms of novelty of the invention, the following elements are important to mention:

1. Use of wireless medical equipment to increase their ease of use and reduce their setup time;
2. Use of high bandwidth medical feeds with low latency to enable high quality medical imaging;
3. Use of DICOM-RTV as standardized means to capture, transfer, process and combine multiple live medical image feeds from different types of medical imaging modalities;
4. Use of DICOM-RT as an interoperability standard for all medical imaging sources;
5. Using 5G networking for high-speed low-latency communication and edge/core computing for processing of all medical image feeds.

4.4.3 Exploitation

Thanks to 5G Tours two eHealth use cases AMA was involved in, several customers are already starting to use new features that were demonstrated. Simultaneously sharing the view of a doctor wearing smart glasses and a second view such has a share screen of a dedicated medical device (e.g., ECG) or a contextual camera is in testing phase in several hospitals.

BCOM was heavily involved in use case 8 and provided the Core part network of the 5G network. This work allowed BCOM to improve its platform and Core network used in those two experimentations. The project helped to improve the performances of the 5G Core NSA solution, as a first step before reaching the 5G SA Core solution as a 5G private network, named Dome to be deployed in a platform such as xG testbed. Thanks to this project, such 5G solution will be the basis for others research projects, such as Engage5G&Beyond, which aims at demonstrating the benefits of the 5G for Energy use cases with smart grid and Augmented Technician, and e-health use case to deploy an ephemeral reanimation service. A lot of contacts and discussions are also currently running to propose this 5G private network to prospects and customers.

4.5 Innovation #15 *Optimal ambulance routing*

4.5.1 Summary of the innovation

This innovation addresses real time navigation of the ambulance, both to the site of the emergency, to ensure that medical help will be provided as quickly as possible, as well as from the site of emergency to the hospital, as soon as possible once the patient has been stabilized on site (i.e., on emergency location). While optimal ambulance positioning and routing has been addressed extensively from a decision-making perspective and a more theoretical aspect, the emergence of technologies such as 5G enables the fast and reliable acquisition of data on changing factors of an urban or suburban environment such as traffic flow, changing road graph, population mobility, and hospital capabilities, and availability to be exploited by AI powered decision making for dynamic optimal ambulance routing.

WINGS' platform, STARLIT capabilities are exploited to calculate the optimal route both from the ambulance dispatch location to the emergency location as well as from the emergency location to the nearest (or in another way most appropriate) hospital, while considering relevant patient data. Information taken into consideration, in this respect refers to traffic conditions, regulations and other mobility related factors. Moreover, for the optimization procedure, it will be considered if the patient's condition demands rich data exchange, in which case, a steady 5G coverage during the journey is most needed.

4.5.2 Innovation value

The innovation has great potential to improve on current healthcare practices. In terms of the quadruple aim, the following advantages can be noticed.

1. **Improved patient experience**:
   The innovation makes it possible to get an ambulance as fast as possible to the patient, avoiding traffic and closed roads. This will prevent the waste of time and discomfort for the patient.
2. **Better health outcomes**:
   The innovation enables paramedics to reach the patient faster than today, to provide the necessary care as soon as possible and thereafter transport the patient as fast as possible to the hospital for further care. This will enable the patient to recover faster and have a more successful care journey.
3. **Lower cost of care**:
   The innovation reduces the cost of care, because time is saved in both getting to the patient and bringing the patient to the hospital. Also, all important medical data of the patient is communicated directly to the hospital so that only the necessary medical staff is involved, and interventions can be prepared in advance.
4. **Improved staff experience**:
   The innovation significantly improves the experience of the paramedics on the ambulance, because they will be guided by the system to get to the patient as soon as possible, thereby reducing their stress levels. At the hospital, the medical staff will be aware of the patient's condition through the and what needs to be done, so that they have time to make all necessary preparations on arrival of the patient.

In terms of novelty of the invention, the following elements are important to mention:

1. Advanced, dynamic AI based algorithms that take many parameters into account for continuous optimal route calculation:
   a. Population mobility
   b. Traffic conditions
   c. Regulations
   d. Dangerous situations along the route
   e. Hospital capabilities in relation to patient's condition
   f. 5G coverage when needed for advanced real-time support when needed
   g. Weather conditions

2. Use of open APIs for continuous data gathering to feed into the AI algorithm
3. Advanced cloud-based platform (STARLIT) that hosts the AI algorithms and that takes care of all data gathering.

4.5.3 Exploitation

WINGS develops digital solutions (software and hardware) for various vertical sectors. Through the solutions developed in the context of 5G-TOURS, WINGS can mature its health-related solutions and enhance them with new services and consequently expand its portfolio and becoming more efficient in its offerings. The solutions developed in 5G-TOURS have enhanced the WINGS STARLIT suite for digital health and wellbeing and AI components for optimal ambulance routing based on a large variety of relevant parameters that are related to the health of the patient, availability of suitable hospitals and environmental parameters such as traffic, road-blocks and weather conditions. The WINGS STARLIT suite targets public and private hospitals, clinics, healthcare professionals and healthcare businesses. In all cases the Greek market is the first target, with the European market being pursued in parallel. There are various ongoing efforts and activities for commercial exploitation aimed at municipalities and stakeholders in the health/wellness domain.

4.6 Innovation TMOG Assessment

5G-TOURS innovations applicable to the health sector were assessed according to the TMOG framework described in chapter 2. We applied the sector ratings of section 2.8.2 to reflect the preferences of a buyer a generic buyer of 5G products and services in the health sector The outcome was that innovations #01 and #12 were considered as presenting the best opportunity to leverage 5G infrastructure investment and deliver the best overall returns against TMOG criteria at the time of writing.

4.6.1 Assessment of Innovation #01 Business Viability

Innovation #01 is considered to be at the validation stage and therefore reasonably mature. However, the innovation is some way from being ready for commercial deployment as it needs robust, reliable and contiguous public 5G coverage in order to be available at the point of care, i.e., accident and emergency locations. It is assumed that in order to provide the necessary quality of experience and deliver, for example, HD video, dedicated network resources such as network slicing will be required. At the same time, the impact of the innovation has the potential to be significant in improving health outcomes in emergency situations by facilitating timely access to expert help and such help being more widely available. Experts will be able to have a greater impact by reaching more patients earlier on in the care pathway.

From a market perspective, as with innovation #12, this innovation needs to prove itself to be reliable and accurate in order for it to inspire greater consumer confidence and gain market traction on the back of demonstrable outcomes. The potential for commercial value is significant in terms of delivering better outcomes for patients that reduce the cost of longer-term care. The innovation also leverages the investment in public networks and would need less investment than for dedicated infrastructure. Highly paid experts are able to be utilised more effectively and efficiently delivering further savings. However, the business model is immature and will need developing. It will be important to be able to demonstrate outcomes in a proper operational setting in order to justify the investment.

Organisationally, as with Innovation #12, Innovation #01 is a new form of providing care and whilst it may not need a significant additional staffing to run it, it will need an element of reorganisation to ensure the availability of experts and that all parties are trained in the use of the technology. However, the incentive to improve outcomes should be a good source of motivation to all parties in making it a success. From a socioeconomic perspective the social benefits are rising from the provision of better healthcare in terms of the value of extended human life and prolonging the contribution to society of recovered patients provides a social benefit many times greater than the promise of greater efficiency and cost savings. As with Innovation #12 the business model will require some development to maximise these benefits.

The innovation itself is not likely to have a significant positive impact on the environment. The Smart ambulance innovation, Innovation #15, which has the potential to reduce environmental impact, is considered separately.

However, when it comes to caring for those in need of help, the strong values and high standards of the healthcare sector in general means that the innovation is viewed highly for its credentials.

4.6.2 Assessment of Innovation #12 Business Viability

Innovation #12 assessed highly in terms of technology impact and socioeconomic value. From a technology perspective the innovation is considered to be reasonably mature, particularly with regard to 5G network infrastructure. However, it should be noted that the success of the innovation depends on the availability of reliable 5G coverage. For maximum benefit, patients should be able to lead as normal a life as possible, which means having robust connectivity in their homes and also when outside and on the move. It may be feasible to deploy a dedicated private network in densely populated areas with high levels of morbidity in the population [6], but if the ambition is for widespread adoption, a good public 5G service will be required.

There is a further dependency on 5G compatible wearable devices for monitoring health metrics and vital signs, which can be considered complimentary assets. For the innovation to be a success will be determined by how the device ecosystem develops in terms of their capabilities, availability and affordability to healthcare providers.

Such dependencies notwithstanding, the innovation has the potential to be hugely impactful in that it has a potential to make a real difference to patient outcomes and reduce the burden on other parts of the health sector. For example, leading to reduced use of emergency services and requiring fewer hospital or GP appointments. The development potential is also judged to be high by using to use the data to improve accuracy and better predict health outcomes for more complex issues.

In terms of market readiness, Innovation #12 will depend heavily on consumer confidence in its capability to deliver meaningful outcomes in order to gain traction. However, the technology is readily scalable and therefore has a potential to offer a significant commercial value predominantly through cost savings, including reduced residential care costs if people can be monitored at home for longer.

From an organisational perspective it is felt that some work is required to establish robust processes and procedures to ensure that cases are appropriately assessed and prioritised. This may require additional staff or for the provision of training to develop current staff. However, there is a potential for AI to augment and improve the innovation in the future, which can help support staff in their roles. Given that any outcomes can be proven to deliver significantly better for patients and deliver cheaper healthcare costs then stakeholders within the ecosystem should be well motivated to work together to make it a success.

Finally, focusing on governance, it is clear from the work done in D2.3, that in terms of the value, the socioeconomic benefits of better health outcomes create much more value than commercial returns. The health sector has a long history of adopting strong values and prioritising better care for the general population, which means the innovation scores highly on ESG credentials. There is also the secondary effect of reduced travelling to GP surgeries or hospitals for appointments which has a small impact on reducing the environmental impact of providing care.

[6] "Liverpool 5G Health and Social Care Testbed: Benefits, Outcomes and Impact", November 2019

5 Tourism and Media Sector Business Models, Deployment and Operations (aspects of usage of broadcast for deployment options)

5.1 5G-TOURS Tourism and Media Sector Innovations

During the last decade, museums all over the world witnessed a decrease in visitors. In addition, Tourism has been among the sectors more seriously affected by the pandemic, with restrictions both to travel and to the ability to do any relevant activity at the destination, due to the restrictions put in place in most countries, such as quarantine, closures, and other public health measures and safety precautions.

This disruptive event put the touristic industry in front of the necessity to rethink tourism according to new paradigms, so to re-emerge from this period in a better shape, suitable to cope also with other essential objectives that require a change, in particular the aspects of sustainability and inclusiveness, with the consciousness that the future recovery can only pass from the use of digital technologies to allow the management of both services and the relationship with tourists in a different and innovative way.

In particular, two concepts are taking place to evolve Smart Tourism: Slow and Never-ending Tourism, both expression of a drastic change from the pre-pandemia “hit-and-run” tourism, to match the interest of people to travel with the need of sustainability.

Slow Tourism means responsible and sustainable tourism, allowing preserving natural and cultural resources. It safeguards and promotes the growth of territories, even those which are poorly known, and makes them valuable tourism destinations. It is strictly related to the concept of slow mobility and the research of new itineraries, for visitors to experience new, different emotions passing through natural landscapes, to live and “taste” them while at the same time promoting their protection as patrimonies of inestimable worth, as a richness to be safeguarded for our common wellbeing. Already in 2016, Italian MiBACT’s Minister created an atlas of paths, which includes a wide network of paths passing through the whole country. It is a great way to identify all the existing paths, all the interconnections among them and all the possibilities and ways to travel them. At the same time, it is allowing to value their cultural and natural heritage (https://ecobnb.com/blog/2017/12/paths-italy-atlas/).

Never-ending Tourism comes as a specific proposal to respond to the Covid-19 pandemic, to allow travelers to extend their visit also before and after the visit itself, transforming the simple touristic experience into a more complex one, creating a strong link between the tourist and his destination. This creates new commercial possibilities for the tourism sector and for the whole territory on which it rests. The extension of the tourist experience, at the basis of the Never-ending Tourism concept, cannot be separated from a digital implementation, going to foresee a new tourist offer made up of contents and services to be distributed through digital channels to anticipate in the pre-trip and continue in the post-trip relationship with the customer and generate additional sources of income. Never-ending Tourism builds on the concept that the future of tourism cannot be separated from digital innovation that involves all of our lives. And it is through digital innovation that the physical touristic experience can be integrated/augmented or even replaced by virtual experiences, removing barriers and reducing environmental impact, for a sustainable world.

As for the Media sector, in the era of the "giants" (Netflix, Amazon, etc.), the media companies are called to an epochal challenge, since the new actors competing for the television screen are based on very aggressive and world-wide business models. This challenge is not only based on new technologies but on offering attractive content to attract the end user. The challenge between the various actors is marked by huge investments in the creation of cinematographic content. For this reason, the television world knows how to try in every way to optimize the production processes of television content that can compete on the current market. Broadcasters hope that 5G can be used to improve technical and operational efficiency, increase flexibility, and reduce production cost. 5G is also hoped to enable new production workflows, in particular in news gathering, remote production, coverage of live events, and user engagement. Demonstrating the maturity of the technology would allow the media companies to pave the way for a new innovative production chain, where a mixture of remote and on-site equipment could allow reducing production costs and time.

In these evolving scenarios, the Touristic City of 5G-TOURS is a place where citizens and visitors enhance their experience thanks to innovative technologies enabled by 5G. Innovations developed and experimented in 5G-TOURS allow to accompany the Touristic and Media sectors in its evolution. These include:

- Augmented Tourism experience: VR/AR technologies to provide the tourist with an improved and more engaging visit of touristic sites, through digital interaction and gamification;
- Telepresence: virtualisation access to touristic areas for inclusiveness and improved accessibility and video surveillance;
- Robot assisted museum guide;
- High Quality video services distribution;
- Remote and distributed video production.

The following of the chapter analyses the 5G-TOURS innovations in, highlighting the benefits they could bring to the touristic and media sectors to cope with the challenges beneath the evolving scenarios.

5.1.1 Innovation #02 *Autonomous 5G operated robotic system for telepresence and museum guide*

The innovation #02 has been divided in Innovation #08 Telepresence (5.1.3) and Innovation #09 Robot assisted museum guide (5.1.4).

5.1.2 Innovation #07 *Augmented tourism experience*

Over the next decade, a new era built on "digital interaction" that is based on "digital reality" will have a massive impact on human interaction behaviors as well as on every industry sector but mainly on the cultural and creative industry. In particular, XR is going to improve the tourism experience, and traditional means that give context to travelers will soon be replaced by such modern platforms that will be able to provide rich multimedia information on demand. The main goal of this innovation is to enhance the museum visit with an improved and more engaging experience that relies on XR technologies to augment the visit and knowledge of touristic assets offered at each site. XR is the umbrella term that includes VR, AR, and Mixed Reality (MR). Even though these technologies are different from each other, they share some common goals that include the enhancement and the augmentation of the user experience with the introduction of digital objects such as: interactive 3-Dimensional (3D) models, binaural 3D audio, virtual avatars, and immersive (360 degrees) videos. Thanks to the use of all of these technologies in a seamless way it is possible to provide users with the best possible experience, according to each user's hardware, location, network capacity, and needs.

In particular this innovative solution targets educational tourism, with the gamification of the exploring experience, providing new ways to make the visitors learn by playing and enhancing the interaction between humans and art. That is why UC1 Augmented Tourism Experience (ATE) is not only targeted to the visitors of selected museums but is also aimed to at-tract and involve tourists/citizens/students nearby identified "Point of Interests" thanks to the development of engaging smart city services. The concept of "immersive" experience requires the involvement of the user both indoors and outdoors, offering a set of services to the user, accompanying him from identified paths on the outside of the targeted museums to the most thrilling indoor experiences. Consequently, the purpose of those innovations is to enrich the cultural and touristic experience using technologies like immersive media content, intelligent video analysis and interaction with 3D art pieces deploying different and integrated involvement strategies, such as:

- smart guide to Museum;
- gamification;
- entertainment through multi-faceted informative services;
- blended Learning experiences;
- access to smart city services for a better tourism experience.

The target users of this innovation are general users from 6 to 99 years of age. The idea is that everyone can enjoy culture and tourism through technology enhanced paths, regardless of their level of digital literacy. That's why devices and equipment must be easy to use, possibly in each identified location and by anyone, youngster and aged, even with a strong inclusive approach towards disabilities (physical and cognitive).

Technology must not "disturb" the cultural experience, but instead accompany and enhance it, possibly without too many pieces of hardware, allowing a fast-learning experience. Also, technology should not isolate individuals, but help organize and put in place community experiences, offering spaces for interactivity and real aggregation opportunities, through gamification and group of visitors/students' engagement.

The use of most common devices like smartphones and tablets allows an integrated, continuous and homogeneous experience for all both outdoors and indoors, with different levels and intensity from outside to indoor locations (e.g., museums, schools). 3D scans of selected objects, combined with several smart city services, giving them information on (i) indoor (comfort) and outdoor (environmental) conditions, (ii) cultural/touristic interest, and (iii) tourist facilities provided by the city allow enhanced cultural experiences. Expectations are that augmented reality can help increasing museum visits, reversing the current trend, acting as a flying and motivating visitors to visit a museum through simple and easy to use technology. This is expected particularly from youngest generations, typically less interested in visiting museums. The possibility to interact with art through the use of technologies they are familiar with may increase their interest. The same for the gamification experience, which in addition to involving the youngest in the discovery and comprehension of an artist and museum, generates an educational and social benefit by promoting connections and social inclusiveness. The fruition can be on site, during the visit itself, but could also be made available after (or before, in preparation of) the visit. Or even represent elements of a virtual visit or telepresence.

5G ultra-low latency and high bandwidth are crucial in the implementation of XR technologies, say VR (Virtual Reality), AR (Augmented Reality), and Mixed Reality (MR). Augmented Tourism experience innovation in 5G-TOURS investigates the possibilities offered by 5G and XR for the so called "digital reality". This could represent an important opportunity to improve the production process: the possibility to integrate in the studios virtual and natural elements, thanks to the modelling of objects and spaces, allows to reduce costs and potential risks, removing obstacles to the creativeness of TV programs' authors. The ability to create complex virtual worlds provides producers with unlimited creative options. Against a backdrop of restrictions resulting from Covid-19, virtual production allows creative teams to augment their film and TV sets with large LED walls paired with gaming engines and camera tracking technology to speed up the creative process and reduce the time needed in post-production.

The trials in 5G-TOURS have demonstrated the technology readiness, as well as the interest by stakeholders. The Municipality of Turin and FTM have expressed, since the beginning of the project, their interest in *Augmented Tourism experience*, assessed highly, providing an innovative museum visit thanks to the integration of different technology. The expected benefits are to guarantee the visitor a unique experience with additional contents compared to a "traditional visit", and to ensure an interaction with other users, also for educational purposes. Benefits therefore take into consideration cultural, social, and educational aspects. Moreover, making available a series of information regarding the city (such as the weather, the level of crowding of the rooms or data concerning the mobility to the visitor), the experience covers a wider range than that of the only visit to the museum, facilitating and promoting the visit of the entire City. The trial museums therefore acquire an added value in providing an innovative and more complete experience to visitors. They will represent new points of attraction for the city's tourist offer.

Extending to a less conventional point of view, VR/AR products could also represent an added value opportunity for Media companies, both for their live channels and their OTT platforms: the VR/AR product could represent a specific content for a Travel documentary, to be consumed on demand, either independent, present in the internet platform of the media company, or linked to a linear program. The TV program describes the travel opportunity, and the VR visit of a remote location is offered to the audience. Narrative of the VR TV program: the user access RaiPlay and select the Travel documentary program episode dedicated to the city of Turin. A selection of different cultural sites is presented, and the user selects the Visit of the Chinaware Collection in the Palazzo Madama Museum of Torino.

5.1.3 Innovation #08 *Telepresence*

Museums are responsible for reaching out to expose their educational resources, and create meaningful and engaging experiences for, as many people as possible. Telepresence robots have the potential to authentically extend access to historically excluded audiences such as disabled people, social disadvantaged people (e.g., substituting or complementing school field trips), people outside the country (in a way to attract tourists/users), providing enhanced education activities at schools (without moving from their own classroom) as well as offering niche experiences to a wider audience for a longer time. The most prominent applications of this teleoperation use case are a visit to the museum by a visitor located at a remote station (school, home, hospital, etc.) or the surveillance of the museum by an operator external to the museum. The innovation targeted in Use Case 2 is constructed around a robot located inside a museum controlled by a remote user to enable telepresence in touristic sites. The underlying 5G network, capable of meeting the strict Key Performance Indicators (KPIs), allows an effective control of the robot.

The substance behind this innovation is the possibility to enlarge the public for selected exhibitions in order to make these experiences more accessible to all and for a longer period and/or to use these exhibitions to attract foreign visitors/tourists. A strong focus is towards disadvantaged groups that could have difficulties joining the exhibitions in real life (disabled, people in hospitals, elderly in retirement homes, marginalized communities, etc.). Indeed, telepresence enabled by 5G can act as assistive technology, allowing people with physical or cognitive disabilities to enjoy visits and experiences and open the cultural offer for all. Additionally, the idea is to use telepresence to attract tourists from outside Piedmont and thus offer a "taste" of Turin through robot-led experiences. This means that target involvement strategies will be identified to accompany these experiences to adapt to different conditions (mental vs physical disabilities), languages and final objectives (involvement vs attraction of tourists). *Telepresence* has a great social value: telepresence robots have the potential to contribute to accessibility and inclusiveness by extending access to previously excluded audiences. Another interest is to be able to show to everyone, remotely, previous inaccessible areas of museums. The selected location for the experiment of the innovation is Palazzo Madama, where exhibitions are cured by highly specialized professionals that often live outside the city or abroad. These professionals can give tours of the exhibition during the opening days to very few people. Using a telepresence robot, the possibility evolves to arrange 2 to 3 curator led visits to the temporary exhibitions or to the permanent collections, allowing more people to benefit from their expertise.

In addition, telepresence allows to offer enhanced educational activities to students at school, to be integrated in their school programs. The target audience for this application is schools/families with children from 6 to 13 years of age. Thanks to Telepresence, students can enjoy educational and gamification experiences around modern art remotely. Finally, telepresence by means of robotic tools can enable enriched tele-surveillance functionalities. The robots, controlled remotely by a security operator in a local or in a remote-control room, can expand – and not substitute – security professionals, offering enhanced tools to carry out their work in a safer way. The museum surveillance can take place both during day and night hours, according to the features of the robots that will be used.

There are several socio-economic drivers for Telepresence: reduction of travel costs, reduction of carbon footprint and environmental impact, improve employee's work/life balance and productivity (e.g., surveillance of the museum(s)). Telepresence favors, among others, the inclusiveness and accessibility of disadvantaged groups from a geographical or economic point of view, providing everyone with the opportunity to visit a specific museum and promoting the connection between national and international schools. (e.g., in Palazzo Madama exclusive exhibitions for all). The aspects related to the use of telepresence for surveillance purposes also proved to be of great interest during the Industrial Workshop in Turin. In addition to the social benefit of making museums open to everyone, there is therefore the added benefit of safety: a not negligible aspect talking about cultural heritage and its promotion for tourism purposes.

5.1.4 Innovation #09 *Robot assisted museum guide*

The innovation consists in an upper-body humanoid robot equipped with wheels. The robot can be positioned in a museum to allow users to visit the museum from a remote location or the museum personnel to inspect the museum for surveillance. In addition, the robot can operate autonomously to guide visitors inside the museum.

The robot can navigate autonomously thanks to the wireless connection that uses 5G technology to guarantee necessary performance in terms of latency, bandwidth, and reliability. With respect to Telepresence, in Robot assisted museum guide the innovation is guaranteed using robotic technology to provide an enhanced museum visit experience by a humanoid robot that accompanies visitors inside the museum independently. The innovation allows to facilitate the interaction between the robot and the visitors in the touristic area, thanks to the humanoid aspect and behavior of the robot. Typically conceived as a guide for in presence visits, being able to provide new or additional content through the robot, it may be also used for rooms' surveillance.

Robot assisted museum guide improves employee's work/life balance and productivity. The robot will not replace employees, of course, but will offer them a lightning on some activities on one hand. On the other, it will allow visitors to get more information about museum locations and additional details. Investigations have shown the existence of an increasing demand for products like the R1 robot developed in 5G-TOURS, while few offerings are currently available. Expected time to market is in the order of 5 to 10 years.

5.1.5 Innovation #10 *High Quality video services distribution*

For distribution, 5G offers a composite standard tool to enhance user consumption of media, with a specific target for people on the move. In particular, the innovative distribution technology proposed in 5G-TOURS, through the joint use of 5G-Broadcast operated by the BNO (Broadcast Network Operator) on the HPHT (High Power High Tower) network and 5GMS operated by the MNO (Mobile Network Operator) on the LPLT (Low Power Low Tower) network, allows the provision to the users of high quality media with the high Quality of Service generally applicable to conventional TV and at the lowest costs for all the actors in the value chain, including the content provider, the service provider, the network operator and the viewer.

The BNO and the MNO run their own separate networks, while cooperating at a service level to offer a hybrid broadcast/multicast/unicast service distribution. This solution guarantees service continuity in potentially challenging scenarios, such as the indoor reception and/or the urban areas where the 5G Broadcast signal could not be available.

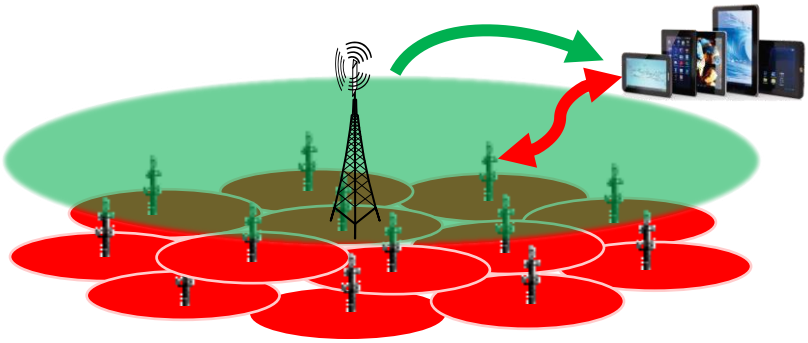

Figure 32. Service-level cooperation.

Figure 32 illustrates this scenario, where different frequencies are allocated to the BNO and the MNO to provide the users complementary services: when the broadcast services provided by BNO are not available to the users, these can be (automatically) requested in unicast to the MNO. For the best user-experience of the broadcast service, the switch from the broadcast network to the mobile one should be automatic and seamless for the user (e.g., the authorisation to use the data when out of the BN reach could be done once). This type of cooperation opens up the way to other possible applications that might benefit from the presence of the synchronisation between the broadcast and mobile network delivery. For example, it could be used to retrieve personalized content on demand along with broadcast linear channels (e.g., previous episodes, multi-camera view, targeted advertising, etc.), for a new distribution paradigm, with a mixture of linear and personalised content, where the users can benefit from an enhanced viewing experience, while being completely agnostic of the architecture that supports it. In this sense, LTE based 5G Broadcast and 5GMS (5G Media Streaming) unicast delivery, integrated in a unified service layer, would allow mobile devices to flexibly consume the services in an optimal and cost-efficient way, overcoming the limitations imposed by a single (mobile or broadcast) distribution mean.

This solution could allow:

- the content providers to extend their offer to a wider audience, by including mobile terminals among the served platforms;
- the Service providers to decrease CDN costs in the region where service is provided by BNO;
- BNOs to use the existing infrastructure (with limited investment on additional sites) while increasing their reach of FTA contents to mobile devices;
- MNOs to achieve savings in network resources by off-loading broadcast video traffic, thus increasing the availability of more valuable resources;
- the end-user to receive TV services without consuming data from their plans and without the need of a contract from a specific operator (no authentication required), when in the coverage of the BNO. The SIM-card and an active tariff are needed for coverage extension, and authorisation by the user. As an alternative, this could be also part of a cooperation agreement between the service provider and the MNOs, in the form of zero-rating offer.

The technology is based on Rel.16 3GPP standard, with new features introducing the possibility to use sub-700MHz bandwidth and channelization to be introduced in Rel.17 and 18. 5G Broadcast transmitting technology is available on the market since 2019, while first 5G Broadcast enabled smartphones have been first presented at MWC 2022 (https://www.rohde-schwarz.com/us/about/news-press/all-news/first-end-to-end-live-5g-broadcast-streaming-to-smartphones-at-mwc-barcelona-2022-with-qualcomm-and-rohde-schwarz-press-release-detailpage_229356-1180480.html) and more recently used in the first pan-European 5G Broadcast showcase delivering the Eurovision Song Contest live to mobile terminals by Rai in Turin, ORS/ORF in Vienna, France Télévisions in Paris and ARD/SWR in Stuttgart. The trials at ESC showcase how live content could be distributed to mass audiences over 5G Broadcast enabled smartphones. Consumers in the heart of Paris, Stuttgart, Vienna, and Turin had a first-hand look at an advanced live mobile experience. The trials also allowed to verify the maturity of the technology and the potential interest of the users, who could benefit high QoS for the fruition of linear services on the move, comparable to the one they are used to, while at home, without consuming their data budget.

The first availability of prototype smartphones implementing 5G-Broadcast is a first step towards exploitation of the technology by the media verticals. The commitment by the different stakeholders needs to be clarified, before the commercial introduction of the service can take place, because of the huge investments required for the launch of a service, both by the BNOs and by the chip and smartphones vendors.

On a smaller scale, *High quality video services distribution* allows the users, through the use of smartphones, tablets, AR devices and monitors, to receive educational and informative content during their visits to the city and its museums. The innovation could represent interesting technologies for the Municipality and its cultural offer in guaranteeing high quality video distribution for tourism, but overall, in proposing new innovative forms of cultural events.

5.1.6 Innovation #11 *Remote and distributed video production*

The main objective of the idea of this innovation is to exploit the 5G network features for remote television production and analyse how 5G networks could support various scenarios in which high-quality video (e.g., in 4K, HD/HDR or Video 360°) is generated and transmitted. In a typical TV production environment, video contents are delivered from cameras located in places where an event is taking place to a TV studio in the broadcasting centre or to a remote studio facility on the event location itself. Such video contents could be used both for immediate live broadcasting of the event or recorded to be further edited and used in TV programs later on.

In distributed TV video production, the content needs to be produced by mixing local and remote audio and video contributions in the TV studio. The remote contributions are thus delivered to the main editing site via the 5G network in real time. The challenge in this scenario is the end-to-end delay between the local and the remote site, which must be kept very low and constant. Furthermore, each AV flow at the remote site can be

only mildly compressed before transmission to preserve sufficient headroom for editing and distribution coding, so the content size needs to be large. On the other end, the number of required remote flows is planned in advance and kept fixed during the program production. The final program can then be distributed to the users either live or later.

Introducing 5G technologies, MNOs will offer new services for remote distributed production in city areas allowing customers such as broadcasters and media companies to use new tools to produce television content, the personnel involved in the production of a television program include creative talent such as actors, directors, writers, and producers as well as technical crew members such as camera operators, electrical technicians, and sound technicians.

Currently almost all TV content producers are using what in popular language is called “backpack unit” for video transmission in remote areas. The backpack unit bundles multiple 4G connections together to transmit the video signal back to the TV studios for further processing.

This Innovation item and relevant architectures will improve the available bandwidth of live connections (real-time transmission) and enable low delays leveraging on features of 5G network. The 5G system will enable the increase of bandwidth used for live connections, providing specific slices with a guaranteed Quality of Service (QoS). Furthermore, 5G architecture could enable video processing at the very edge of the network instead of studios, reducing high production costs of multi-camera events covering.

In addition, in the future, the possibility to deploy an SNPN (Standalone Non-Public Network) as an architecture of a private 5G network which has been deployed separately to the public 5G network, could offer the possibility to support nomadic and ad-hoc audio-visual content production applications and workflows. Spectrum regulators are currently considering various new licence models for making spectrum locally available for non-public 5G networks, this may work in a fixed location such as a studio, a venue, or a frequently visited news location.

The remote and distributed production innovation exploits 5G technologies to obtain a new elastic and efficient production model. The considered use case is very challenging, with stringent requirements in terms of huge data volumes, very short delay requirements as well as minimal jitter, to allow perfect synchronization of a multitude of sources that are far apart one from each other.

The Itinerant Orchestra event performed in November, the 9th, has been a prime example of this new innovative cultural offer. Cellular bonding technology invention changed live newsgathering by providing easy and cost-effective tools to do media acquisition from the field.

Today the players on this domain (like LiveU) providing live IP video solutions with professional live broadcasting and video production. This allows native 5G HD/1080p60 and 4K HEVC solutions enable broadcasters of all sizes to acquire and share the highest quality live video reliably on any viewing platform. This technology is being used today more and more for other domains, including tourism.

In the context of 5G for tourism, such solution is part of the Itinerant Orchestra experiment in which musicians located in the main concert hall play together with other itinerant musicians walking in the street. Each itinerant musician is followed by one (or more) camera operator, shooting their performance, and providing cues to stay in sync with the main orchestra performance. TIM provides the 5G network and RAI producing the whole event. The music has been composed especially for these trials by the renowned Andrea Molino.

The high-quality AV signal is transmitted with units equipped with the 5G network to the main control room in the concert hall where it is processed and mixed; the spectators in the concert hall watch the itinerant musicians playing, as a real-time virtual presence, on LED walls while listening to their performance, mixed with the local orchestra, until they enter the concert hall and join the orchestra.

This use case requires stable 5G bandwidth and more importantly – stable latency. The synchronization between the musicians is critical and depends on these stable parameters. The media acquisition uses either single 5G modem or dual 5G bonded modems to achieve this synchronized stability at a low enough latency.

There is a raise in commercial projects related to tourism, enabling various kinds of applications that can be expanded and become mainstream today thanks to 5G technology. More examples of such 5G acquisition projects are live advertising projects aired on TV or at central places such as bus or train station to bring live picture from far locations.

Another unique case was live streaming of a scuba diver connected to a 5G unit on the boat. There are more 5G acquisition opportunities for scuba divers or any other extreme sports professional streaming live from all over the globe. 5G acquisition provide excellent opportunities to explore the potential of 5G networks and collect useful insights and experiences for such projects and use cases.

5.2 Media role in the mobile network ecosystem

5.2.1 Analysis of market context / Market needs

Deliverable D8.3 [3] already included an analysis of the market context that is still valid, as the situation has not change in the current post pandemic scenario. As we said back then, the COVID health crisis has severely impacted the tourism sector, especially in countries like Spain and Italy. Even though we are slowly coming back to the "new normality", our lifestyle has changed for ever. Our society is now less open and global than it was before and, therefore, the human interactions and the way people do tourism, visit places on holidays and participate in cultural events are different.

In this context, touristic destinations are currently looking for new services and experiences to sell in order to attract people despite the increased perception of risk and the economic recession context. Countries with a rich cultural heritage are not an exception, on the contrary, museums, art galleries, Palaces, etc., particularly those that offer their service in closed spaces, are strongly suffering this situation.

We live in an increasingly digitalized society where new technologies such as eXtended Reality (XR) will make possible to consume cultural content in a different way. In closed venues, a key requirement is having good broadband access with high data rate and very low latency in all rooms. Here is where 5G can help as it fulfils such requirements. 2021 and 2022 have been the years of 5G rollouts and of the appearance of compatible devices allowing this type of scenarios, which indicates that the moment to develop innovative solutions that open the possibility of a new paradigm in the content distribution in a cultural spot is now.

5.2.2 Service description / Purpose of the service

Although the service was already described in deliverable D8.3, we briefly describe it here again in benefit of the reader.

Currently, customers visiting a museum can´t interact with the art pieces and have limited information about them. This information is usually provided in murals located next to them around which people get together to read, having even to wait for it, which causes mobility issues, something that needs to be avoided especially now. The main goal of the proposed solution is to offer any kind of art centres the possibility of enhancing and enriching their visit and engaging the visitor through active interaction with the art pieces. Improving that interaction engages visitors and makes them feel like they are more part of the visit than they ever could be before.

What proposed is an affordable mean to overcome the current limitations so that users can access extended information with their own mobile. Visitors are able to seamlessly interact with digitalized 3D art pieces, get extended information about those of their interest, or even plan their visit in advance (logistics, which rooms to visit, how long it takes, overcrowded spots, etc.).

Potential customers

The target customers for this type of Augmented Tourist Experience (ATE) solutions are city museums, art galleries, palaces, municipalities, or any other touristic service provider that would like to provide end users, either tourists or local residences, an enhanced and more interactive experience.

Identifying value chain actors

The introduction of innovative technologies and the digitalization of cultural content can make the difference for the tourism market in cultural spots, providing the mechanisms to attract more audience and cultural tourists.

This kind of services may open new opportunities for stakeholders of the tourism sector value chain. However, the introduction of new technologies is not always straightforward, and it can´t be considered a narrow market,

but very specialized. The solution integrates different leading technologies such as, AR techniques, digitalization of art pieces, edge computing, etc. It also includes the effort of integrating the product into an existing / new 5G infrastructure and doing the corresponding integration test to verify and validate the robustness, performance, scalability, and security compliance of the solution.

There are several of actors that influence in the enhanced visit experience:

- **Visitors:** These are the main actors because they are the main target of the provided service.
- **Touristic service provider (museum, art gallery, etc.):** These are the actors that directly provide the service to the end-users by making use of owner's infrastructure resources and connectivity assets.
- **Network Provider:** The actor that provides the communications infrastructure within the museum. Sometimes it is necessary to extend or deploy specific communication infrastructure.
- **Infrastructure Provider:** The actor that provide the required infrastructure to support the solution, as datacentres as well as links to connect them.
- **App developer:** The actor in charge of developing the app which allows visitors to interact with are pieces and have access to extended information.
- **Software company:** This actor is a professional digital media content creator in charge of digitalizing the cultural content.
- **IT Integrator:** Organization that integrates the whole solution.

5.2.3 Atos Business Model and go-to-market Strategy

In 5G-TOURS, ATOS acted as the developer of the application to be offered by the museum in order to engage and enhance the visit experience of their clients. This application is fully aligned with ATOS´ Media Content Supply Chain offering, so, as such, it might be included as part of the ATOS business media portfolio of products, which would provide ATOS with new business opportunities.

Figure 33. Atos Telecom, Media and Technology (TMT) portfolio.

However, having in mind the profile of the organisation, global leader in digital transformation that provides tailored end-to-end solutions for all industries, instead of just providing the app, ATOS could play several of the above-mentioned roles, such as the IT integrator one. On the other hand, to provide a one-stop-shop solution, another approach would be to create partnerships with other technological players to create a market-ready service for not professional users, who could then easily provide enhanced visits and additional services to their clients and a personalized and interactive experience with the use of new XR technologies. Any of these potential options will be in-depth evaluated now that the results of the project after the proof of concept in Palazzo Madama in Turin are available.

It is important to highlight that the results derived from ATOS´ participation in R&D EU projects play a vital role to booster the innovation process within the TMT Industry, a well defined process which happens regularly and implies a fluid communication among all the interested parts that work together with one objective: getting internal/external support for developing assets further, bringing them to a market ready stage and incorporating

them to the sales portfolio for the benefit of the European research, the company TMT business and the digital transformation of ATOS customers.

As stated in D8.3, such innovation process includes the elaboration of a thorough business plan would have to be elaborated before taking any action, including:

- Research on **market potential / service demand,** which is not an easy task for novel services like this. As it is not possible to know a priori how the demand will be, a sensitive analysis with the definition of relevant use case scenarios could be done.
- The **Barriers** to enter the market would have to be also analysed as well as a **Risk assessment.**
- Deep understanding of **customer needs** in order to determine how the current development should be transformed or adapted before sale and estimated time to market.
- **Competitors´ analysis.** In case there are other companies in the market already developing such innovative services. **Easiness to replicate** the services and potential actors should be also considered as well as the **service lifetime.**
- Detailed **go-to-market strategy** considering the creation of the **value proposition** with unique selling point, the definition of the **pricing model**, the c**ost analysis** and, in short, a complete **Business case.**

At the moment of writing this deliverable, potential vias of commercial exploitation are being internally analysed by ATOS, now with the experience gained thanks to the participation of the organisation in the proof of concept in Palazzo Madama in Turin. As stated in D8.3, potential strategy might consist of creating a set of additional innovation pilots of these new experiences in other cultural centres in the tourism sector, early adopters as Palazzo Madama in the 5G-TOURS project, with the purpose of breaking the first customers barriers and multiplying the effect to further create more interest with these good references.

5.3 Cost Assessment for City Wide Use Cases

In D8.3 [3], we provided an introduction and methodology to the city-wide UC analysis considered from the evaluation case 4 in the City of Turin. We also provided the TCO for the base case and the methodology for incremental cost analysis for the other use cases listed in Table 5.

Table 5. Use cases considered for cost estimation.

Industry Vertical	Description
Base case	Macrocell network infrastructure is deployed to serve the growing demand without considering additional UCs listed below
Tourism	Excursion on an AR/VR-enhanced bus. Provide AR and VR 5G services for passengers inside a bus
Tourism	XR immersive city tour experiences. Provide several application services in and around tourism UCs
Broadcast	Broadcasting services on 5G network
Healthcare	Remote health services on 5G network

In this section, we present the cost analysis for the two use cases listed below under the physical settings of *the city of tourism*:

1. Provide AR and VR 5G services for passengers inside a bus (Excursion on an AR/VR-enhanced bus (UC13);
2. Provide several application services in and around tourism UCs (XR immersive city tour experiences (UC1).

For each use case, the total demand in the network would be the demand from each UC plus the demand from eMBB services (i.e., base case). For the purposes of these scenarios the tourist footfall is kept constant. Significant uncertainties regarding tourism numbers retention (due to COVID-19 legacy, economic downturn of the global economy, sustainability and NetZero pressures) led to the approach of assessing other network dimensioning factors rather than speculating on volumes of users.

5.3.1 Excursion on an AR/VR-enhanced Bus

Table 6 provides the key assumptions used for the cost estimation. These assumptions are aligned with the assumptions used in the benefits estimation Deliverable D2.3 Technical requirements of the use cases, economic and deployment implications [6].

Table 6. Key assumptions used for cost estimation.

Take-up	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Tourists per year in Turin	#	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428
Tourists per day in Turin	#	5,286	5,286	5,286	5,286	5,286	5,286	5,286	5,286	5,286	5,286
Percentage of the tourists using AR_VR bus	%	8%	14%	23%	35%	50%	65%	77%	86%	92%	95%
Tourists use AR_VR bus	#	440	750	1224	1873	2643	3413	4063	4536	4846	5035
Percentage of users using 5G AR_VR kits	%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
Throughput per Min	Mbps	40	40	40	40	40	40	40	40	40	40
Min throughput requirements	Mbps	7,035	11,997	19,578	29,970	42,289	54,608	65,000	72,580	77,543	80,566

The TCO to support AR/VR bus use case using the MNO spectrum for different demand profiles is shown in Figure 34. AR/VR kits require high bandwidth connection i.e., 40 Mbps. As a result, supporting AR/VR buses requires an additional 24% TCO over 10 years (for the medium demand case). For the high demand case, the incremental TCO is increased to 27%.

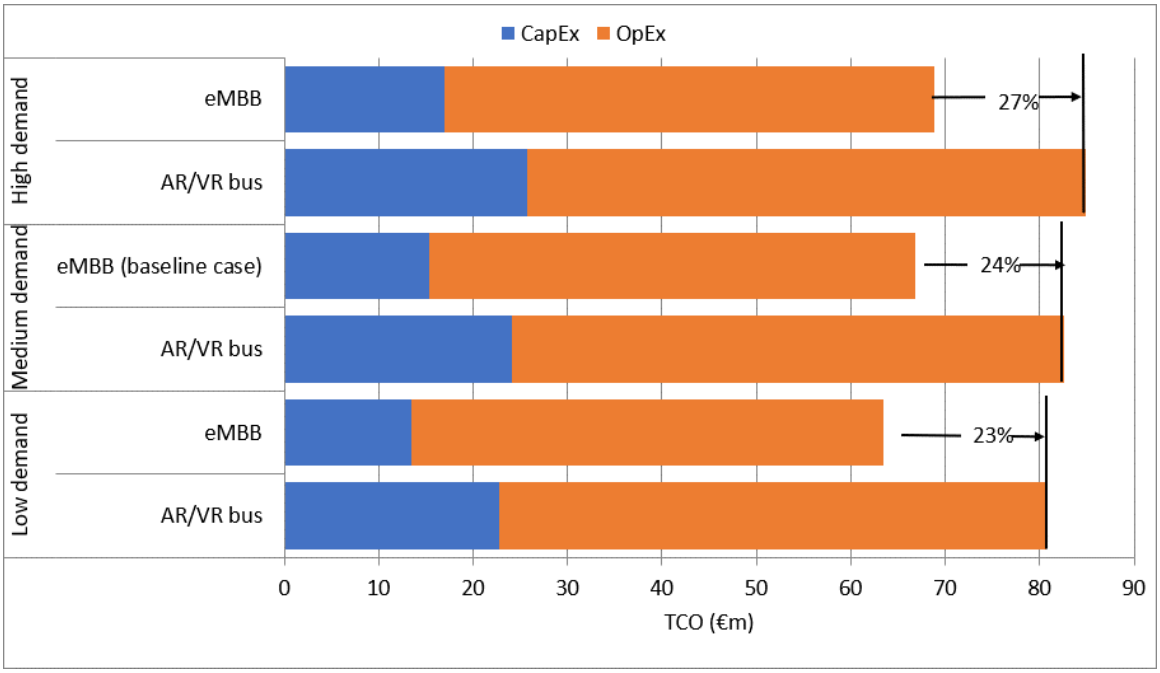

Figure 34. TCO comparison between excursion on an AR/VR-enhanced bus and the base case.

5.3.2 XR immersive city tour experiences

Table 7 provides the key assumptions used for the cost estimation.

Table 7. Key assumptions used for cost estimation.

Take-up	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Tourists per year	#	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428	1,929,428
Tourists per day	#	5,286	5,286	5,286	5,286	5,286	5,286	5,286	5,286	5,286	5,286
Service take up i.e., % of tourists walking with AR/VR kits	%	8%	14%	23%	35%	50%	65%	77%	86%	92%	95%
Tourists use AR_VR kits	#	440	750	1224	1873	2643	3413	4063	4536	4846	5035
Percentage of users using 5G AR_VR kits	%	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%
Throughput per user	Mbps	40	40	40	40	40	40	40	40	40	40
Minimum	Mbp	4,690	7,998	13,05	19,98	28,19	36,40	43,33	48,38	51,69	53,71

through-put re-quire-ments	s			2	0	3	5	3	7	5	1

Figure 35 provides the TCO to support XR immersive city tour experiences using the MNO spectrum for different demand profiles. AR/VR kits require high bandwidth connection i.e., 40 Mbps. The results show that supporting AR/VR experience using 5G requires an additional 15% to 24% TCO over 10 years.

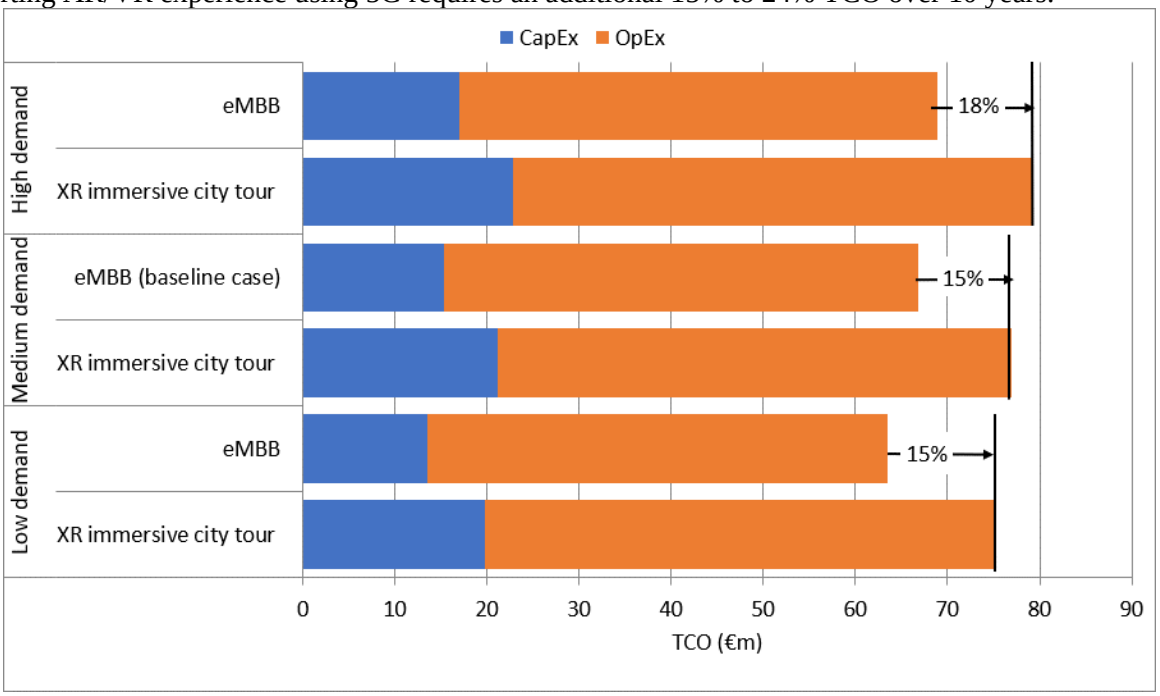

Figure 35. TCO comparison between excursion on XR immersive city tour and the base case.

Figure 36 shows the TCO comparison between the Tourism use cases presented in this section and the base case for medium demand. Results show that serving AR/VR-enhanced bus and the XR immersive city tour experiences require an additional 24% and 15% investment over 10 years.

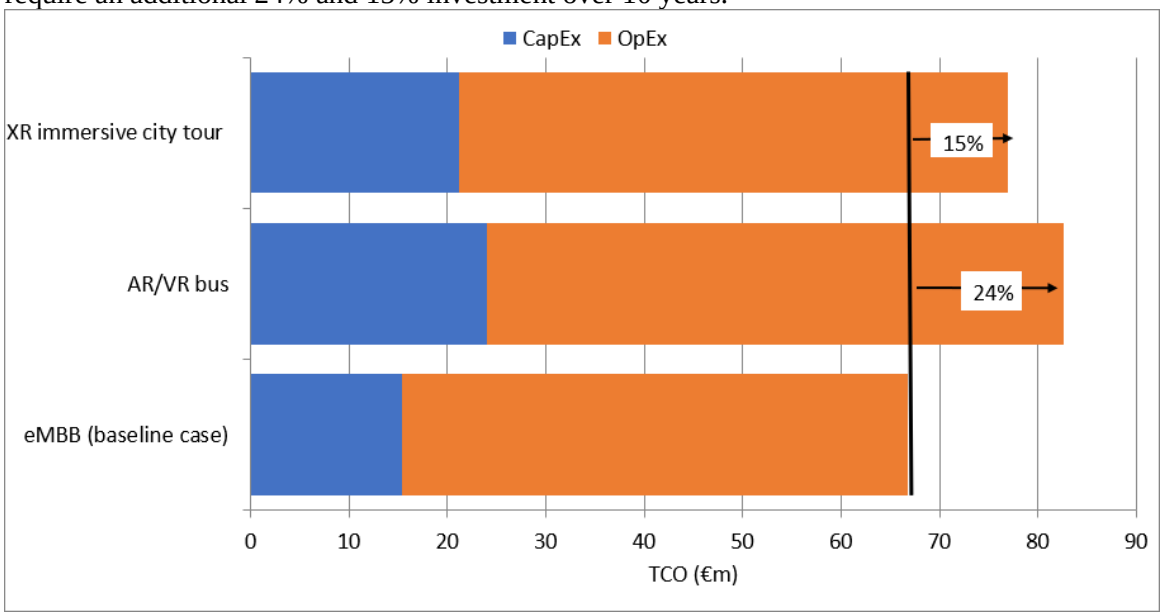

Figure 36. TCO comparison between tourism use cases and the base case.

5.4 5G-TOURS Network Implementation Aspects for Turin site

Work Package 4 – Touristic City – in Turin is utilizing the 5G technology to implement several use cases that aim to provide value services at the visited touristic attractions. The use cases are targeted to enhance museum visits by the means of VR support, AR applications, robot-assisted tours, and robot interactions at the related venues, as well as live events enabled by mobile communications such as multi-party concerts.

Ericsson has contributed in WP4 by addressing the network aspects. In the following sections, the experience gained so far is presented at a high level to provide an understanding of some of the aspects that needs to be taken into consideration in a network deployment of this kind.

Some current reflections related to the portability of the specific Robot use case to other environments is also touched upon and could be further detailed in final 5G-TOURS deliveries, once the WP4 is fully implemented and the final conclusions can be drawn from the experiences achieved.

5.4.1 Network deployment

The general scheme on which the 5G-TOURS network deployment is based, rely on an extension of the TIM commercial Network to cover the indoor locations identified for the use cases tests, trials and demos. The two identified locations are Palazzo Madama, placed in Piazza Castello, and Galleria civica d'Arte Moderna e contemporanea (GAM). The needs of an ad-hoc indoor coverage were dictated by the specific use cases´ location and, mainly for Palazzo Madama, by the thickness of the walls composing the historical building. The existing 5G network covering the outdoor environment couldn't provide the service inside the identified rooms.

From technical solution perspective, the Indoor Network installation are the extension of the TIM commercial Network: a dedicated Ericsson baseband (BB6630 Digital unit) has been connected to the Non-Stand-Alone architecture core, and then connected on fronthaul side to the radios located in the museum; the radio solution inside Palazzo Madama is based on the Ericsson 5G Radio R4422, while inside GAM the solution is based on the 5G Radio Dot solution.

The solution identified was strongly driven by three main factors:

i. **Performance** requirements coming from the use cases (mainly related to throughput and latency);

ii. Location infrastructure requirements: mainly for Palazzo Madama, many choices are driven by the architectural specificities and **aesthetical** needs (e.g., UNESCO site);

iii. **Regulatory** compliance and **local legislation** (including superintendence approval).

Starting from these three aspects, the process to identify the final solution was common to the two museums despite the constraints were very different.

5.4.2 Palazzo Madama

Palazzo Madama first implementation during 2020 was the occasion to learn the process, and the role of each interlocutor to be involved during the development period. The solution identified at that time was not fulfilling all requirements, mainly as it was not fully compliance with (iii) and for that reason it was authorized for very limited time period.

A crucial understanding (not only for Ericsson) was the fact that all the stakeholders must be involved from the beginning in the project to secure alignment on all requirements; not only the Museum owners, the telecom operator, the telecommunication and network supplier; but also, important not to forget, the superintendence organism of the city municipality. Lesson learned, with all the stakeholder's requirements understood, the project refined the approach and, in 2021, the implementation re-started the Network design phase involving from the day one some specific competences in the field of art and architecture.

In the context of Palazzo Madama, the new starting point was "how to match the three factors: performance, aesthetic/architecture and regulatory". A new cross functional team was established and driven by Ericsson. The final solution was identified after several iteration and adjustment: at the end, the solution was excellent on all three aspects.

Figure 37. Indoor Radio Installation masked result and R4422 radio detail.

5.4.3 GAM

GAM indoor coverage implementation started after Palazzo Madama solution was completed. It took advantages by the experience gained for Palazzo Madama, even more considering the context in which the Network must be deployed. The building is equipped with modern furniture, and this gave many opportunities to identify an easier solution using existing infrastructural accessories and technologies.

From the process perspective, all the experience gained at Palazzo Madama was applied; from the very beginning, a complete team driven by the Ericsson as technology provider, the operator (TIM), the museum owner (FTM) and the superintendence officer was established. With that approach, the solution was rapidly identified. In this case, some constraints on the location were relaxed, according to the officer indication and this allowed to quickly identify an optimized solution to match Performance requirements considering regulatory indication.

Figure 38. 5G Dot 4479 installation at GAM.

Figure 39. Ericsson Dot 4479.

5.4.4 Summary and opportunities for other deployment environments

Based on the experience gained so far in the deployment of the Museum use cases in Turin, some general high-level considerations can be concluded (but not intended to be exhaustive in any way). The Turin experience, in generic terms shows that there is a need for a very close cooperation between the vertical of the offered product/service and the selected MNO (Mobile Network Operator) to align and create an understanding of the main characteristics, as for example the three main factors identified for the specific Museum use cases in Turin. The importance of this initial phase of a deployment cannot be stressed enough to avoid delays and additional cost and even worse, performance and functionality not aligned with the end customer expectations.

Likewise, the vertical of the offered product/service needs to understand if it needs to be adapted to the end customer from functionality or form perspective as well as understanding any limitations or regulatory aspects to be taken into consideration when discussing with the MNO as outlined above. As an outcome of this initial alignment and requirement phase, an MNO will be able to provide one or more possible network solutions based on the available building blocks provided by the telecommunication provider(s) the MNO is utilizing.

As an example of building blocks that are available from a network perspective to select, the following link showcases the Ericsson Radio System Product Portfolio that is used to address the end customer requirements and characteristics of a wanted network. Similar product portfolios are provided by other Telecommunications and Network providers.

The Robot use case in Turin should not be considered limited to this specific environment, on the contrary. The experience achieved shows that a use case as advanced as the guiding Robot in a very complex environment as a museum is feasible and as such, is highly portable to other environments where the presence of a robot could be beneficial. Adaptation of the tasks to the specific environment is needed. New specialized functionalities can be added to the Robot adapting the control and application SW of it without excluding the possibility to also develop new mechanics and HW if so required and justified by a sound business case.

Such new environments to exploit could be, but not limited to:

- Hospital – Robot as information provider using natural language as input and output to facilitate communication with visitors at a hospital. Robot as guiding help leading a visitor to the right department within a large hospital. Robot as a “mesmerizing distraction” for younger visitors making their hospital experience less stressful and frightening.
- Airport – Similar to the hospital as information and guiding help. It can also be used in the duty-free areas to create curiosity and lead customer into the shops as well as to provide promotional information and maybe even offer something to taste. It can also be used as an addition to the already present surveillance system if so wanted.
- Shopping Center – Similar to the Airport but also with additions of providing suggestion for Cinema and Restaurant visit based on preferences provided by a visitor at the shopping center.
- Sports Stadium and any other environment or venue providing similar opportunities.

Key to success is to find a suitable base business model that can easily be adapted, if so needed, to a specific end customer environment of operation for the vertical product/service to sustain a valid business case. The verticals need to evaluate the different business models that can be identified and select a business model that is easily deployed, maintained, scalable and sustainable. The sustainability aspect is becoming an important and real business differentiator for any business and in the next chapter some aspects related to this are highlighted from a Telecommunication and Network provider perspective.

5.5 5G Sustainability

Sustainability and responsible business practices are fundamental to Ericsson's strategy and culture. Ericsson is committed to contribute to the sustainable development of society through its technology and solutions, as well as through its partnerships and the contribution and expertise of its employees.

For that reason, in the introduction of 5G technology, sustainability has been a key requirement for the radios and basebands launched since 2015 and 5G platform launched since 2017 that support 5G today. The modular Ericsson Radio system HW and SW architecture brings the flexibility for operators to decide the right time to deploy, expand, and monetize 5G, and the time for new 5G business models and go-to-market strategies.

Flexibility and modularity in deployment is enabling multi-layer network support with low/mid/high band when and where they are needed. This will help MNOs to offer required 5G performance and flexibility to serve multiple use cases with different requirements by securing that the devices are connected to the right band and for the right time accessing the optimized e2e slice instantly.

In this multi-layer network, High-band offer unpresented peak rate, latency and capacity is a great fit for targeted areas like stadiums, cities, hot-spots and key services. Mid-band is the sweet-spot to offer 5G experience since it combines, large Bandwidth, capability of higher system capacity with Massive MIMO and good coverage. Mid-band is also globally available which makes it easier to scale the ecosystem and provide 5G experience for all 5G devices from day one.

FDD low-band with our Ericsson spectrum sharing [9] solution introduces a new way of rolling out 5G that re-uses hardware/spectrum/sites and offers the most economically feasible way to introduce 5G in existing bands – enabling nation-wide 5G coverage with existing installation and simple re-configuration. It also helps other TDD bands to increase coverage using carrier aggregation.

In the journey to 5G Ericsson is shaping network operations of the future [10] to enhance the level of automation and openness of network leveraging on Artificial Intelligence and Machine Learning (AI/ML) to build data-driven, predictive and proactive zero-touch solutions.

5.6 Innovation TMOG Assessment

5G tours innovations applicable to the tourism sector were assessed according to the TMOG framework described in chapter 2. We applied the sector ratings of section 2.8.2 to reflect the preferences of a buyer a generic buyer of 5G products and services in the tourism sector The outcome was that innovations #7 and #10 were considered as presenting the best opportunity to leverage 5G infrastructure investment and deliver the best overall returns against TMOG criteria at the time of writing.

5.6.1 Assessment of Innovation #7 Business Viability

This innovation aims to provide the visitors of targeted museums with an improved and more engaging experience based on the use of eXtended Reality (XR) technologies. In terms of the TMOG assessment the innovation scored highly on technical readiness, technical impact and commercial value.

From a technology perspective the innovation seems to be relatively mature, with XR solutions having been under development since the 1990's, however, technology advancement in the area has accelerated significantly in the last decade. This innovation is intended to deliver a marked improvement in user experience and create truly interactive services by leveraging many of the attributes of 5G such as low latency and high reliability. At the same time virtual and augmented reality experiences are becoming far more widely available and there is a healthy ecosystem of devices capable of supporting the technology.

Commercial deployment could happen very quickly once 5G networks are rolled out since all the key components appear likely to be available with negligible additional development compared to some of the other innovations. However, in order for the innovation to be successful in long term and capitalise on early achievements it will be necessary for service providers to continue to provide interesting and meaningful content in order to maintain the appeal beyond the novelty value of initial offerings.

The innovation is considered to also have the potential for high impact. The ability to connect users with objects and people across space and time offers the opportunity to deepen experiences and appeal to a broader user base, therefore being eminently scalable across different providers in the tourism, hospitality and entertainment industries.

From a market perspective it is judged that there is a growing appetite for more immersive and personal experiences through the consumption of tailored content and also for interactive, shared experiences where users are able to work and play together, even if they are physically apart.

There is potentially a big advantage for first movers in this space to grab a larger portion of market share, particularly where actors within a town or city can come together, pool their offerings and make their particular destination more attractive as a whole. However, virtual experiences typically have to be grounded in a historical, cultural or social reality to have a high degree of authenticity and appeal, therefore a significant ongoing effort is required to differentiate offerings from others, which might be perceived as a gimmick or toy.

Where XR offerings are delivered in collaboration with established attractions then there is an opportunity for those attractions to generate additional sources of revenue not only through charging for use, but also from increased footfall. The novelty aspect means that there is likely to be a noticeable peak in sales and footfall. The challenge is to maintain a flow of new and repeat customers on an ongoing basis.

From an organisational perspective it is uncertain whether the tourism and hospitality ecosystem has the specific skills to implement and support XR services. However, it is clear that in the supporting sectors of media, marketing, and technology the skills are likely to be more developed. The fastest route to market may well be to embrace the wider support ecosystem and outsource much of the early effort, but this will require a significant effort to build good working relationships. Those attractions and actors that already have mature relationships will clearly have an early advantage e.g., in sport.

The socioeconomic value aspect of XR services really boils down to the ability and desire to deliver education and culture cultural offerings. A high assessment becomes harder to justify if the only motivation is for private commercial benefit. However, if such services can be offered in line with other initiatives to highlight for example social injustice, promote cultural diversity and acceptance then certainly there can be some wider benefit.

In 5G-TOURS, the addition of integrated emergency notification on the service gives a marginal boost to the ESG rating of the innovation.

5.6.2 Assessment of Innovation #10 Business Viability

This use case targets the distribution of enhanced high-quality video and immersive services for tourists to enhance the user experience when visiting a city. It is directly related to the media and entertainment vertical. Users will be able to use their smartphones, tablets, or VR devices to receive educational and informative content during their visits to the city and its museums. This Innovation scores highly on technology readiness, market readiness, commercial value and organisational readiness.

From a technology perspective is felt that Innovation #10 is a relatively mature prototype of a network-based technology which essentially is more about scalability of experience across multiple users than showcasing a smaller number of high-quality video services. Much of the development of content and devices to support high quality video services has already taken place and growth will continue if the prospect of better QoE can be reliably delivered over a wider range of locations and instances.

The potential impact of this innovation is also assessed highly. Video consumption is already high on mobile devices and this innovation offers the opportunity to offer more by joining with broadcast network infrastructure and leveraging the capabilities of 5G in terms of latency low latency and high reliability to deliver improved services. The ability to target and restrict content by geographical location or by user group etc can be used to

deliver more bespoke and shared experiences. Is could be argued that alternative technologies such as 4G & Wi-Fi can support similar services however 5G will improve the quality of experience considerably resulting in greater demand for high quality video content, for which providers can command a premium.

If we consider market readiness it is clear that there is already strong demand for video services in general, and by seeking to improve on existing services gives the assessment of Innovation #10 a boost. By involving broadcast network infrastructure, it is clear there will need to be some development of business models in order to ensure an equitable distribution of revenues. Content providers, event organisers, venue owners etc will also want to have fair access to the market and this may create opportunities for intermediaries. However, it is clear that the opportunities for organisations in the tourism sector to engage further with their customers is a major incentive to make the innovation a success. Live events, novel experiences, enhanced content all command a premium and so the commercial value of this innovation is expected to be high if the distribution and revenue elements of the business models are transparent and robust.

Organizational readiness and effectiveness are also assessed highly. Many of the organisational building blocks are likely to exist already and have been proven on several fronts e.g., interactive live sport where media companies have been able to deliver high quality interactive and immersive content. This innovation should create opportunities for this mature ecosystem to open up new opportunities by leveraging their knowledge, experience and relationships to develop appealing mobile experiences using 5G.

Finally, in terms of governance, in a similar manner to Innovation #7 the assessment of this innovation is neutral as it depends on the motives and actions of the various actors, which there are many and diverse. There is potential for wider socioeconomic value, but it is considered to be low compared to the private commercial benefits of the supply side ecosystem actors. Nevertheless, with the right sense of purpose, there is the potential to create socioeconomic value from using the innovation to support community and public broadcasting, education, and cultural reinforcement or appreciation.

6 Dissemination and Standardisation Achievements and Exploitation

A table summarizing the targets of the project for different dissemination and communication activities, as well as the reached objectives, is given below.

Table 8. Project targets and current number of dissemination activities.

Category	KPI	Target	Current status of dissemination activity
Standardisation and industry fora	Standards and industry groups impacted	3GPP, ETSI, GSMA, NGMN, DVB, DICOM, PCHA	3GPP, ETSI, GSMA, DVB, DICOM, PCHA
	Total number of standards contributions	More than 50	121
	3GPP standardization	Continue leading the activity on communication services for critical medical applications (SA1). Contribute to SA2, SA4, SA6, RAN1, RAN2, RAN3	Partners have already contributed to SA1, SA2, SA4, RAN
	ETSI ENI	Set up an official use case and a proof of concept	Was done by UC3M, WINGS, TIM, SRUK
	GSMA	Contribution to a white paper on vertical experiences and interfaces	NESTs for the project UCs were already developed
	DVB	Contribute with the experience of 5G trials with broadcast	Contributed with the Commercial Requirements for Adaptive Media Streaming over IP Multicast
	DICOM	Establish a WG focusing on the evolution of DICOM-RTV to 5G	Finalization of DICOM-RTV by BCOM
	PCHA	Format and procedures to store medical data with 5G	Was developed by PRE
Intellectual Property	Number of patents applications	At least 20	10
Open-source software	Number of open-source releases published	2 (vertical SDK, orchestration Open Stack-based software)	3
Industrial dissemination	Participation in industry events	MWC, IPWC and at least two others	MWC 2022, EuCNC 2020, EuCNC 2021, EuCNC 2022
	Number of small-scale demonstrations	3 (one per site)	3
	Organisation and attendance of 5G-TOURS industrial workshops	Three workshops, one per site, each with 100+ attendants	3
	5GPP activities	Take a leading role in trial related activities	Nokia continue to take a leading role in trial related activities
	Verticals related groups impacted	Airports (ACI, IATA), education (EDEN, ESEA, ESHA), healthcare (MEDICA, CARS), museum (NEMO), media (IBC)	All the groups were impacted by the project partners
Scientific dissemination	Organisation of scientific events and attendance	One scientific workshop with 50+ attendants and one special issue in a top journal	Two scientific workshops were organized by the partners
	Number of publications	More than 40	33

Communication to the general public	Number of press-releases	10+	17
	Web site visits outside the consortium	More than 75% of the visits coming outside the consortium	85-90% visits coming outside the consortium
	Social media channels used	Twitter, LinkedIn, Instagram, YouTube	Twitter, LinkedIn, YouTube, ResearchGate
	Webinars	At least 3	8
	Blog posts	At least 10	28
	Newsletters	4	4

At the final stage the project has already achieved a substantial impact in terms of dissemination activities.

As shown in Table 8, almost all the objectives related to the number of the dissemination activities have been successfully achieved. In the innovations assessments earlier in the document some of the bottlenecks to market deployment have been linked to availability and readiness of standardised solutions. This awareness of short-comings in Standards that assist with the availability of the Standard has led to 5G-TOURS partners taking leading roles in the contribution to the 3GPP standards. Partners have contributed to SA1, SA2, SA4, RAN. Total number of contributions to the standards is 121. UC3M, WINGS, TIM and SRUK have set up an official use case and a proof of concept in ETSI ENI (PoC#9 “Autonomous Network Slice Management for 5G Vertical Services”).

The number of dissemination activities related to international journals and conference papers has reached 33 contributions. Regarding the number of keynotes and panels together with the participation in 5G events, dis-semination has already reached the number of 52. The targeted number of workshops in major IEEE conferences has been reached. During the project 2 scientific workshops have been organised. Partners have issued two patents’ applications and 3 open-source releases. 5G-TOURS was presented at MWC 2022. Three industrial workshops in Turin, Rennes and Athens were organised by the 5G-TOURS during the last year. These events were quite successful, and number of verticals were already impacted there in an appropriate way. Nokia con-tinue to take a leading role in trial related activities in 5GPPP. Communication to the general public is on-going. The main following dissemination channels were: blog post, newsletter, press releases, workshops, and webi-nars. Project has prepared several demo videos about the UCs. These videos are available on the website: http://5gtours.eu/videos/ and on 5G-TOURS official YouTube channel: https://www.youtube.com/chan-nel/UCYdXMN027pe_Nkc6Hr92-Mw.

To promote the project website and project partners' achievements a blog post has been prepared. Finally, 28 blog posts were published. 5G-TOURS issued 4 Newsletters, which were distributed among more than 200 institutions from academia, industry, verticals, etc. Finally, all the targeted public deliverables were submitted as scheduled, and made available in the project website http://5gtours.eu/deliverables/.

All these mentioned above dissemination activities have helped to reach a large number of people from aca-demia, industry, civil society, media, etc.: in particular, 7200 people from the scientific community, 4899 people from the industry, 180 people from the civil society, 3330 people from the general public, 392 policy makers, 580 people from media, 829 customers and 1544 people from other sectors were reached. In total, 18954 people have been reached with the 5G-TOURS dissemination activities. These estimates were obtained based on the analysis of the involvement of the audience in social media, website traffic, and the number of participants in various events where partners participated.

6.1 Journal Articles and Magazines

5G-TOURS partners were targeting and have been publishing at the most prestigious journals and magazines in the field. The main results of 5G-TOURS project have been published during the third year in 3 journal papers and 1 book chapter, during the second year in 6 journal papers and 2 book chapters and during the first year in 2 journal papers and 1 book chapter. The full text can be found in (http://5gtours.eu/journal-papers-books-and-chapters/). The joint work between partners is also highlighted.

Table 9. Journal Articles and Magazines (3rd year).

#	Authors	Title	Journal / book information
1.	Odarchenko R., Dyka T.	QoE Estimation Methodology for 5G Use Cases	Future Intent-Based Networking. Lecture Notes in Electrical Engineering
2.	Roman Odarchenko, Giorgi Labadze	Links between 5G PPP projects: the road from the past to the future	Scientific and Practical Cyber Security Journal (SPCSJ)
3.	Jamil Al Azzeh; Roman Odarchenko; Anastasiia Abakumova; Serhii Bondar	Method for QoE monitoring and increasing in cellular networks based on QoE-to-QoS mapping using spline-approximation	EURASIP Journal on Wireless Communications and Networking

6.2 Conference papers

5G-TOURS partners have published up to 5 conference papers during the first year, 7 papers during the second year and 4 papers during the third year. All the conference papers were added to the OpenAire repository and are also available on our public website (http://5gtours.eu/conference-papers/). The full list of conference papers, either published or accepted, are listed below. The joint work between partners is also highlighted.

Table 10. Conference papers (3rd year).

#	Authors	Title	Conference information
1.	V. Prodomo, R. González, M. Gramaglia	Trading Accuracy for Privacy in Machine Learning Tasks: An Empirical Analysis	IEEE CNS
2.	L. Vignaroli, D. Desirello, A. Trogolo, G. Sacco, R. Rahav and B. Altman	The itinerant orchestra, a 5G, multi-camera, remote and distributed video production experiment	IBC 2021
3.	Gaetan Lelu, Yithian. Zhou, Guillaume Pasquier, Albert Murienne	Towards Wireless 5G Operating Room	CARS 2022
4.	Roman Odarchenko, Alexander Didenk, Konstantin Sunduchkov, Oleksii Verhovets, Vladislav Fesenko, Andrii Fesenko	The concept of a channelling system for satellite mobile communication for media delivery with increased efficiency	TCSET 2022

6.3 Presentations, keynote speeches, invited talks

The main results of 5G-TOURS project have been presented in 18 talks and presentations during the first year, 22 during the second year and 14 during the third year.

Table 11. Presentations, keynote speeches, invited talks (3rd year).

#	Main Author	Title	Event	Date	Place	Type of Audience
1	Roman Odarchenko	Links between 5G PPP projects: the road from the past to the future	PCSIS 2021	16/04/2021	Tbilisi	Industry / Academia
2	Roman Odarchenko	Development of 5G cellular networks: experience of Horizon 2020 projects	The night of science 2021	18/05/2021	Online	Industry / Academia
3	Simon Fletcher	Paper entitled "Operation of 5G NPNs: Industry Sector Considerations for Deployment and Sustainability"	2021 EuCNC & 6G Summit - WS6	8th June	Online + Porto Portugal	Industry / Academia
4	Baruch Altman	ACCIO Info Horizon Week: Mobility, Cluster 5; Use Cases	Horizon Europe Week 2021: Mobility, ACCIO (Government of Catalonia)	Jun 1st 2021	Online	Industry / Academia
5	Bel Mouhouche, Alvaro Ibanez	5G-XCAST and 5G-TOURS H2020 projects, 3GPPP standardization	5GIA-TSDSI Online webinar on 5G Tests and Pilots	Sept 22, 2021	Online	Industry
6	Roman Odarchenko	Features of European projects in the field of 5G	EU4USociety	Sep 17, 2021	Online	Industry / Academia
7	Roman Odarchenko	Methods for testing and improving the efficiency of 5G cellular networks: experience in implementing Horizon 2020 projects	Applied systems and technologies in the information society	Sep 30, 2021	Online	Industry / Academia
8	Nikos Papagiannopoulos	5G Airport use cases in action by Athens Airport & Panel Discussion: The Journey to 5G	Dubai Airshow, TechExplore Conference	18 November 2021	Dubai	Industry
9	Ioannis Patsouras	5G-TOURS Mobility Efficient City Network Performance Monitoring	InfoCom 2021 World Conference	26 November 2021	Online	Technical / Industry

10	Ioannis Patsouras	ACTA 5G Network KPIs Measurement ecosystem – Applications for Verticals	FITCE Hellas 2021 Conference	17 December 2021	Athens	Technical / Industry
11	Luca Vignaroli	The Itinerant Orchestra, a 5G, multi-camera, remote and distributed video production experiment	IBC 2021 - in the session 'Cutting Edge Technologies – A preview of some experimental concepts'	Thursday 16th December 2021	Online (Amsterdam)	Technical / Industry
12	Luca Vignaroli	5G-TOURS – The Itinerant Orchestra, a 5G, multi-camera, remote and distributed video production experiment	5G-SOLUTIONS Broadcasters' Workshop	February 2nd	Online	Technical / Industry
13	Lorenzo Natale	UC3 presentation	Robotic thematic workshop Genoa ELLIS Unit	8 April 2022	Genoa	Technical / Industry
14	Lorenzo Natale	UC3 presentation	ASTAR – IIT internal workshop	15 April 2022	Genoa	Technical / Industry
15	Nikos Papagianno-poulos	5G-TOURS project overview and 5G Airport use cases in action by Athens Airport	Passenger Terminal Expo 2022	June 16th	Paris	Technical / Industry
16	Giorgio Metta	Showcase various applications of robotics in IIT, including 5GTOURS UC3	Hightech Summit 2022, Automatica, Munich	June 22nd	Munich	Technical / Industry
17	Lorenzo Natale	Showcase UC3, live demonstration with simulated robot	ERF 2022	June 22nd	Rotterdam	Technical / Industry

6.4 Scientific workshops

A joint 5GASP and 5G-TOURS Special Stream in 5G Networks Technologies and Security on IEEE IDAACS (https://www.idaacs.net/2021) conference was held on 23rd of September 2021. Due to the pandemic, IEEE IDAACS 2021 was held as a hybrid conference allowing registrants the choice to participate virtually or in-person in Krakow, Poland.

This special session has covered the innovative technologies that were studied in various research projects and standardised by 3GPP in Rel 15 and Rel 16. The special session encouraged the submission of papers studying the current status of 5G research and early deployment and to assess how this relates to the initial 5G vision. The evaluation of the current solutions and/or deployment for features such 5G eMBB, URLLC (Ultra Reliable and Low Latency Communications) and mMTC (massive Machine Type Communications), Security and privacy aspects were considered as well. Published papers are accessible and provide a reality check for a wider audience on IEEE Digital Library.

The proposed special session was organised and technically co-sponsored by two of the flagship projects in the Phase III of the H2020/ 5GPPP initiative – 5G-TOURS and 5GASP. Finally, 7 highly qualified research papers were presented related to the 5G networks technologies and security issues in 5G. This was only the first edition of the special stream and 5G-TOURS partners aim to organize more similar sessions or workshops on other major conferences in the field even after the end of the project.

6.5 Industrial workshops

5G-TOURS consortium involves a number of partners whose activity has a strong social emphasis, such as a hospital, a school, a museum, a municipality, an airport and a security agency. Driven by these actors, many of the use cases addressed by the project have a strong societal impact. In order to assess the resulting benefits for society, 5G-TOURS has conducted the subjective evaluation which was fed, with the feedback received from the verticals participating, in the project workshops.

The project members have organised three industrial workshops devoting particular efforts to reach vertical industries outside the consortium and make them aware of the advantages that 5G can potentially bring to their businesses. These workshops were organised in the end of 2021 (Turin) and in 2022 (Rennes and Athens). Also, one joint virtual workshop was organised together with 5G-HEART project.

Through this series of workshops, each focusing on a specific study node, project partners aimed to investigate how 5G technology & architectures are aligned with creating stakeholder value within the industry verticals and how they might contribute to the long-term goals of an enterprise by creating superior performance, complimenting internal resources, and exploiting external opportunities.

A brief report about these successful events is presented in this section below.

6.5.1 Industrial workshop in Turin

On 30 September 2021, the House of Emerging Technologies in Torino hosted the 5G-TOURS Industrial Workshop “Torino – The touristic city” in a hybrid format, gathering more than 50 participants including attendees in the presence and online (Figure 40).

Figure 40. Industrial Workshop "Torino – The touristic city".

The aim of the workshop was to inform the local verticals (museums, cultural organizations, innovation centres, etc.) about the opportunities offered by the use cases developed by 5G-TOURS in the fields of augmented reality/virtual reality, robotics, broadcasting and remote video production and distribution applied to the cultural and tourist sectors. The ultimate goal was to stimulate a conversation on the benefits, usability and long-term sustainability of such solutions.

The works were opened by the perspective of the verticals involved in the 5G-TOURS implementation on the Turin site. In particular, Fondazione Torino Musei, hosting in Palazzo Madama and GAM (the museum of ancient art and the modern art gallery in Torino) several 5G enabled applications, stressed the importance of developing an innovative approach in the daily work of the museum staff in order to improve several types of activities, from the educational offer to the security of collections and spaces.

RAI, the Italian national broadcasting corporation, in turn, stressed the challenges of live broadcasting as well as the great opportunities that a faster network could offer to live shows in terms of accessibility and quality of video and audio contents.

After a lively presentation of the 5G-TOURS use cases by the project partners, including videos and demos of the applications, the audience was invited to reflect upon the presented solutions from the perspective of their "everyday work", but also looking at the future of the tourist and cultural sectors vis-à-vis the universe of emerging technologies and innovations.

Among the most active participants to the conversation, interesting contributions came from Museo Pietro Micca, Urban Lab, Polo del '900, Associazione Abbonamento Musei and Fondazione Torino Musei.

The discussion was facilitated by Fondazione Links, an organization external to the 5G-TOURS consortium, but with relevant experience in the topic of 5G applied to culture also thanks to their involvement in the IN-VENTA project.

The main outcomes of the workshop, which represent valuable food for thought for the 5G-TOURS partners, identify on the one side the great potential of the presented solutions in terms of accessibility, storytelling potential (e.g., history of places in different areas) but also in terms of security and facility management.

On the other hand, the technological obsolescence, the scarce interest of certain types of audiences and the difficult sustainability of some applications in the long period emerged as key issues that the 5G-TOURS consortium must tackle to grant full applicability to its use cases.

The Industrial workshop was just one of the opportunities to dialogue with the end-users of the 5G-TOURS solutions. The recording of the workshop is available at: https://www.youtube.com/watch?v=WxZ6vK0ue44&ab_channel=5G-TOURS

Photos are available here: http://5gtours.eu/first-5g-tours-industrial-workshop-hosted-in-torino-the-touristic-city/

6.5.2 Industrial workshop in Athens

On 25th February 2022, the *5G-TOURS Workshop of Athens, a mobility-efficiency City* took place in Greece. The event was held virtually and was broadcasted on live streaming by 5G-TOURS YouTube channel, gathering 178 registrations, 70 attendees and more than 440 views (Figure 41).

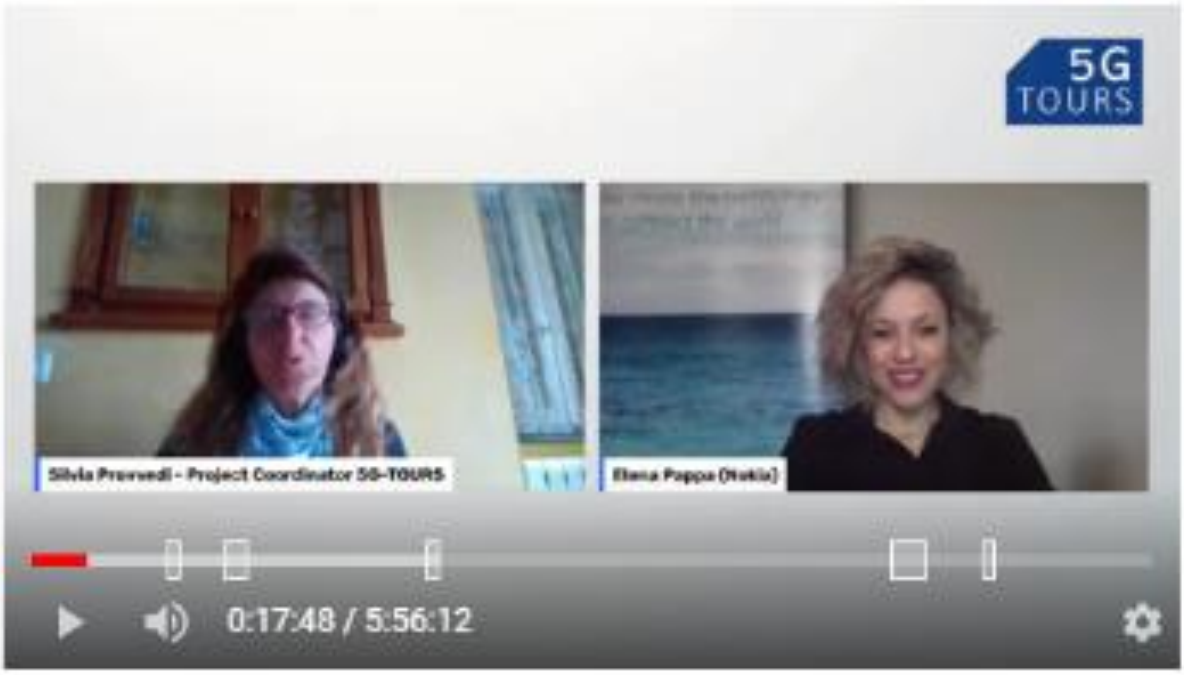

Figure 41. 5G-TOURS Workshop of Athens, a mobility-efficient city.

The purpose of the event was to present to local business and vertical industries the solutions developed by the partners of the Greek node and inform the audience about future opportunities and potentials. The focus fields were the use cases that took place in the airport of Athens offering 5G technologies for Smart Parking Management, AR/VR Bus-excursions, Video-Enhanced Ground-Based Moving Vehicles, Emergency Evacuation accompanied with a thorough analysis about the Innovations and the KPIs.

The event was hosted and organized by Nokia Greece and started with a welcome message by the 5G-TOURS Project Coordinator, coming from Ericsson Italia, who introduced to the audience the concept of the project and shared the information about the implementations. Focusing on Athens, the WP6 leader by OTE, shared with all participants a view of the Use Cases, the technology and the applications developed to support the 5G solutions. The infrastructure presentation and video of Nokia Greece closed the first part of the Workshop and launched a fruitful conversation concerning challenges, improvements, and impressions.

Continuing with the agenda the Use Cases' presentations and videos took the lead, offering to the audience the opportunity to view the developed solutions in detail and observe how the applications can contribute to new learning methods, leverage passengers' experience, grant safety, leverage passengers' experience, contribute to new learning methods and improve the handling of health emergencies by expanding 5G capabilities.

Use cases as presented in the event:

- Smart Parking Management, presented by WINGS ICT Solutions (WINGS);
- Video-Enhanced moving vehicles', presented by Athens International Airport (AIA);
- Emergency Airport Evacuation solution, presented by WINGS ICT Solutions (WINGS);
- Excursion on an AR/VR-Enhanced Bus, presented by Ellinogermaniki Agogi and WINGS ICT Solutions (WINGS);
- Remote health monitoring, emergency situation notification, presented by WINGS ICT Solutions (WINGS);

- Optimal ambulance routing powered by 5G, presented by WINGS ICT Solutions (WINGS).

The last part of the event was dedicated to the network KPIs and the Innovations. Partner ACTA Ltd partner shared the KPIs by explaining in detail the framework of the metrics and showing to the audience the results and the network capabilities based on the latest measurements. In the Innovation slot, participants had the opportunity to watch how the correlation of measurement the results of ACTA Ltd and WINGS ICT Solutions, led to the design and development of an advanced performance diagnosis platform and a tool for AI-enhanced orchestration by WINGS ICT Solutions, aiming to maximize the impact of the trials and validate the 5G vertical applications. in designing and developing an advanced performance diagnosis platform and a tool for AI-enhanced orchestration aiming to maximize the impact of the trials and validate the 5G vertical applications.

The workshop came to highlight that the 5G services do not only improve the quality of life for citizens and tourists, but also represent an important business opportunity as they address industry segments accounting for more than 50% of the estimated revenues generated by verticals.

In parallel to the workshop a virtual world was created in "GatherTown" for socializing and hosting offline and parallel conversations (Figure 42). The visitors had the ability to watch the workshop's videos, visit partners' booths, grab a coffee, and meet other people for networking and chit-chatting.

Figure 42. Virtual world "GatherTown".

The recording of the workshop is available at:
https://www.youtube.com/watch?v=QziD_DIJCgo&t=3732s&ab_channel=5G-TOURS

6.5.3 Industrial workshop in Rennes

During 2021, the partners of the health work package (WP5) of 5G-TOURS have decided to join forces with those of the health use cases of 5G-Heart to carry out common actions.

The first was the organization of a webinar on October 21st, 2021. The second was a face-to-face meeting between 5G players and health professionals, users and potential beneficiaries.

On 2022 June 2nd partners organised an industrial workshop to reach healthcare professionals who were not directly involved in the project consortium and make them aware of the advantages that 5G can potentially bring in patient care and process improvement. A strong emphasis was given to the use cases demonstrations, to show the advantages and benefits of 5G technology to address real problems and provide practical solutions.

Due to the health crisis and the triggering of the white plan at the Rennes University Hospital, the workshop had been postponed twice. To meet the deadline of the 5G projects, early June was the very last opportunity. Therefore, it was planned on June 2nd.

Despite a major new crisis currently affecting all French hospitals faced with an unprecedented lack of staff, 81 people signed up for the Workshop and it was a great success.

Partners came from Norway, Ireland, Greece, Nederland, UK, and different parts of France. Doctors, nurses, executives, directors, laboratory technicians, computer engineers, network, biomedical equipment, clinical research were present.

The program was rich:

- In a first session, after a word of welcome from the Deputy General Director of the CHU, Frédéric Rimattei, lectures made it possible to pose the subject of 5G in a fairly general way, then to describe some of the use cases and finally to outline the prospects for deployment and use:
    - Thierry EVANNO, *Nokia*, 5G AT A GLANCE;
    - Per H Lehne, *Telenor Research*, 5G Heart-e-Health trials;
    - Nicolas Bihannic, Sofiane Imadali - *Orange Innovation*, Leveraging 5G for healthcare and ties to other verticals;
    - Xavier Gilles, *AMA*, 5G and e-Health in other country (China case);
- Then, while videos concerning the use cases were broadcasted in a loop on several monitors, several stands animated by - stakeholders in the two projects presented their equipment -, allowing the participants to test usages and above all to exchange directly face-to-face:
    - **Nokia**: Safety demonstration: diagrams from Nokia: Radiation simulation, measurements, and audits from ANFR/Emitech;
    - **WINGS**: Use case H3C and UC 6 demo: Wings Startlit PF;
    - **RedZinc:** Urban Search and Rescue;
    - **AMA**: Demo: Teleguidance for diagnostics and intervention support of an emergency ambulance;
    - **Philips**:
        - Demo 1: 3D telepresence for remote ultrasound guidance;
        - Demo 2: Multi-stream digital ultrasound transfer;
        - Demo 3: Guided ultrasound with remote expert control;
    - **B<>com**: Demo: Use Case operating room:
        - Calibration process for ultrasound and X RAY;
        - How to get probe position to allow Augmented Reality fusion application;
    - **CHU**: Use Case operating room: phantom;

- Finally, questions were collected during the afternoon through an interactive Web questionnaire (accessible with a QR code), which were able to feed the discussions, exchanges and debates of the panel session which took place at the end of afternoon.
    - Speakers of the session: Nicolas Bihannic (Orange), Bessem Sayadi (Nokia), Sofiane Imadali (Orange), Per Hjalmar Lehne (Telenor), Guillaume Pasquier (b<>com). Some of the questions:
        - Security: advantages of 5G compared to other mobile technologies;
        - Low latency, what are we talking about?
        - Private network versus slice of a public network;
        - Economic model: who will pay?
        - Energy sobriety.

At the end of the workshop, some partners had the opportunity to visit the SAMU regulation centre. Finally, the organizing partners and a few doctors met for dinner, which made it possible to continue the discussions.

Many testimonials of satisfaction have reached us by email and on social networks.

A satisfaction questionnaire was also offered in interactive mode (QR code) as well as word cloud, a summary of the feedback is presented on Figure 43 below.

Figure 43. Just one word to express your feelings (*juste un mot pour exprimer votre ressenti*).

Participants gave an average rating of 4.6/5.

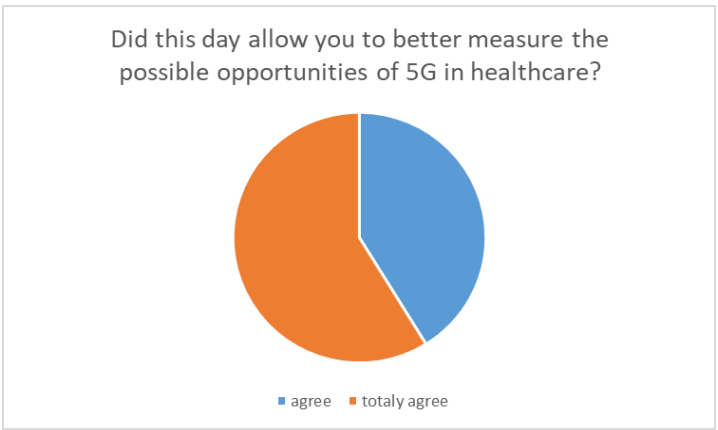

Figure 44. Summary on the feedback regarding the possible opportunities of 5G in healthcare.

Comments summary:

The three sequences were much appreciated especially the demo and the panel session.

For some professionals, it was not usual to exchange with foreign speakers (in English). They appreciated the effort to organize this diversity; it was very interesting but a bit complicated sometimes.

The plenary session (https://www.youtube.com/watch?v=KkynIoh8LU0&ab_channel=CHUdeRennes) as well as reactions of participants recorded during the event (https://www.youtube.com/watch?v=_NCi-TOScPkY&ab_channel=CHUdeRennes) can be reached on the CHU YouTube channel.

Some photos from the event are available on Figure 45 below.

Figure 45. Photo report from the event.

6.5.4 Virtual workshop on Tele-Health Solutions Powered by 5G

A virtual event was held on 22nd October 2021 to discuss 'Tele-Health Solutions Powered by 5G' and hosted by two EU supported projects 5GHeart and 5G-TOURS (Figure 46).

Figure 46. Virtual event 'Tele-Health Solutions Powered by 5G'.

The event was a huge success with a turnout of almost 100 attendees from all over Europe. The workshop was divided into three parts, the first of which was a series of presentations on 'Tele-health applications addressed by the 5GPPP'. The presentations were given by Cyril Krykwinski from the European Commission, Adrien Bresson from the French Ministry of Economy and Finance, and Sofiane Imadali, Orange from the 5G-TOURS project and Per Hjalmar Lehne, Telenor, from the 5GHeart project. The second part was a panel discussion on Tele-Health solutions for Ambulance Care and the third part was a panel discussion on Business Models for 5G Tele-Health.

5G brings the benefits of low latency, higher speed, better coverage, and reliability which lead to higher quality provisioning. This allows many applications such as video, robotics, remote monitoring of health and medication. It brings enhanced mobile broadband, massive machine-type communications, and the current wave of EU-supported projects is based on trials with a focus on vertical applications.

Cyril Krykwinski talked about technology changing the healthcare paradigm and becoming more personalised due to data monitoring and predictive analysis which enables in turn preventative care. The EU Horizon programme will continue to drive investments in 6G to maintain European competitiveness.

We learned from Adrien Bresson that the French government's 5G national strategy aims to support 5G/6G technological and industrial ecosystems by accelerating demand, supply, R&D, and training in future telecoms, creating 20,000 jobs by 2025 in this area.

Sofiane Imadali talked about the 5G-TOURS connected and remote healthcare use cases which are enhanced by 5G – focused on 3 different cities in Europe – improving logistics in Athens airport, innovative museum visits in Turin, and enhancing healthcare for patients in the city of Rennes. The 4 healthcare use cases leverage 5G features of slicing, ultra-low latency and high reliability, and massive machine-type communications in healthcare applications. The 'Safe City' pilot in Rennes is focused on remote monitoring in time-critical, emergency situations using machine-type communications devices, and linked ambulance routing in order to guide a tourist to the hospital. This culminates in the 'wireless operating room' which has all the data and imagery of the tourist and the associated emergency all with the help of 5G networks.

Per Lehne spoke about the ongoing pilots in the 5GHeart project which focuses on health, transport, and aqua-culture. The healthcare applications consist of remote support using wearable video for paramedics, augmented reality and ultrasound, critical health events, vital sign patches with geo-location facility. These pilots are based in Norway, Finland, Netherlands, France and Greece across several 5G testbeds with learnings on video and network quality and the network bottlenecks which 5G would relieve.

There were a number of recurring themes in the panel discussion on Tele-Health solutions for Ambulance Care hosted by Mohammed Hamza, CHU. Quality of healthcare remains of utmost importance in emergency care for patients while onboarding new network technologies and the new applications these enable. Emergency services, conveyance, and pre-hospital services form the first stage of tele-health and it will continue to grow from here. Stakeholder engagement is also of top priority by encouraging the widespread adoption of new technologies. A personalised approach tailored to the needs of stakeholders such as the government, hospitals, ambulance service, and patients is needed.

The panel discussion on Business Models for 5G Tele-Health, hosted by Donal Morris, RedZinc focused on 5G readiness, connectivity, and applications. 5G readiness is continuing to improve with connectivity becoming more widespread and applications becoming more available as the networks mature. Operators need to invest in infrastructure and hospitals and other stakeholders in equipment and new innovations, supported by the government. It is important to keep patient data secure by ensuring data protection as well as making investments in infrastructure. Hospitals wish to have local governance on data storage infrastructure rather than utilise global resources. In the end, investment in business and technology relationships will help bring about tele-health.

The recording of the workshop is available at: https://www.youtube.com/watch?v=pCIL8Ng8kdg.

6.6 Myrtis

6.6.1 UC13 – Myrtis exhibition at Aegina

EA initiated the idea for an exhibition at the Archaeological Museum of Aegina, a small island one hour from Athens. With the help of the Cultural NGO of Aeginitissa and the support of the Municipality of Aegina, EA has co-organised an Art and Photographic exhibition which took place from the 27th of May till the 3rd of June.

It was such a successful event that attracted more than 2000 visitors, thus we had to extend it twice till the 10th of June. All local stakeholders were informed and participated in the opening ceremony. There, Mr. Gregory Milopoulos, head of the project for EA, presented the 5G-TOURS project and the work that has been performed in UC13 (video of the speech, story and video of the whole exhibition provided by aeginaportal.gr).

200 students from all schools of the island visited the exhibition and experienced the AR applications of ATOS and WINGS through the posters that we have also used at AIA.

Students were amazed by the AR applications and they have been asked to write their impressions in the Museum's log book (see Figure 47):

> *"I would like you to create a site with this information (if you haven't already)", "when I came I didn't understand much, but then I understood and the things they showed us were very interesting", "I was shocked by the story of Myrtis", "I really liked the story of Myrtis and it moved me", "very difficult what you have achieved", "it was very nice and we had a lot of fun, except that the boys made a fuss", "it was a perfect experience and I hope she comes too someone else have a great time like me", "I really liked it because we travelled back 1,000 years".*

From a technical point of view, we have used the commercial 5G network through a commercial 5G router with a commercial SIM card. It worked flawlessly. This test revealed that we can also use the commercial 5G network to the events that we plan to organise in the future. This is very important for the sustainability and the exploitation of the project results (i.e., the AR apps and the content created for UC13).

The scope of this event was to test and showcase the exploitation potential of the UC13 content and applications. Thanks to the use of advanced technologies such as the 5G networks and to the great content and application created for UC13, we are enabled to present students with high quality content during educational visits to

archaeological sites and Museums (Figure 48). Presenting augmentations in front of students' eyes (even primary schools' students) is helping them to gain a deeper understanding of the issues they are studying.

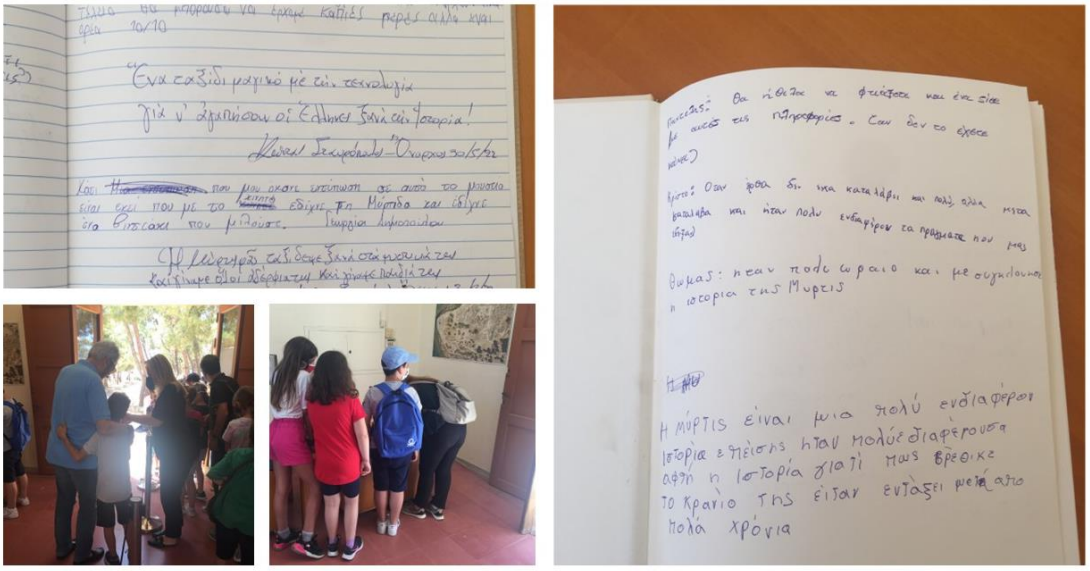

Figure 47. Students write their impressions on the Museum's log book.

Figure 48. Students using Samsung's S20s to read the AR Tags from the Myrtis poster.

Blending with the photographic exhibition, UC13's amazing AR applications (through a commercial 5G network) a new way of teaching the history of Myrtis from the 5th century BC was presented. With the technique of digital storytelling, the events 'come alive' and through them, unique stories and approaches to historical events emerge that make them familiar to students. Through this unprecedented experience, an amazing "dialogue" unfolded between the modern works of art, the archaeological artifacts of the Museum and the augmented reality poster of Myrtis, since one was next to the other. To disseminate the event and the project we have created a brochure, an official invitation and a poster (Figure 49) which were placed in strategic places within the city of Aegina, major villages and the ferries.

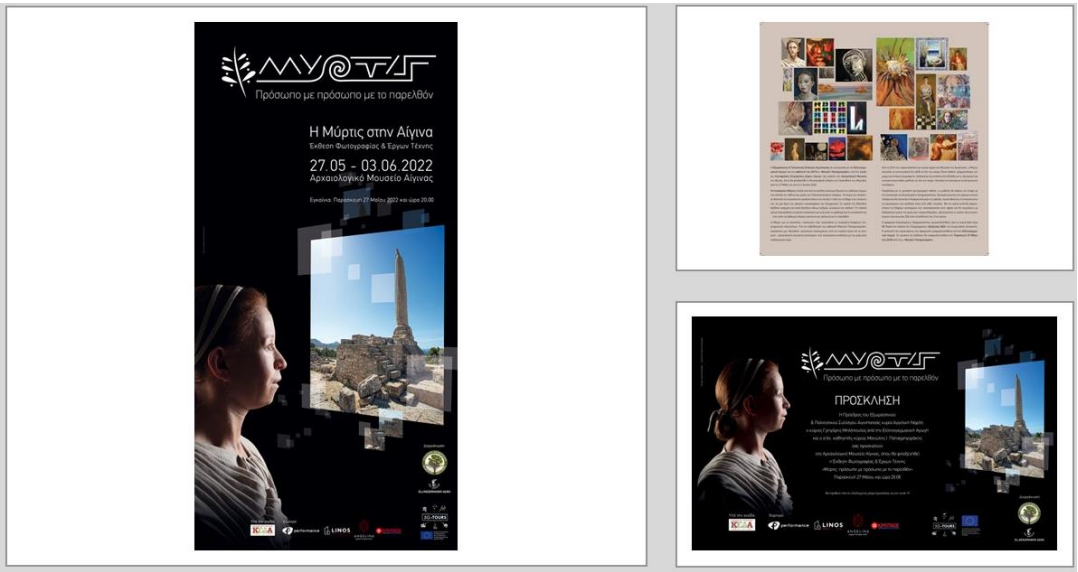

Figure 49. The dissemination material produced for the exhibition, the brochure and the invitation.

The event was extensively covered by national and local media and by the Athens News Agency - Macedonian Press Agency which has a presence in the media sector that extends for more than a century, cooperating with international and national news agencies like, Reuters, AP, AFP, DPA, EFE, ANSA and global information companies including Factiva, Bloomberg and the Financial Times. Naftemporiki and Ethnos (national high circulation newspapers and websites) also covered the event. Other well-known sites referred to the exhibition, such as iefimerida.gr, saronicmagazine.gr and cretalive.gr.

6.6.2 UC13 – Myrtis Summer Camp at EA

EA organised a Summer Camp on its premises, from the 27th of June till the 1st of July, based on the story of Myrtis and the AR applications developed for UC13. In this event 19 students have participated. Myrtis presents her city and her entire era to her "classmates". She presents her house, her games, talks about her diet, shares information about the music she listened to. Students discovered how the archaeologist researcher works, they did an archaeological excavation and presented their findings (Figure 50), they walked to Kerameikos (where Myrtis was found), they got to know how the reconstruction of Myrtis' face was done, they got to know the DNA and they isolated their own genetic material.

Figure 50. Students discovering Myrtis' story through the AR tags.

Through the UC13 AR applications, from a "classmate" Myrtis gradually turns into a "teacher" and a distant great-great-great-grandmother who advises on what the young students need to know so that they do not repeat the mistakes of the past but instead learn everything that will help them create a better society. And all this happens in the area of the Ancient Agora, in the Acropolis, the Pnyka and the Kerameikos, where the greatness of antiquity subdues the visitor and creates suitable conditions for learning and teaching.

Technically, we used the AR tags created by ATOS and WINGS but this time not in a poster but as separate pieces of paper, "hidden" in the Kerameikos area. Students played a treasure hunt game and discovered the tags in the area which were relevant to the specific spot! We also used the commercial 5G network.

For the purposes of the summer school, a printed programme/brochure was created (Figure 51). The event was covered by the printed version of one of the biggest newspapers in Greece: Kathimerini.

Figure 51. Myrtis Summer Camp Programme and the newspaper abstract from Kathimerini.

6.6.3 UC13 – Myrtis in the Greek Curriculum

Thanks to the efforts of Dr. Manolis Papagrigorakis (father of Myrtis), Ms Semiramis Mentesidou (Public Relations of Myrtis) and Dr. Sofoklis Sotiriou (Head of the R&D Department of Ellinogermaniki Agogi), Myrtis will now be part of the Greek Curriculum at the fourth grade of Primary School and at the first grade of High School. The project had a contribution to this development since EA is collaborating constantly with the Institute of Educational Policy (IEP) of the Ministry of Education in Greece. IEP is responsible for the curriculum and is trying to reform it to include new technologies. From the next school year books will also include AR tags. EA has demonstrated to IEP the VR & AR applications created in UC13 and the inclusion of Myrtis in the curriculum will give us the opportunity to reuse the project results in the coming years so that gradually, most of the Greek students will become aware of Myrtis and enjoy a new way of learning.

6.6.4 UC13 – Educational Leaders Awards

For the 7th year, the Education Leaders Awards were organized by BOUSSIAS, highlighted the panorama of best practices in education and awarded institutions and teachers from all levels and from all regions of Greece. The award ceremony was held with great success on June 3rd at the "Hellenic World" Cultural Centre, with the presence of the President of the Evaluation Committee, Mrs. Anna Diamantopoulos, former Commissioner and former Minister of Education in Greece.

Ellinogermaniki Agogi and Dr. Manolis Papagrigorakis (the "father" of Myrtis) won the Gold Medal in the field of Digital Education (Figure 52). This gave us the opportunity to have a small talk at the award ceremony where we referred to the 5G-TOURS project in general and UC13 specifically.

Figure 52. Receiving the Gold Medal in the award ceremony of Educational Leaders Awards 2022.

6.7 EuCNC2022 Event

During the second week of June 2022, 5G-TOURS took part at the EuCNC2022 conference in Grenoble, France (Figure 53). In fact, 5G-TOURS had a stand there (Figure 54), where various demos for the use cases in the tourism, the health and the transportation sectors were shown to the public. Several visitors, both within academia and industry, stopped by our stand, watched the demos and enquired about our latest technologies.

We have also been honored by the visit of Mr. Pearse O'Donohue (Figure 55), Chair of the conference and Director Future Networks at the European Commission. We showed Mr. O'Donohue our use cases, starting from the itinerant orchestra and the R1 robot guide-assistance (tourism sector), the airport evacuation and smart parking (transport sector) and the remote assistance (health sector).

Figure 53. Part of 5G-TOURS consortium attending the event.

Figure 54. 5G-TOURS stand.

Figure 55. Demonstration during Mr O'Donohue visit.

6.8 Touristic City trial phase and "Art meets 5G" final event

In April and May, the visitors of Palazzo Madama and GAM had the opportunity to be part of the enormous trial phase of the Touristic City, being engaged in the various innovative use cases that have been developed and implemented thanks to the collaboration of the partners City of Turin, Fondazione Torino Musei, Atos, Samsung, TIM and IIT. The trial activity has leveraged on the 5G coverage inside the two museums deployed by TIM with Ericsson technology, solutions that perfectly integrated with both environments and able to guarantee high transmission data rates and very low latencies [4]. Around 500 users, including visitors, schools, museum staff etc. were involved in the experimentation of the "Augmented Tourism Experience", "Telepresence" and "Robot assisted museum guide" use cases and their feedbacks have been collected through

targeted questionnaires. The trial phase has been accompanied by a huge dissemination campaign, with one joint press release, around 40 news publications on different cultural and scientific sites (including international) and, last but not least, 2 TV news on as many national TV channels.

In September 2021 we held a first Industrial Workshop, called "Art meets 5G", for museum and tourism sector experts, with the aim to present the final results of the WP4 activities (https://5gtours.eu/first-5g-tours-industrial-workshop-hosted-in-torino-the-touristic-city-2/). On the 25th of May, 5G-TOURS organized a second event where, after an introduction of all the use cases developed by WP4, the participants had the opportunity to personally try the Interactive Wall, enjoy a guided visit of the permanent exhibition with R1 robot, interact with the children remotely involved in the treasure hunt with DOUBLE 3 robot, as well as have some demo highlights of the use cases related to Palazzo Madama (including a short remote visit of the underground). With more than 40 participants, this event represented the worthy conclusion of the 5G-TOURS activities in the context of the Touristic City.

Figure 56. Presentation of the use cases at "Art meets 5G" event at GAM.

Figure 57. Interactive Wall demonstration (during "Art meets 5G" event).

Figure 58. Permanent exhibition visit with R1 robot (during "Art meets 5G" event).

6.9 Website and social media

So far, the main dissemination activities have been shared via the project website, Twitter and LinkedIn. A public website (http://5gtours.eu/) presents the news, events, description, consortium, and public deliverables of the project. The public website is the central hub for the dissemination activities. 5G-TOURS website is reachable via 5G PPP projects page https://5g-ppp.eu/5g-tours/. Open access to scientific publications is being ensured by publishing submitted papers in compliance with IEEE rules. The following Figure 59 shows as an example part of the publication section, where blog posts of the partners are shared.

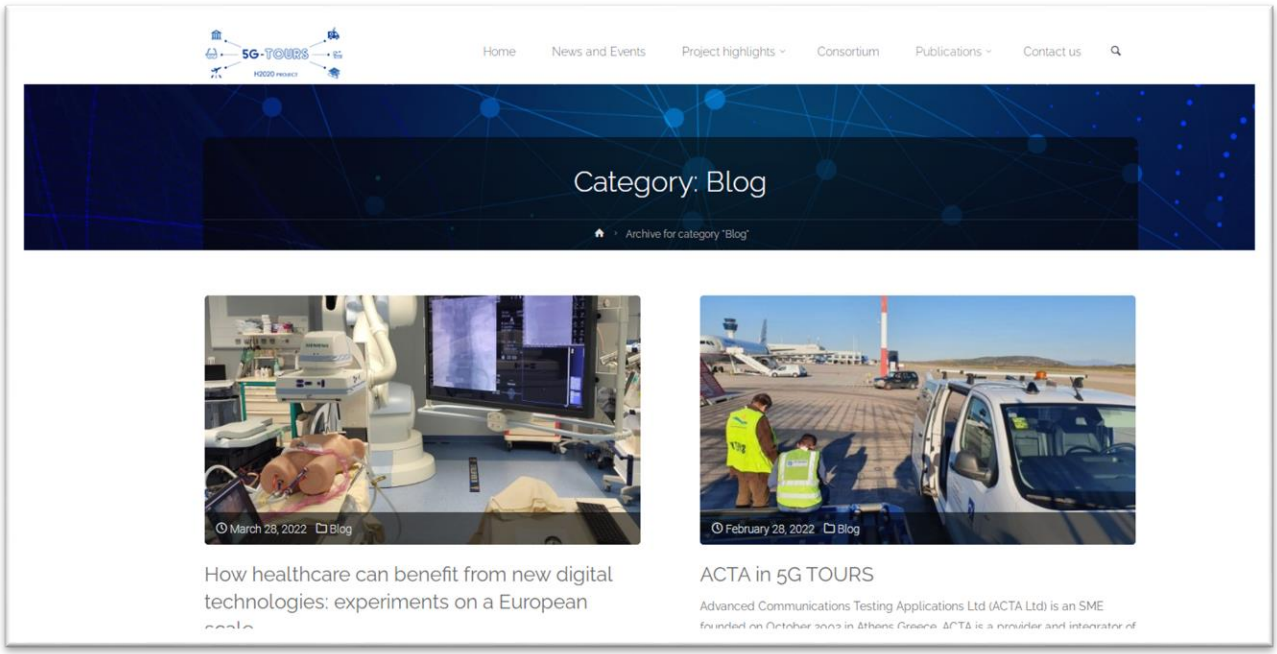

Figure 59. Official website of 5G-TOURS project (blog posts).

Website visits analysis using Google Analytics tool is shown on the following Figure 60.

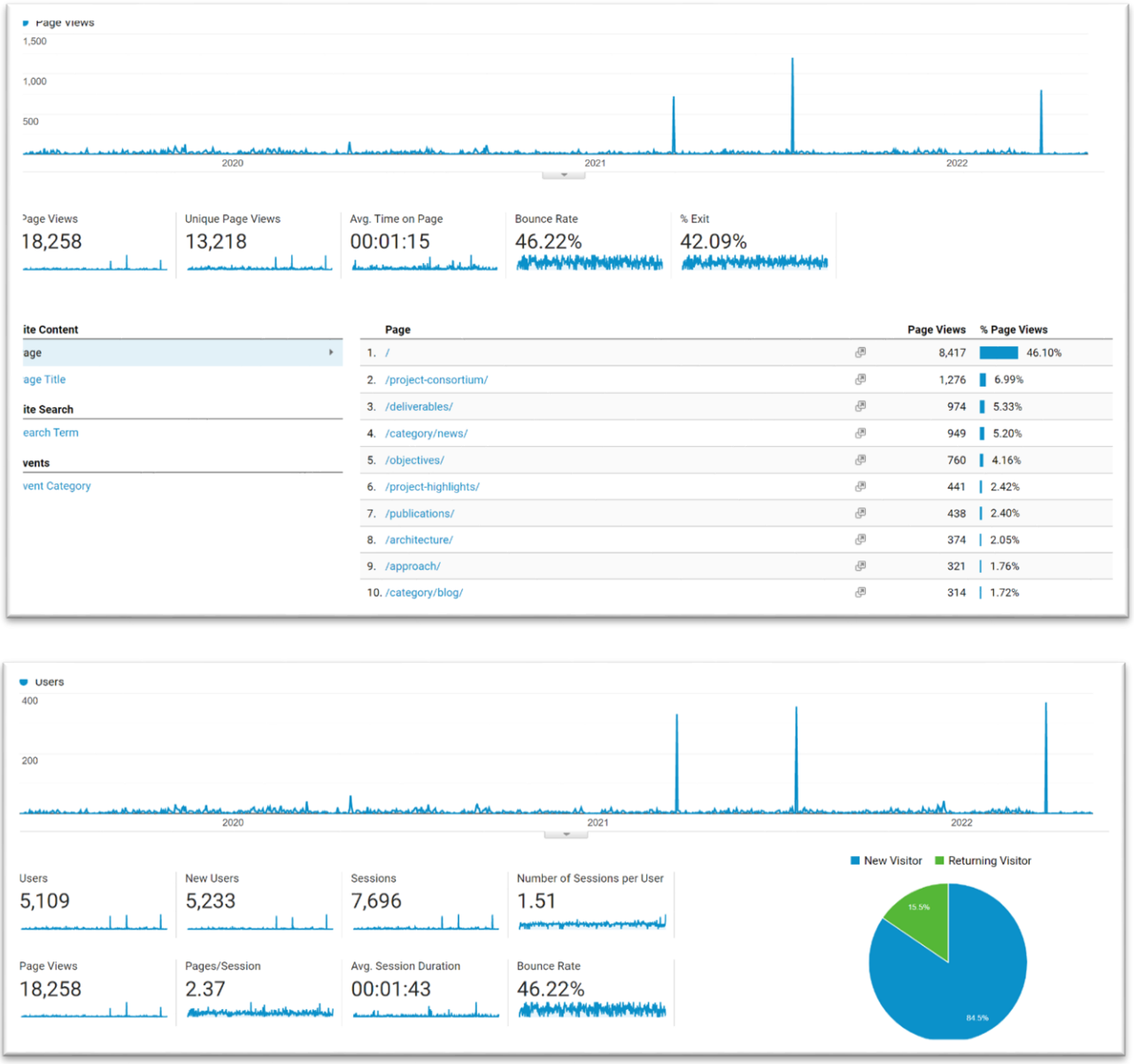

Figure 60. Website visits analysis.

Currently, the website contains the following pages:

- **Home:** General information about the project;
- **News and events:** Information regarding the last news and future events;
- **Project highlights:** This page consists of three subpages “Objectives”, “Approach” and “Architecture”;
- **Consortium:** Information about project partners;
- **Publications:** This page contains the following subpages: “Blog”, “Deliverables”, “Dissemination materials”, “Videos”, “Open Source Releases” and was constantly updated, in accordance with the progress in publishing activity, video production, preparation of presentation materials, etc;
- **Contact us**: Feedback form for the website visitors;
- **Blog:** Blog posts from all the partners were published according to the developed plan;

- **Dissemination materials (press releases, brochure, project presentation):** These materials were posted (up-dated) as they are produced;
- **Newsletters:** Newsletter issues were periodically published on the website and social media, also emailed to stakeholders (a contact list was updated on a regular basis).

The project is using Twitter (https://twitter.com/5gtours) as a key tool for dissemination. Not only news related to the project or published on the website, but also the main activities related to 5G-PPP or 3GPP were continuously shared through this platform. Currently, the project has shared 116 tweets reaching more than 1200 impressions in total. This impact has led our Twitter account to have 359 followers and more than 1600 profile visits. The current number of tweets, followers and links on twitter are also observed in Figure 61.

Figure 61. Official 5G-TOURS twitter account.

LinkedIn is another social media tool used to promote the 5G-TOURS work. The release of new project deliverables, news articles related to project meetings and the participation in 5G-PPP or other events are continuously shared through this platform. 5G-TOURS is present on LinkedIn under the name of '5G-TOURS' (https://www.linkedin.com/company/30118784). 5G-TOURS profile visitors come from different professional sectors, showing the project impact on different fields. 5G-TOURS LinkedIn profile page is shown in Figure 62.

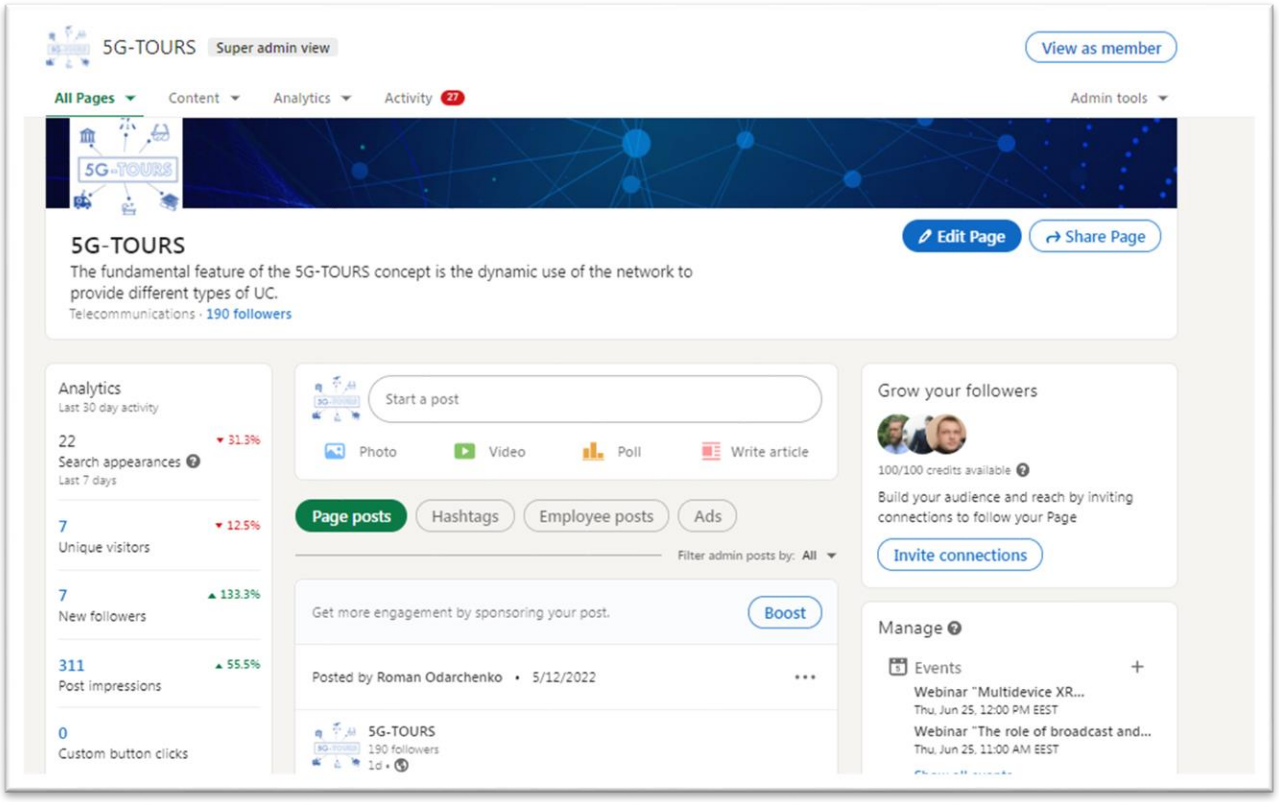

Figure 62. 5G-TOURS LinkedIn profile.

A YouTube channel (https://www.youtube.com/channel/UCYdXMN027pe_Nkc6Hr92-Mw/featured) has been used as one of the most effective dissemination channels and has captured several presentations from demonstrations, workshops, webinars and test-bed trials. The following figure presents the updated project profile.

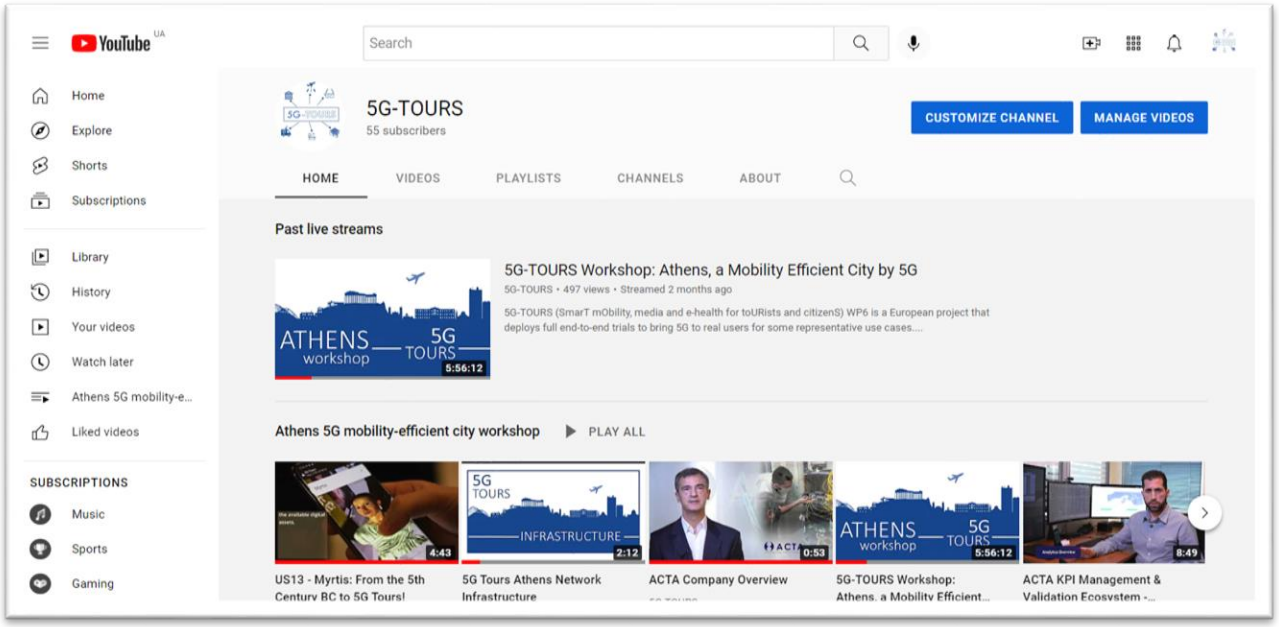

Figure 63. 5G-TOURS profile on YouTube.

Some channel statistics you can find on Figure 64.

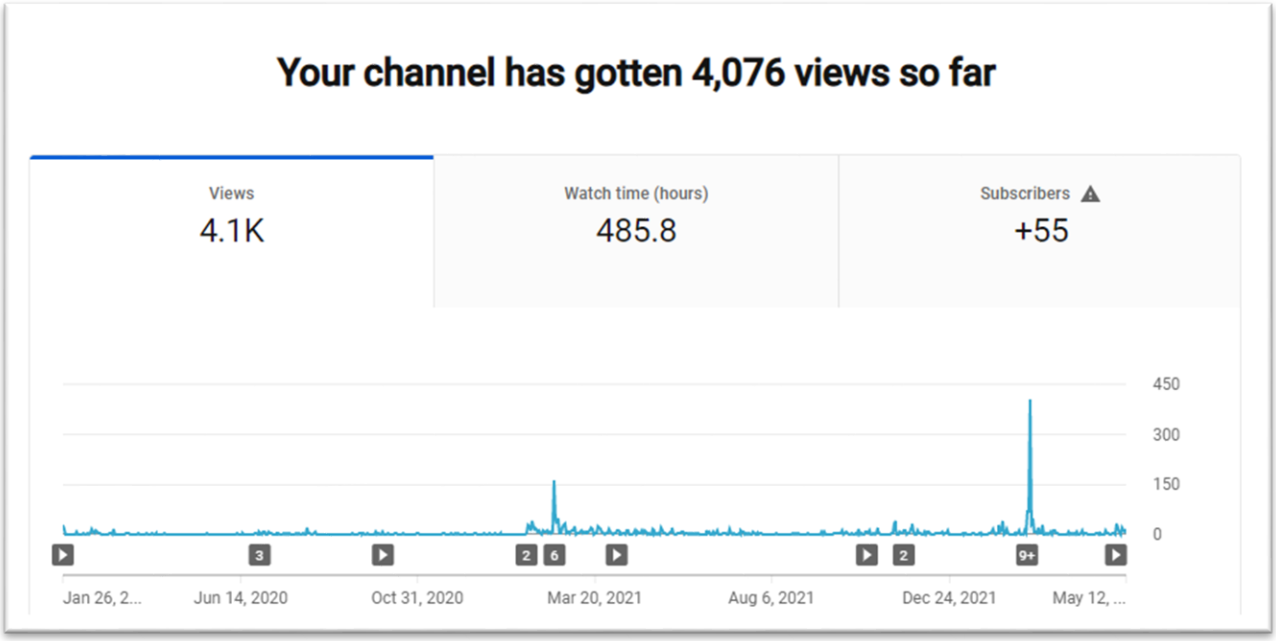

Figure 64. 5G-TOURS YouTube channel statistics.

29 videos were already published on the YouTube channel and official website accordingly: http://5gtours.eu/videos/.

6.10 PRs and industry articles

For the current moment partners have already published several PRs, which achieved a very high exposure. These PRs are represented in Table 12 below.

Table 12. Press releases published during the third year.

#	Partner	Issue date	Publication	Link
1	CHU	September 2021	Améliorer l'accès aux soins avec la 5G	https://www.lefigaro.fr/ameliorer-l-acces-aux-soins-avec-la-5g-20210929
2	CHU	October 2021	Le CHU de Rennes expérimente deux cas d'usages de la 5G	https://www.ticsante.com/story.php?story=5911
3	CHU	October 2021	Le CHU de Rennes engage dans plusieurs projet 5G	2020.03.01_Corriere_5GtoursPaM.pdf
4	CHU	September 2021	La santé au bord de sa révolution 5G	https://www.egora.fr/actus-medicales/e-sante-sante-publique/67934-la-sante-au-bord-de-sa-revolution-5g
5	CHU	September 2021	Améliorer l'accès aux soins avec la 5G	https://www.lefigaro.fr/ameliorer-l-acces-aux-soins-avec-la-5g-20210929

6.11 Newsletters

5G-TOURS team, according to the developed schedule (Table 13) periodically issued four Newsletters, which highlighted and described in more details project achievements, innovation stories, and relevant events.

Table 13. Newsletter issues schedule.

#	Expected outcomes	Date
1	Use case description at high level	October 2020
2	First trials results	April 2021
3	Business case analyses	December 2021
4	Project results	July 2022

Each Newsletter was distributed among more than 200 institutions from academia, industry, verticals, etc. 5G-TOURS. This first edition was focused on 6 of 13 innovative use cases. The second edition described other 7 project use cases. Third newsletter presented the Business cases analyses. And, naturally, the last edition highlighted all the project achievements and stories of success. The first pages of different issues of the newsletter are presented below on Figure 65. Full versions of newsletters are also available on the official website: http://5gtours.eu/newsletters/.

Figure 65. 5G-TOURS Newsletters.

6.12 Flyers and posters

A flyer was chosen as a form of paper advertisement intended for wide distribution and typically posted or distributed in a public place by 5G-TOURS. After the pandemic, the first huge event, where 5G-TOURS participated, was MWC 2022. To present the overall vision of the project, the special flyer (Figure 66) and a poster (Figure 67) were developed.

Figure 66. Official 5G-TOURS flyer.

Figure 67. Official 5G-TOURS poster at MWC 2022.

Together with other 5GPPP projects (5G-HEART and 5G-SOLUTIONS) our 5G-TOURS team participated at MWC 2022 and was represented at the 7F13 booth. A lot of attendees visited project booth to learn about Smart City deployment concepts, trials and testbeds ongoing in Rennes, Turin, and Athens (Figure 68).

Figure 68 – 5G-TOURS team at MWC 2022

At MWC 2022, Belkacem Mouhouche (Samsung UK) gave a presentation about the 5G-TOURS project at the MWC session "Travel Tech round grouped around Catalonia's ICT Tourism Cluster".

Also, other 5G-TOURS partners participated in the event. For example, Atos had its own stand at the event (Figure 69).

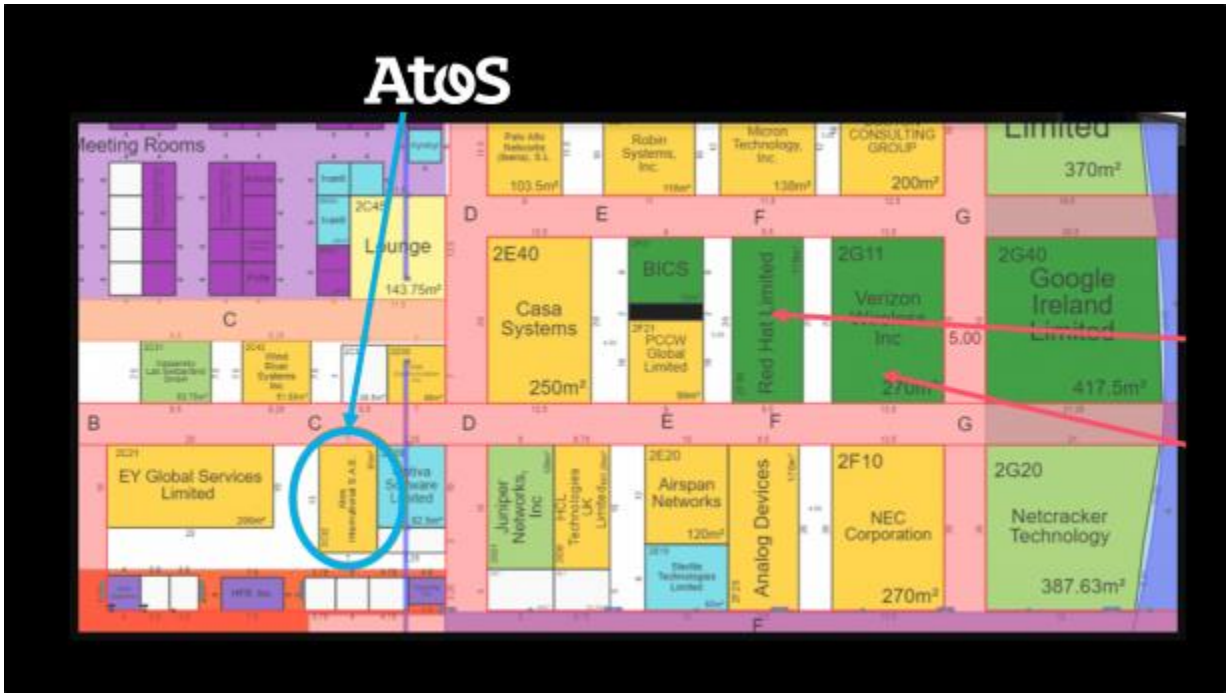

Figure 69. Atos booth location at MWC 2022.

Atos Research & Innovation group (ARI) presented three demos on AI-based Network Management Automation based on the work resulting from their participation in two different EU-funded projects: 5G-TOURS and Affordable5G (Figure 70):

- **Demo 1**: AI-based Close loop automation for NFV MANO. Automated scaling (in/out) based on VNF CPU usage level forecasting. Video is available at: https://www.youtube.com/watch?v=t-uH6XlP0Ak&ab_channel=5G-TOURS;
- **Demo 2**: AI-based Close loop automation for NFV MANO. Automated scaling (in/out) based on road traffic image recognition. Video is available at: https://www.youtube.com/watch?v=q9-RoXs_hgc;
- **Demo 3**: Radio parameter optimization via ML-assisted near-real-time control loop.

Figure 70. Atos team at MWC 2022.

7 Conclusions

Business validation analysis has progressed, from early stages of the project where a high-level framework for looking at the City context through the eyes of City strategic planning, which could utilise City Index benchmark thinking. To the generic (typically supply side oriented) 5G business models that were only just emerging at the time of the end of the first year. Then progressing into the development of a deeper appreciation of the costs as a large component of the investment decision. An appreciation of the substantial emphasis being placed by the industry sectors or demand side decision makers, weighing up opportunity cost of investing in 5G against other projects and technologies that might benefit their enterprise. This appreciation led to the research and identification, and the refinement of a framework that could be applied to assist in the commercial value-based assessment of innovations that may emerge from the 5G supply side. The model can be considered as a multivariate conceptual space within which pragmatic and business-oriented assessments of the value propositions of innovations can be carried out. By illustration an application of the framework applied to the innovations that are being promoted by 5G-TOURS gives an objective view on the innovations assessment. Transparency undoubtedly facilitates open discussion between stakeholders, leads to better investment decisions and can increase the chances of successful multi-stakeholder collaborations by ensuring that participants make a fair and proportionate contribution to the cost of implementing and running 5G infra-structure.

By the end of year 1 the business analysis survey of the 5G-TOURS project members had established a view of the project partners on the prospects for the use cases and the sorts of business models that currently apply to their business at that time. By the end of year 2 tooling had been developed and tested to carry out environmental and deployment cost assessments. By the end of the project, in a process led by the Innovation managers, the innovations have been positioned and assessed in the context of the industrial sectors' needs. Sector specific considerations have been articulated and 5G-TOURS project partners have had the opportunity to refine their views on the competitive landscape, their competitive advantage and their exploitation plans adjusted appropriately. The innovations that emerge in the networking technology domain have also been captured in this report as they are important enabling innovations to realize the value of the project not only for the vertical sectors but also for the wireless industry (including telecoms operators) sector. They have been placed in the sector and use case that most effectively illustrates their potential.

The project catalogued 121 contributions across various standards bodies over the last three years. This quantity has exceeded expectations. The project also has secured standards Rapporteur level participants amongst its numbers evidencing influence in shaping the standards. Project partners have become influential in newly formed industry collaborations, such as 5G-MAG for the Broadcast sector.

The number of dissemination activities related to international journals and conference papers has reached 34 contributions. Regarding the number of keynotes and panels together with the participation in 5G events, dissemination has reached the number of 57. After both MWC20 and MWC21 were cancelled 5G-TOURS was highly energised to participate in MWC22 and collaborated with two other H2020 projects to finance and staff a stand. Taking into account the COVID-19 imposed restrictions different customised or bespoke workshop experiences and use case user participation workshops have been delivered. These have provided invaluable insights to 5G-TOURS in the refinement of our assessments on the value propositions of the innovations. EuCNC22 was the final showing of 5G-TOURS with a substantial presence of use cases and project partners, topped by the honour of a visit from the European Commission to discuss the findings of the project. All of these dissemination activities have helped to reach a large number of people from academia, industry, civil society, media, etc.

In addition to the collaborative dissemination activities each 5G-TOURS partner has reported activities regarding their findings and have used those individual experiences in the refinement of their exploitation planning. This provides evidence of the closing of the loop from the Technology deployment and demonstration and the anticipation of exploitation.

Since 5G has the potential to create enormous social and economic benefit, i.e. beyond its own market value, major vertical stakeholders need to decide whether it is appropriate to spend time, money and resources trying to monetise 5G connectivity or, alternatively, understand that there is greater value to be had in the ecosystem by looking to maximise the capability of the infrastructure, distribute costs fairly amongst those who would seek to benefit from it and make it available as widely as possible.

By the end of the project, there has been substantial engagement by potential users of 5G system in the three sectors of interest to this project. It is evident that there is acceptance of the potential of 5G as a key enabling technology for industry verticals as part of the greater digitisation revolution, supporting transformational technologies and applications such as IoT & digital twinning, AI, AR/VR etc. Yet, wireless connectivity is not a core part of the verticals' business and thus there are gaps in expertise and knowledge regarding the optimum method of delivery (whether technology or architecture related) or concerning the most appropriate business models. Workshop attendees have emphasised that what verticals really care about are business outcomes rather than the detailed features of the technology.

All significant value ideally needs to be captured otherwise opportunities will be missed, therefore, it is as important to understand the social environmental and wider economic value as it is the direct commercial opportunities. The key to maximising investment in 5G infrastructure is to really understand the potential to create value through the articulation of the innovation value propositions and the bringing to life of the quality of experience through high user community engagement, trialling, and targeted Standardisation. 5G-TOURS has demonstrated best practice approaches to such activities, customising messages and engagement processes to address innovation adoption challenges of the three sectors, paving the way to acceleration of diffusion of innovations.

Acknowledgment

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References

1. 5G-TOURS: Deliverable D8.1 “First Report on Innovation Management, Dissemination, Standards and Exploitation Plans” - (http://5gTOURS.eu/documents/deliverables/D8.1.pdf)
2. 5G-TOURS: Deliverable D8.2 “Second Report on Innovation Management, Dissemination, Standards and Exploitation Plans” - https://5gtours.eu/documents/deliverables/D8.2.pdf
3. 5G-TOURS: Deliverable D8.3 “Business Model Archetypes of vertical industries and the 5G-TOURS commercial opportunity” - http://5gTOURS.eu/documents/deliverables/D8.3.pdf
4. 5G-TOURS: Deliverable D4.4 “Final Touristic City use case results” - http://5gtours.eu/documents/deliverables/D4.4.pdf
5. 5G-TOURS: Deliverable D5.4 “Final Safe City use case results” - http://5gtours.eu/documents/deliverables/D5.4.pdf
6. 5G-TOURS: Deliverable D2.3 “Technical requirements of the use cases, economic and deployment implications” - http://5gtours.eu/documents/deliverables/D2.3.pdf
7. Philips Lumify - https://www.usa.philips.com/healthcare/sites/lumify/tele-ultrasound-solution
8. Philips Lumify – https://reacts.com/reacts-with-lumify/
9. Ericsson Spectrum Sharing, 2021 - https://www.ericsson.com/en/ran/spectrum-sharing
10. Ericsson Network Operations, 2021 - https://www.ericsson.com/en/network-operations
11. Technology readiness level - https://en.wikipedia.org/wiki/Technology_readiness_level
12. XpertEye - https://www.amaxperteye.com/
13. STARLIT - https://www.wings-ict-solutions.eu/startlit/

Annex A: Contribution to standards

List of all agreed / accepted contributions in standardisation bodies proposed and supported by 5G-TOURS partners during the project. Extended table is available at: https://5gtours.netcom.it.uc3m.es:8443/confluence/pages/viewpage.action?spaceKey=5GTOUR&title=Contributions+to+the+Standards

#	Date	Partner	Stand' Body	Title	UC
1	06/06/2019	EXP	3GPP TSG SA	Revised SID: Architectural enhancements for 5G multicast-broadcast services	UC4c
2	16/08/2019	EXP	3GPP SA4	pCR 26.512 Consumption Reporting API	UC4c
3	16/08/2019	EXP	3GPP SA4	CR 26.501-0002 rev 3 Correction of Architecture, Unicast Streaming Procedure, QoE metrics reporting, Consumption reporting and Session Handling for 5GMS (Release 16)	UC4c
4	23/08/2019	BCOM	3GPP SA1	CR on Addition of robotic aided surgery and diagnosis performance requirements in TS 22.104	UC8
5	23/08/2019	BCOM	3GPP SA1	CR Addition of section 4.2 on key parameters for critical medical applications in TS 22.263	UC8
6	23/08/2019	BCOM	3GPP SA1	CR Addition of security requirements for critical medical applications in TS 22.261	UC8
7	23/08/2019	BCOM	3GPP SA1	CR Addition of medical telemetry requirements in TS 22.261	UC7 UC8
8	23/08/2019	BCOM	3GPP SA1	CR Addition of a new synchronisation performance requirement	UC7 UC8
9	23/08/2019	BCOM	3GPP SA1	Addition of Abbreviations section in TR 22.826	UC7 UC8
10	23/08/2019	BCOM	3GPP SA1	Addition of a synchronisation requirement in use case 5.3.3 (Communication QoS requirement for robotic telesurgery)	UC8
11	23/08/2019	BCOM	3GPP SA1	TR 22.826 final clean up	UC7 UC8
12	23/08/2019	BCOM	3GPP SA1	Addition of Conclusion and recommendations section in TR 22.826	UC7 UC8
13	23/08/2019	BCOM	3GPP SA1	Alignment of use case description text and Survival Time requirements in TR 22.826	UC7 UC8
14	23/08/2019	BCOM	3GPP SA1	Consolidation for clock synchronization in TR 22.826	UC8
15	23/08/2019	BCOM	3GPP SA1	FS_CMED_Updates related to cardiac telemetry monitoring	UC6
16	23/08/2019	BCOM	3GPP SA1	TR 22.826 Study on Communication Services for Critical Medical Applications v1.1.0	UC7 UC8
17	16/09/2019	BCOM	DICOM	Finalization of DICOM-RTV (sup202)	UC8
18	19/09/2019	BCOM	3GPP SA1	Study on Communication Services for Critical Medical Applications	UC8
19	16/10/2019	SEQ	3GPP RAN	Rel-17 NR-Light scoping discussions	UC6 UC10
20	18/10/2019	EXP	3GPP SA2	Key issue for levels of service	UC4c
21	25/10/2019	EXP	3GPP SA4	CR TS 26.501 on Consumption Reporting API	UC4c
22	14/11/2019	SEQ	3GPP RAN2	NB-IoT UE specific DRX – Backward Compatibility	UC6 UC10
23	18/11/2019	SEQ	3GPP RAN1	Consideration for scheduling multiple UL/DL TBs	UC6 UC10
24	19/11/2019	BCOM	3GPP SA1	Addition of missing "5.1 Introduction" section in TR 22.826	
25	19/11/2019	BCOM	3GPP SA1	Addition of missing 5.5.1 section in TR 22.826	
26	19/11/2019	BCOM	3GPP SA1	Removal of brackets and correction on required bitrates in TR 22.826	

27	19/11/2019	BCOM	3GPP SA1	Correction on #UE density for use cases using services delivered by PLMNsin TR 22.826	UC7 UC8
28	19/11/2019	BCOM	3GPP SA1	Correction of network dependability figures in 22.826 KPI tables	UC7 UC8
29	19/11/2019	BCOM	3GPP SA1	Addition of general section 6.x for CMED in TS 22.261	UC7 UC8
30	19/11/2019	BCOM	3GPP SA1	Correction of CMED KPIs tables in TS 22.104	UC7 UC8
31	19/11/2019	BCOM	3GPP SA1	Correction of CMED KPIs tables in TS 22.263	UC7 UC8
32	19/11/2019	BCOM	3GPP SA1	Update of text in section 4.4 of TS 22.263	
33	22/11/2019	SRUK, EXP	3GPP SA2	Key Issue: unicast multicast delivery mode switch	UC4c
34	22/11/2019	SRUK, EXP	3GPP SA2	Key Issue: unicast broadcast delivery mode switch	UC4c
35	09/12/2019	SEQ	3GPP RAN	Rel-17 NWI Non-Terrestrial Networks scoping discussions	N/A
36	09/12/2019	SEQ	3GPP RAN	Rel-17 NB-IoT and LTE-MTC enhancements, Phase 1 and 2 discussions	UC6 UC10
37	17/01/2020	EXP	3GPP SA2	Key issue on transition from E-UTRAN/EPC MBMS service to 5G MBS and vice versa	
38	17/01/2020	EXP	3GPP SA2	Additional components for 5MBS Architecture	
39	11/02/2020	UC3M, WINGS, TIM, SRUK	ETSI ENI	PoC#9 Autonomous Network Slice Management for 5G Vertical Services"	
40	18/11/2019	SRUK	3GPP SA2	Key Issue: Unicast – multicast delivery mode switch	UC4c
41	18/11/2019	SRUK	3GPP SA2	Key Issue: Unicast – broadcast delivery mode switch	UC4c
42	24/02/2020	SRUK	3GPP SA2	Slice service experience data collection corrections	UC4c
43	14/10/2019	SRUK	3GPP SA2	Miscellaneous corrections/updates to TS 23.288	UC4c
44	14/10/2019	SRUK	3GPP SA2	New Key Issue on Slice SLA Guarantee	UC4c
45	17/01/2020	SRUK	3GPP SA2	Solution to support slice SLA guarantee	UC4c
46	11/02/2020	UPV	ITU	Final Evaluation Report from the 5G IA on IMT-2020 proposals	
47	24/01/2020	EXP	3GPP SA4	Triggering conditions for Consumption Reporting	UC4c
48	24/01/2020	EXP	3GPP SA4	Feasibility Study on Multicast Architecture Enhancements for 5GMSA (FS_5GMS_Multicast)	UC4c
49	25/05/2020 to 05/06/2020	SEQ	3GPP RAN1	Reduce Capability NR devices - 1st RAN1 meeting	UC6 UC10
50	29/06/2020 to 03/07/2020	SEQ	3GPP RANP	Reduce Capability NR devices - RANP meeting	UC6 UC10
51	17-28/08/2020	SEQ	3GPP RAN1	Reduce Capability NR devices - 2nd RAN1 meeting	UC6 UC10
52	10-mar-2020	EXP et alii	3GPP SA4	Guidelines for HLS Media Presentation Delivery	UC4b - c
53	10-mar-2020	EXP et alii	3GPP SA4	Support of HLS and hybrid DASH/HLS service over eMBMS	UC4b - c
54	10-mar-2020	EXP et alii	3GPP SA4	Support of hybrid HLS/DASH services	UC4b - c
55	10-mar-2020	EXP et alii	3GPP SA4	Support of HLS and hybrid HLS/DASH services	UC4b - c
56	10-mar-2020	EXP	3GPP SA4	Triggering conditions for Consumption Reporting	UC4c

57	9-apr-2020	EXP	3GPP SA4	Consumption Reporting Procedure API- M1d and M5d	UC4c
58	3-giu-2020	EXP et alii	3GPP SA4	Consolidated changes from SA4#108-e et seq.	UC4c
59	3-giu-2020	EXP et alii	3GPP SA4	Consolidated changes from SA4#108-e and SA4#109-e	UC4c
60	3-giu-2020	EXP et alii	3GPP SA4	API for Service Access information acquisition (Stage 3)	UC4c
61	3-giu-2020	EXP	3GPP SA4	Consumption reporting in M7d interface	UC4c
62	27-ago-2020	EXP et alii	3GPP SA4	Update on consumption reporting	UC4c
63	Jan 2020	SRUK	3GPP SA2	23.288 CR0103: Clarification on definitions and NSI	UC4c
64	Jan 2020	SRUK	3GPP SA2	23.700-91: Solution to support slice SLA guarantee.	UC4c
65	Feb 2020	SRUK	3GPP SA2	23.288: Slice service experience data collection corrections	UC4c
66	Feb 2020	SRUK	3GPP SA2	23.288: Corrections to UE mobility event notification	UC4c
67	Feb 2020	SRUK	3GPP SA2	23.288: Updates to AMF event exposure and event filters	UC4c
68	April 2020	SRUK	3GPP SA2	Miscellaneous FASMO corrections to service experience analytics	UC4c
69	April 2020	SRUK	3GPP SA2	NWDAF service descriptions corrections	UC4c
70	April 2020	SRUK	3GPP SA2	Updated Event IDs for analytics	UC4c
71	April 2020	SRUK	3GPP SA2	NEF event exposure service corrections	UC4c
72	April 2020	SRUK	3GPP SA2	AF event filter for service experience area of interest	UC4c
73	June 2020	SRUK	3GPP SA2	Corrections for maximum number of objects and Maximum number of SUPIs	UC4c
74	June 2020	SRUK	3GPP SA2	Updates to Sol#2 on support for slice SLA guarantee	UC4c
75	June 2020	SRUK	3GPP SA2	Solution for unicast-multicast delivery mode switch	UC4c
76	June 2020	SRUK	3GPP SA2	KI#1: update Annex A to clarify MBS architecture alternatives.	UC4c
77	June 2020	SRUK	3GPP SA2	Architecture option 2 update	UC4c
78	Aug 2020	SRUK	3GPP SA2	Service experience analytics discrimination	UC4c
79	Aug 2020	SRUK	3GPP SA2	Location event filter for trusted AF	UC4c
80	Aug 2020	SRUK	3GPP SA2	KI#4, Sol#2: Removal of ENs on slice load analytics	UC4c
81	Aug 2020	SRUK	3GPP SA2	KI#10, New solution on user plane optimization	UC4c
82	Aug 2020	SRUK	3GPP SA2	Key Issue #4 solution evaluation and interim conclusion	UC4c
83	Aug 2020	SRUK	3GPP SA2	KI#7, Sol#24: Removal of ENs on unicast to multicast switch	UC4c
84	Aug 2020	SRUK	3GPP SA2	KI#7, Sol#24: Updates introducing multicast to unicast switch	UC4c
85	15/05/2020	BCOM	3GPP SA1#90	Correction of CMED KPIs tables	UC7 UC8
86	15/05/2020	BCOM	3GPP SA1#90	Update description for medical application in section 4.4	UC7 UC8
87	15/05/2020	BCOM	3GPP SA1#90	Correction of service performance requirements in tables of annex A.6	UC7 UC8
88	Feb 2020	SEQ	3GPP RAN2	Impact of CG-SPS with periodicities non dividing HF length	UC6 UC10
89	Feb-May 2020	SEQ	3GPP RAN2	NB-IoT UE Specific DRX	UC6 UC10
90	Aug 2020	SEQ	3GPP RAN2	Enhancement for support of time synchronization	UC6 UC10

91	Jan 2020	PRE	PCHA	PCHA released the 2019 version of the Continua Design Guidelines	
92	April 2020	PRE	PCHA	The new IHE DEV Personal Connected Health (PCH) subdomain produced and published the Personal Health Device Observation Upload (POU) Profile	
93	June 2020	PRE	PCHA / IHE-DEV	New stand-alone simplified information model independent of the transport technology. Once released, ACOM will become the IEEE 11073-10206 standard	
94	Sep 2020	PRE	IHE-DEV	New IHE DEV Profile for Direct-to-Cloud-Constrained Devices that transports heath data according to IEEE 11073-10206 ACOM.	
95	Oct 2020	SRUK	3GPP SA2	KI#7, Sol#24: Multiple updates to solution.	UC4c
96	Oct 2020	SRUK	3GPP SA2	Clarification on individual delivery definition.	UC4c
97	Oct 2020	SRUK	3GPP SA2	KI#2, Sol#1: Completion of multicast service levels.	UC4c
98	Oct 2020	SRUK	3GPP SA2	KI#1: Sol#3: Evaluation and Conclusion on IGMP JOIN.	UC4c
99	Nov 2020	SRUK	3GPP SA2	KI#7: Evaluation and Conclusion of KI#7.	UC4c
100	Nov 2020	SRUK	3GPP SA2	KI#2 conclusion	UC4c
101	Nov 2020	SRUK	3GPP SA2	KI#7, Sol#24: procedure updates and alignment with KI#1	UC4c
102	Nov 2020	SRUK	3GPP SA2	KI#7 conclusion update	UC4c
103	Nov 2020	SRUK	3GPP SA2	KI #1, Update to Evaluation and Conclusion on UE Join via UP	UC4c
104	Feb 2021	SRUK	3GPP SA2	Service levels definitions	UC4c
105	Jun 2020	SEQ	3GPP RAN2	Correction on reception type combination for eMTC	UC6 UC10
106	Nov 2020	SEQ	3GPP RAN2	Mobility aspects of time synchronization	UC6 UC10
107	Feb 2021	SEQ	3GPP RAN2	Mobility aspects of time synchronization	UC6 UC10
108	Feb 2021	EXP	3GPP SA4	Aggregated essential corrections from various change requests	UC4c
109	Feb 2021	EXP	3GPP SA4	pCR TR 26.802 - key issue on MABR support in 5GMS	UC4c
110	Nov 2020	EXP	3GPP SA4	Feature Request for 5G Broadcast	UC4c
111	April 2021	Enensys et alii	3GPP SA4	pCR to TR 26.802 - on 5GS broadcast-multicast user service	UC4a, UC4b
112	April 2021	Ericsson et alii	3GPP SA4	Interworking of DVB-MABR with 5MBS (Scenario #2)	UC4a UC4b
113	May 2021	SRUK	3GPP RAN1	Support of group scheduling for RRC_CONNECTED Ues	UC4a UC4b
114	May2021	SRUK	3GPP RAN1	On mechanisms to improve reliability for RRC_CONNECTED UEs	UC4a UC4b
115	May2021	SRUK	3GPP RAN1	On basic functions for broadcast/multicast for RRC_IDLE/RRC_INACTIVE UEs	UC4a UC4b
116	June 2021	Ericsson et alii	3GPP SA4	New Work Item (WID) on 5GMS AF Event Exposure	UC4a UC4b
117	September 2021	Ericsson et alii	3GPP SA4	[5MBUSA] Agreements from offline	UC4c

118	April 2021	Qualcomm, Nokia, SEQ, Ericsson	3GPP RAN2	Report of [AT113bis-e][301][NBIOT/eMTC R17] NB-IoT Carrier Selection	UC6 UC10
119	May 2021	SEQ, Nokia	3GPP RAN2	Correction on flow remapping to an added DRB	All
120	September 2021	SEQ	3GPP RAN	New WI: Upper_700_MHz_A_Block new E-UTRA Band in the US	UC4 UC10
121	November 2021	SEQ, et alii	3GPP RAN2	Summary of [301] RLF measurements	UC4 UC10

Annex B: Scientific Publications

List of all accepted Scientific Publications from 5G-TOURS partners during the project. Extended table is available at: https://5gtours.netcom.it.uc3m.es:8443/confluence/display/5GTOUR/Scientific+Publications

#	Title	Author(s)	Journal / Conference / Workshop	Issue Date
1	Introduction to DICOM-RTV: a new standard for real-time video communication in hospitals	Saad El Jaouhari	IEEE Healthcom	15/10/2019
2	vrAIn:: A Deep Learning Approach Tailoring Computing and Radio Resources in Virtualized RANs	J.A. Ayala Romero, Andres Garcia Saavedra, Marco Gramaglia, Xavier Costa Perez, Albert Banchs, Juan José Alcaraz	ACM Mobicom	21-25/10/2019
3	vrAIn Proof-of-Concept A Deep Learning Approach for Virtualized RAN Resource Control	J.A. Ayala Romero, Andres Garcia Saavedra, Marco Gramaglia, Xavier Costa Perez, Albert Banchs, Juan José Alcaraz	ACM Mobicom	21-25/10/2019
4	A 5G Mobile Network Architecture to Support Vertical Industries	Albert Banchs, David M. Gutierrez-Estevez, Manuel Fuentes, Mauro Boldi, Silvia Provvedi	IEEE Communications Magazine	Dec 2019
5	AZTEC: Anticipatory Capacity Allocation for Zero-Touch Network Slicing	D. Bega, M. Gramaglia, M. Fiore, A. Banchs and X. Costa-Perez	IEEE INFOCOM	Jul 2020
6	3GPP Enhancements for Television Services: LTE-based 5G Terrestrial Broadcast	David Gomez-Barquero, Jordi Joan Gimenez, Roland Beutler	Wiley Encyclopedia on Electical and Electronics Engineering	
7	DeepCog: Optimizing Resource Provisioning in Network Slicing with AI-based Capacity Forecasting	D. Bega, M. Gramaglia, M. Fiore, A. Banchs, X. Costa-Perez	IEEE JSAC	
8	Experimenting with open source tools to deploy a multi-service and multi-slice mobile network	G. Garcia-Aviles, M. Gramaglia, P. Serrano, F. Gringoli, S. Fuente-Pascual, I. Labrador-Pavon	Elsevier Computer communications	
9	AI-based Autonomous Control, Management, and Orchestration in 5G: from Standards to Algorithms	Dario Bega, Albert Banchs, Marco Gramaglia, Marco Fiore, Ramon Perez, Xavier Costa-Perez	IEEE Network	
10	5G Broadcast implementation and demonstration in an SDR laboratory experiment	Alvaro Ibañez, Manuel Fuentes, Borja Iñesta, David Gomez-Barquero, Diarmuid Collins	IEEE BMSB	

11	Constrained Network Slicing Games: Achieving service guarantees and network efficiency	Jiaxiao Zheng, Gustavo de Veciana, Albert Banchs	WiOpt	
12	Identifying Common Periodicities in Mobile Service Demands with Spectral Analysis	Cristina Marquez, Marco Gramaglia, Marco Fiore, Albert Banchs, and Zbigniew Smoreda	IEEE MedComNet	
13	The case for serverless mobile networking	M. Gramaglia, P. serrano, A. Banchs, G. Garcia-Aviles, A. Garcia-Saavedra and R. Perez	IFIP Networking	
14	Network Slicing Meets Artificial Intelligence: an AI-based Framework for Slice Management	D. Bega, M. Gramaglia, A. Garcia-Saavedra, M. Fiore, and A. Banchs	IEEE Communications Magazine	
15	5G New Radio Evaluation Against IMT-2020 Key Performance Indicators	M. Fuentes, et. al.	IEEE Access	June 2020
16	ACHO: A Framework for Flexible Re-Orchestration of Virtual Network Functions	G. Garcia, C. Donato, M. Gramaglia, P. Serrano, and A. Banchs	Elsevier Computer Networks	
17	Experimenting with SRv6: a Tunneling Protocol supporting Network Slicing in 5G and beyond	M. Gramaglia, V. Sciancalepore. F.J. Fernandez-Maestro, R. Perez, P. Serrano, and A. Banchs	IEEE CAMAD	September 2020
18	The Touristic Sector in the 5G Technology Era:The 5G-TOURS Project Approach	Luca Vignaroli, Marco Gramaglia, Manuel Fuentes, Antonino Casella, Roman Odarchenko, Lorenzo Natale, Baruch Altman and Francesco D'Andria	IEEE Globecom Workshop	December 2020
19	Broadcast-Multicast Single Frequency Network versus Unicast in Cellular Systems	Juan Vargas (IMT Atlantique & Enensys Technologies, France); Cédric Thienot and Christophe Burdinat (Enensys Technologies, France); Xavier Lagrange (IMT Atlantique & IRISA, Université Bretagne Loire, France)	WiMob 2020	October 2020
20	Advanced method for QoE evaluation and improvement in modern cellular networks	Roman Odarchenko, Anastasiia Abakumova, Serhii Bondar, Yuri Bogachuk	2020 *IEEE* International Scientific-Practical Conference Problems of Infocommunications. Science and Technology	October 2020
21	Development of a system for registration and monitoring of UAVs using 5G cellular networks	Roman Odarchenko, Yaroslav Horban, Oleksandr Volkov, Mykola Komar, Dmytro Voloshenyuk	Lecture Notes on Data Engineering and Communications Technologies	October 2020
22	3GPP Enhancements for Television Services: LTE ? Based 5G Terrestrial Broadcast	David Gomez-Barquero, Jordi J. Gimenez and Roland Beutler	Wiley Online Library.	May 2020

23	Single Frequency Networks for 5G Broadcast: a Software Defined Radio Experiment	Álvaro Ibáñez, Manuel Fuentes, Borja Iñesta, David Gomez-Barquero, Diarmuid Collins and Joao Santos	IEEE BMSB 2020	October 2020
24	5G New Radio Evaluation Against IMT-2020 Key Performance Indicators	Manuel Fuentes, et al.	Proceedings of the IEEE	June 2020
25	Resource Allocation for Network Slicing in Mobile Networks	Albert Banchs, Gustavo de Veciana, Vincenzo Sciancalepore and Xavier Costa-Perez	IEEE Access	November 2020
26	vrAIn: Deep Learning based Orchestration for Computing and Radio Resources in vRANs	J.A. Ayala Romero, Andres Garcia Saavedra, Marco Gramaglia, Xavier Costa Perez, Albert Banchs, Juan José Alcaraz	IEEE Transactions on Mobile Computing	
27	Trading Accuracy for Privacy in Machine Learning Tasks: An Empirical Analysis	V. Prodomo, R. González, M. Gramaglia	IEEE CNS	
28	QoE estimation methodology for 5G use cases	Odarchenko R., Dyka T. (2022) QoE Estimation Methodology for 5G Use Cases. In: Klymash M., Beshley M., Luntovskyy A. (eds)	Future Intent-Based Networking. Lecture Notes in Electrical Engineering, vol 831. Springer, Cham	
29	Links between 5g ppp projects: the road from the past to the future	Roman Odarchenko, Giorgi Labadze	Scientific and Practical Cyber Security Journal (SPCSJ) 5(2): 45-50 ISSN 2587-4667	
30	The itinerant orchestra, a 5g, multi-camera, remote and distributed video production experiment	L. Vignaroli, D. Desirello, A. Trogolo, G. Sacco, R. Rahav and B. Altman	IBC 2021	December 2021
31	Towards Wireless 5G Operating Room	Gaetan Lelu, Yithian. Zhou, Guillaume Pasquier, Albert Murienne	CARS 2022	June 2022
32	Method for Qoe monitoring and increasing in cellular networks based on Qoe-To-Qos mapping using spline-approximation	Jamil Al Azzeh; Roman Odarchenko; Anastasiia Abakumova; Serhii Bondar	EURASIP Journal on Wireless Communications and Networking	April 2022
33	The concept of a channeling system for satellite mobile communication for media delivery with increased efficiency	Roman Odarchenko, Alexander Didenk, Konstantin Sunduchkov, Oleksii Verhovets, Vladislav Fesenko, Andrii Fesenko	16th International Conference on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering (TCSET)	February 2022
34	A Unified Service-Based Capability Exposure Framework for Closed-Loop Network Automation	Marco Gramaglia, Marton Kajo, Christian Mannweiler, Ömer Bulakci, Qing Wei	Transactions on Emerging Telecommunications Technologies	July 2022