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Deliverable D8.3
Business Model Archetypes of vertical industries and the 5G-TOURS commercial opportunity

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List of Acronyms and Abbreviations

3GPP	3rd Generation Partnership Project
5G	Fifth Generation
AI	Artificial Intelligence
AR	Augmented Reality
AIA	Athens International Airport
B2B	Business to Business
B2C	Business to Consumer
BNO	Broadcast Network Operator
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CDN	Content Delivery Network
COVID	Coronavirus disease
CO2	Carbon Dioxide
CSP	Communication Service Provider
DAS	Distributed Antenna Systems
DB	Database
DL	Downlink
E2E	End to End
EIRP	Effective Isotropic Radiated Power
eMBB	enhanced mobile broadband
ETSI	European Telecommunications Standards Institute
ETSI ENI	ETSI Experiential Networked Intelligence
FTM	Fondazione Torino Musei
GAM	Galleria civica d'Arte Moderna e contemporanea
GHz	Gigahertz
HPHT	High Power High Tower
IATA	International Air Transport Association
ICT	Information and Communications Technology
ICU	intensive care unit
IEEE	Institute of Electrical and Electronics Engineers
IHE DEV	Integrating Healthcare Enterprise devices
IoT	Internet of Things
ISM	Industrial, Scientific and Medical
KPI	key performance indicators
LTE	Long-Term Evolution
LPLT	Low Power Low Tower
MB	Megabyte
Mbps	Mega Bit Per Second
MHz	Megahertz
MR	Mixed Reality
ML	Machine Learning
mMTC	massive Machine Type Communications
mmWave	Millimeter Wave
MNO	Mobile Network Operator
NB-IoT	Narrow Band – Internet of Things
OPEX	operational expenditure
OTT	over-the-top

QoE	Quality of Experience
RAN	Radio Access Network
RAT	Radio Access Technology
RGB-D	Red Blue Green and Depth
ROI	Return on Investment
RoM	Rough order of Magnitude
Saas	Solution as a Service
SCN	Small Cells Networks
SDK	Software Development Kit
SIB	System Information Block
SEM	Search Engine Marketing
SEO	Search Engine Optimization
SEP	Stakeholder Engagement Plan
SID	Study Item Description
SINR	Signal to Interference Noise Ratio
SLA	Service-Level Agreement
SME	Small and Medium-sized Enterprise
STARLIT	cloud baSed ioT smARt LIving platform
STD	Standardisation
TCO	Total Cost of Ownership
TDD	Time Division Duplexing
TETRA	Trans-European Trunked Radio
TIP	Telecom Infra Project
TSG	Technical Specification Group
TSN	Time-Sensitive Networking
UC	Use Case
UHD	Ultra High Definition
UL	Uplink
uRLLC	Ultra-Reliable Low-Latency Communication
UPF	User Plane Function
USSD	Unstructured Supplementary Service Data
UTRAN	Universal Terrestrial Radio Access Network
V2X	Vehicle-to-X
VPN	Virtual Private Network
VR	Virtual Reality
WebRTC	Web Real-Time Communication
WG	Working Group
XR	eXtended Reality

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Executive Summary

This deliverable explores the advantages of 5G for the vertical sectors involved in the 5G-TOURS project in line with the European Vision of "**5G empowering vertical industries**". 5G-TOURS features consortium members from both the supply side and demand side ecosystems, and thus provides an ideal cluster within which to explore the innovations, their anticipated commercial appeal and the business dynamics surrounding their exploitation. The principal consideration in this deliverable is the demand side; the salient properties of which must be understood to anticipate the way in which empowering of the vertical may occur. **Demand generation** requires an understanding of the business models that underpin the opportunity; with the best fit emergent business models being different for each vertical sector and the place where the demand is to be served.

The **commercial considerations of a buyer in the sector** are placed at the fore to enable a simulation of the strategic decision making that would be employed. This process of decision making is sometimes referred to as **Optioneering**. The business model archetype is based on the formulation of a generalised model for the sector and place, and we use the specifics of the network architectures, use cases (UCs), and settings of 5G-TOURS as exemplars of the considerations.

Establishing the Innovations Evaluation Toolkit

During the early stages of the 5G-TOURS project, there was an assertion of value propositions based on UCs and their technology drivers. As the project progresses, whilst the UCs are still a foundational element, the positioning of innovations within their sectors and the demand side dynamics increases in importance.

In the mobile operator industry sector, telecoms technologies are the most prominent value proposition – a business operations critical component of the business model. Within the vertical industry sectors wireless is generally treated as a cost to the business. The way in which wireless can be used to create competitive advantage is often unclear. A Rough order of Magnitude (RoM) assessment of costs helps to assess the scale of the investment. For this reason, an essential aspect of building an investment case is a rapid assessment of cost. Methods of assessing cost for various deployment scenarios have been established in 5G-TOURS and initial insights gained from the Airport deployment are illustrative of the considerations:

- In the Airport – the cost of infrastructure is 38% more to support the UCs over the cost to provide a baseline public service within the terminal buildings.
- If the use cases were to be deployed separately the additional cost rises to 114% of the baseline. However, an integrated approach could save as much as 66% of this additional cost.
- Whilst the potential for cost savings may seem obvious from the perspective of a single stakeholder, it stands to reason that greater economies of scale and greater overall benefit would be realised by capturing the 5G connectivity requirements of many more stakeholders.
- Having the capability to allocate costs, albeit at a high level can promote transparency amongst stakeholders on both demand and supply sides which is important in ensuring proportionality and fairness.
- at the same time fostering closer collaboration and coordination to bring about the anticipated benefits, increase vertical confidence in the technology and strengthen the ecosystems to expand wider and seek even greater value.

The health and tourism verticals have also been analysed, but the results are less mature. The scenarios will continue to be developed over the next period and reported in the final deliverable. Costs are always to be evaluated when appraising the viability of investments in new solutions. However, the capability to determine credible potential socio-economic assessment of benefits is growing in importance. Work Package 2 of 5G-TOURS has established a benefits framework that will allow for the qualitative and importantly quantitative evaluation of the innovations of the project. In this deliverable we have mapped the benefits framework to the industry sector.

Key Findings

- Each industry sector has differences in financial models (blending public and private), appetite for risk, preferred deployment, operations and maintenance models of their ICT systems. A "one size fits all

model" for building, maintaining and operating 5G solutions that applies across all industry sectors that 5G-TOURS considers is not credible.

- The approach to the rapid evaluation of deployment and key benefit and cost aspects is critical to the timely decision making as to the viability of a city solution. The requirements for a suite of cost-benefit analysis tools have been established and the baseline evaluation capability is demonstrated.
- In earlier 5G-TOURS deliverables we found that as a category "5G Business Models" was poorly defined with few referenceable papers from the business modelling academic and research community. 5G-TOURS has chosen to go back to an assessment of relevant generic business models but based on a principle of putting the vertical sector demand ecosystem at the centre. This creates a more heterogeneous business narrative; however, there has now been sufficient analysis by the sector specialist Innovation Managers and the understanding of the value propositions in the sector to determine that this is the most appropriate approach.
- The potential advantage of developing a device and end user experience-oriented solution on a unifying platform that is deployed and re-deployed in several vertical sectors has merits and is an approach to ensuring the portability of innovations that could become systematic and repeatable. By way of the robot-oriented UC we can demonstrate the potential for translation into an adjacent sector.

Next Steps

The transition from supply side ecosystem thinking to demand side ecosystem thinking, such that an articulation of proof points of the "why" and "how" of uptake of innovations is yet to occur. The focus of the project on delivery of technology demonstrators (the progress of which is greatly challenged by COVID-19) maintains a predominant solution delivery culture within the project. However, the approach and design of the project with significant opportunity for demonstrations, and workshops, where critical appraisal and feedback from external stakeholders will become a significant force of change will assist in the transition. A transformational journey is underway and as the project enters the final phase the time to quantify and bridge the gap.

This deliverable establishes the business model scope and framing for the verticals. This qualitative framework guides the further quantitative assessments. 5G-TOURS has established an understanding of the pertinent commercial forces of the different industry sectors in earlier deliverables from WP8. However, high technology markets move fast, 5G-TOURS is a 3-year project and market readiness views must be continually re-assessed. This deliverable advances the business analysis to establish the innovations of the project and the considerations of the business strategy factors that should be considered in the planned deliverable D8.4. In particular, the considerations with respect to making recommendations on the ranking of the value propositions of the approximately twenty claimed 5G-TOURS innovations.

1 Introduction

1.1 Economic Context

The advent of 5G has been accompanied by the anticipation of huge economic and social impact. The technology is regarded in many quarters as the key to unlocking vast amounts of value as part of the great digital transformation, which some have labelled The Fourth Industrial Revolution (World Economic Forum, 2016).

There have been multiple attempts in recent years to quantify the macroeconomic impact of 5G and associated technologies. A recent report by IHS (IHS, 2019), which was further ratified by WEF (WEF, 2020), put a figure of $13.2 trillion on the amount that 5G technologies will enable in the global economy in 2035. To put it in perspective, in 2020 the GDP of the entire EU was estimated to be around $15 trillion (Union, 2019).

With such a considerable source of potential wealth at stake it is no wonder that governments and private enterprise are eager to position themselves and their countries and organisations at the leading edge of technology adoption.

It is important to appreciate that this value is beyond the commercial or market value of the technology itself, i.e., the cumulative impact of the sale of goods and services pertaining to the delivery of 5G. This 5G value chain is estimated by the same study (IHS, 2019) to be $3.6 trillion in 2035. Conversely, the estimate of economic value seeks to quantify all the social and economic gains enabled by 5G in communities, for the good of society, the environment and in other vertical industries.

Societal benefits are typically related to improvements in quality of life for people e.g., improvements in health, reduced unemployment, less poverty etc. Environmental benefits extend to the natural world and aim to capture the value associated with measures that mitigate against climate change, pollution, waste etc. Such sources of value are important to governments, public sector organisations and not-for-profit enterprises. They are also increasingly important to private firms and industries as they seek to evaluate and improve their environmental, social and governance (ESG) metrics, in response to the changing attitudes of investors and customers towards more responsible and sustainable business practices.

The private sector remains at the leading edge of technology adoption and innovation, and despite a growing focus on ESG outcomes, for 5G to be considered a success it also needs to be an enabler of wider economic growth and efficiency by facilitating:

- Increased innovation, driving new products and services.
- Greater productivity, enabling more efficient output of existing products and services.
- Cost savings, which liberate funds for investment in growth elsewhere.

The key challenge initially to the wireless industry and to the verticals who potentially stand to gain most from the adoption of 5G is to understand the best ways to unlock this value in such a manner as to maximise the outcomes identified above.

For the verticals, in particular, who are unlikely to have the same depth of knowledge or experience of 5G technology as the wireless industry, it is important to understand how to engage with the technology and the supply chain ecosystem in order to ensure cost efficiency and manage risk.

The focus of Task 8.1 and in particular D8.3 is to take the perspective of procurement entities in the chosen vertical industries (Transport, Health, Tourism) and to critically examine a number of different innovations, technical solutions and business models in terms of their suitability to deliver 5G services into the respective industrial settings and maximise realised value.

1.2 5G Enterprise Pathfinder Framework

The ability of 5G to act as a lynchpin technology in the creation of wider economic growth is largely predicated on whether 5G can be a commercial success for the firms selling 5G products and services into industry verticals[1].

Solutions implemented by the wireless industry for the provision of 5G services direct to consumers will be able to facilitate certain needs of the verticals; however, to maximise economic value the wireless industry and the key players within it need to seek alignment with verticals' corporate strategies, value propositions (to their customers) and cultural paradigms.

Traditional tools like the Business Model Canvas & Value Proposition Canvas are narrowly focused on individual players' concerns, including profitability. They give a very limited view of the wider supply chain and ecosystem, and the concept of value is quite loosely defined.

The 5G-TOURS 5G Enterprise Pathfinder Framework introduced in (D8.2, 2021) is intended to take a more holistic view; by incorporating elements of corporate strategy and individual sector objectives. The model puts value delivery at the heart and looks beyond the market value and profitability for enterprises in the wireless industry, towards value created within the vertical markets and wider society. The framework seeks to connect the requirements of the verticals i.e., the so-called demand-side ecosystem, with the provisions of the wireless industry i.e., the supply-side ecosystem (Figure 1).

It recognises that there is no one-size-fits-all approach that enables 5G infrastructure or services to meet the strategic demands and objectives of multiple industries, sectors, and organisations. The framework therefore captures several business models, being explored within the 5G-TOURS project, that reflect the flexibility required to optimise supply-side delivery based on the conditions imposed by the demand side ecosystems.

Verticals need diversity in supply-side business models such that the investment in 5G can be led by corporate strategy. Business models will be chosen based on their ability to deliver those features that are deemed strategically important. Where verticals' needs cannot be adequately met by established means, there is scope for disruption and new entrants into the marketplace. Where new models can facilitate wider value creation, they are to be enthusiastically welcomed.

As suggested below, the supply side requires commercial viability and so the ability to create wider economic value on the demand side is driven by the cost of ownership for each of the stakeholders.

All organisations and enterprises, whether public or private, have limited amounts of capital with which to invest. Managers and executives typically have several candidate projects that offer scope to increase returns on their business activities or operations. There is therefore an opportunity cost associated with funds spent on 5G infrastructure as those funds, once committed, cannot be spent elsewhere. It is important therefore to recognise that from the vertical perspective 5G is in competition with other projects for capital investment and therefore must prove its potential in the face of alternatives.

Comprehensive cost modelling is an important part of informing the decision whether to commit capital to infrastructure investment programmes. Real Wireless (RW) has developed a suite of tools to facilitate a comprehensive analysis of the TCO (total cost of ownership) in terms of both CAPEX and OPEX, covering a range of 5G architectures that are central to the project and which represent the range of options open to the verticals. RW were also responsible for developing the economic benefits of the 5G-TOUS UCs under Task 2.3. The two are brought together in WP8 in the form of a straightforward cost-benefit analysis for each of the evaluation case settings and will inform the economic viability of the UCs in question.

[1] Market value can, of course, be generated between actors withing the 5G industry itself and engagement with industry verticals could be subsidised through other enterprise e.g., B2C. However, this would be unsustainable and unlikely to drive the technology adoption and growth that the forecasts of $13.2tn in new economic value would imply.

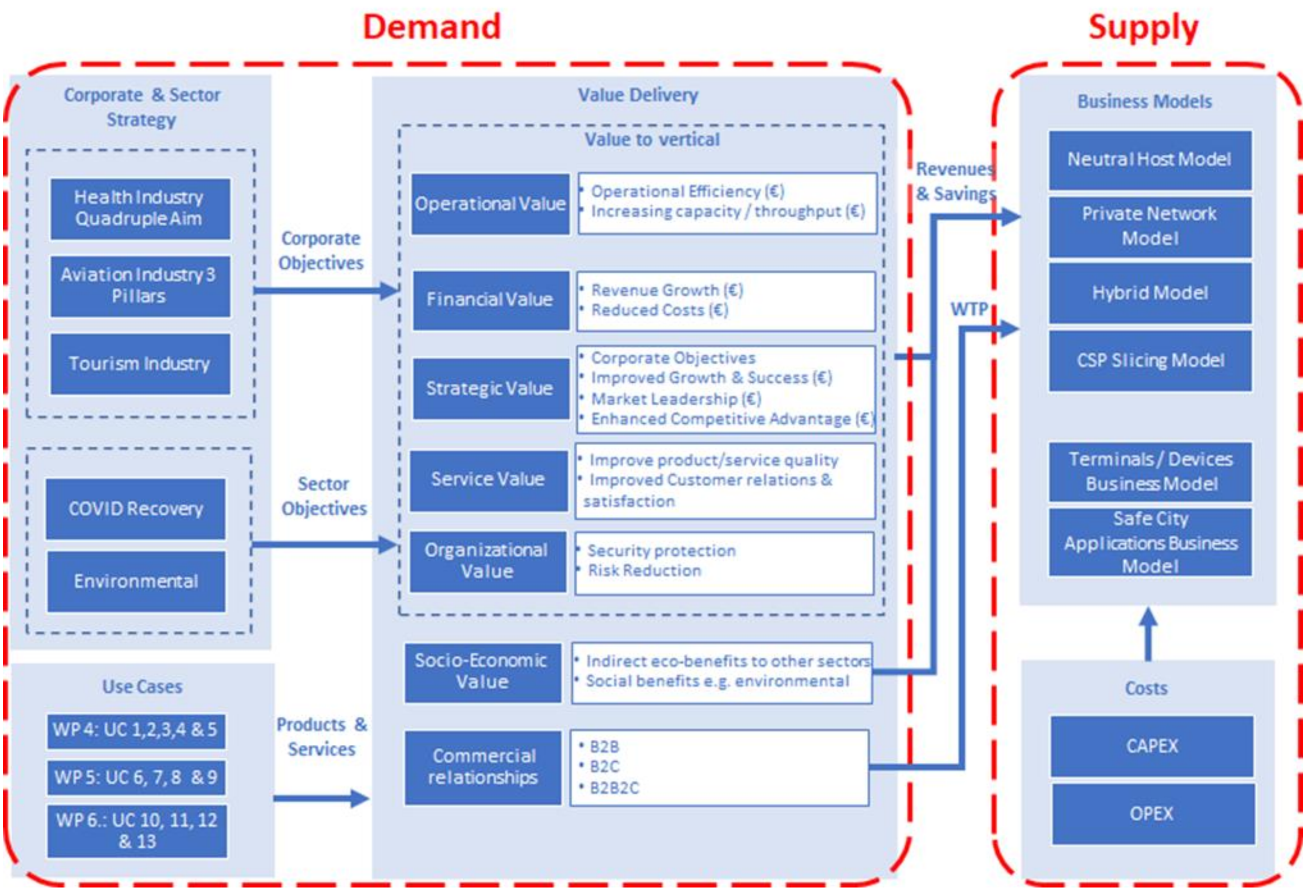

Figure 1. Demand and supply side ecosystems.

A central concept in the analysis is that of the marginal or incremental cost and value. In many settings legacy wireless systems may already exist to serve users with 2G/3G/4G services, and some of the existing infrastructure can be used for the deployment of 5G e.g., equipment rooms, containment etc. provided there is capacity to do so. In other scenarios, it may be that 5G is already planned to be deployed in an environment in order to facilitate a core 5G service or offering e.g., public mobile broadband, but where the principal vertical stakeholder wishes to leverage any infrastructure investment to facilitate additional 5G services. In either case, given any prior commitment, decisions on supplementary expenditure should be based on the additional or incremental costs required to support those extra services and to judge the benefits based on the incremental value they create.

Ideally, all parties, on both the supply and demand sides, will be able to capitalise on any initial outlay and so be incentivised to facilitate expansion of the infrastructure to create the maximum economic and social value.

1.2.1 Technology and market readiness assessment of network innovations

Of particular interest within 5G TOURS is the potential for value creation and commercialisation of the 5G innovations within the industry verticals' demand-side ecosystems. Research innovations of the project are developed specifically within the technical WP3 which deals with network, cloud and system-oriented technologies. Technology developers often have difficulties to assess expected market impact of their technology, especially when technologies are still being nurtured in lab settings. The MTRL methodology proposed here is intended to help them in this endeavour.

The Market & Technology Readiness Level ("MTRL") framework (Cloud Watch Hub, 2017), which has been adapted for 5G TOURS, aims to provide decision makers with a holistic view of a maturity of the project's solutions in a simple way - with a single score. The TRL and MRL are both based on a scale of 0 to 9. The MTRL methodology is designed to help European projects implement their innovation management based on an understanding of both market and technical problems. A typical output is an improved or new product, service, or process in response to known gaps in the market. Therefore, it offers decision makers and evaluators a faster way to assess, measure and support technology projects.

To evaluate the market readiness of innovations, solutions and projects, the MTRL methodology defines a pair of values, TRL and MRL, assigning a score for both the Technology Readiness Level and the Market Readiness Level respectively.

Technology Readiness Levels

Technology Readiness Levels are an accepted method used to assess the maturity of a technology, product or service developed by a project. It emphasises differentiates between Research (TRL 0 – 3), Innovation (TRL 4 – 5) and technology validation closer to the market that is pre-commercial / commercial (TRLs 6 to 9).

Figure 2. Technology Readiness Level Framework (Cloud Watch Hub, 2020).

Market Readiness Levels

Market Readiness Levels (MRLs) are used to estimate the potential for commercialisation of the technology offering and provide a context from by which it can be assessed. The MRLs characterise the work performed behind the scenes in the development of business process and administration, just as TRLs do for the technical activities. MRLs inherit their scale form TRLs, matching the level of granularity. 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.

Figure 3. Market Readiness Level Framework (Cloud Watch Hub, 2017).

Based on MTRL methodology, a following template is proposed for the WP3 technological solution owners, which allows them to clarify the exploitation strategy for the technology solutions and research innovations. Working with the technology experts, MTRL scales will be applied to determine the readiness of the capability. Responses will be collected and analysed in the next period and finally presented in deliverable D8.4.

[Solution name]	*MTRL Assessment*
Exploitation strategy	Please fill in / comment according to the applicable strategies, add claims & references where possible: • **Scientific exploitation:** it is applicable to knowledge and technology transfer e.g., prototypical research solutions which need further work before they are ready for the market, or which will be sustained through continued research. • **Commercial exploitation:** it is applicable to solutions that are "sufficient mature" to constitute commercial software and services. • **Sustainability through open-source:** it is applicable to solutions that have significant reuse value will be sustained through a strategy to transform the solutions into standalone open-source components or commit new modules to existing, widely deployed open-source software products with a significant developer base and interest community. • **Standard exploitation:** it is applicable to solutions impacting 5G protocols/procedures under specification or which have to be extended to incorporate additional features. Indicate, when relevant, if 3GPP Release 15 or Release 16 is concerned. • **Early Adoption:** it is applicable to solutions which will be tested at partner's premises to evaluate their possible integration into existing solutions (e.g. lab technology to product transfer).
Issues to be addressed, Limitations	• List any issues which need to be addressed for a successful exploitation according to the indicated strategy.
Technology Readiness Level (TRL)	*(Please choose ONE level line which applies, delete all others)* 0: IDEA - Idea 1: IDEA - Basic research 2: IDEA - Technology formulation 3: IDEA - Applied research 4: PROTOTYPE - Small scale prototype 5: PROTOTYPE - Large scale prototype 6: VALIDATION - Prototype system 7: VALIDATION - Demonstration system 8: PRODUCTION - First of a kind commercial system 9: PRODUCTION - Full commercial application

Market Readiness Level (MRL)	*(Please choose ONE level line which applies, delete all others)* 0: IDEATION - Hunch 1: IDEATION - Basic research 2: IDEATION - Needs formulation 3: IDEATION - Needs validation 4: TESTING - Small scale stakeholder campaign 5: TESTING - Large scale early adopter campaign 6: TRACTION - Proof of traction 7: TRACTION - Proof of satisfaction 8: SCALING - Proof of scalability 9: SCALING - Proof of stability
Analysis of Competitors (please add link, licence etc.) ***Please specify customer pain(s) and customer gain(s)***	
Competing Solutions	• Enumerate here competing solutions/products/initiatives if any.
POSITIONING: Advantages and disadvantages with respect to the competition	• If competing solutions have been identified here should be indicated the major advantages of the 5G-TOURS exploitable results over the competitive solutions.

1.3 Purpose

This deliverable is the third of a series of four WP8 reports to be delivered by the 5G-TOURS consortium to be delivered over the 36-month duration of the project. One of the two objectives of H2020 ICT-19 projects, within which this project is included, is business validation. WP8 is the work area that leads these deliberations on behalf of the 5G-TOURS project; bringing together both the Business Validation perspective (Task 8.1) and the Innovation Management perspective (Task 8.3). Both perspectives are bought to the fore in this deliverable as we scope business considerations and define business model archetypes (types of businesses) that should evolve within the vertical sectors when enabled by 5G. The innovations of the project provide an initial representative view on the opportunity that should be present in each vertical. The three verticals that we focus on are Tourism, Transport (particularly on the Airport), and Health.

The first report in the series, (D8.1, 2020), was delivered in M12. It provided an initial assessment of business models appropriate to the exploitation of the innovations developed within the project and considered the market context for potential commercialisation. It also captured the intellectual property impact of the innovations through various patent applications, contributions to 5G standards activities and wider plans for exploitation and dissemination of the project output.

The purpose of the second deliverable, (D8.2, 2021), delivered in M24, was to communicate ongoing progress on the possibilities for exploitation of 5G-TOURS innovations. It presented the 5G-TOURS Enterprise Pathfinder Framework as a basis for industry verticals to navigate various 5G deployment options. Further exploitation and dissemination activities were reported whist acknowledging the obvious challenges arising from the COVID-19 pandemic, which curtailed a number of key events.

This third report, “D8.3 Business Model Archetypes of vertical industries and the 5G-TOURS commercial opportunity”, presents progress made on developing tools and process that will help to quantify the value of innovations within industry verticals. It takes the perspective of buyers and decision makers within the demand-side ecosystem and provides them with the foundations to begin optioneering 5G solutions appropriate to their needs and objectives. Several case studies are provided to illustrate how the innovations can be exploited both within and beyond their respective 5G-TOURS setting. Case studies are also provided from the point of view of different actors in the 5G value chain whose breadth and diversity are reflected by the 5G-TOURS partner landscape illustrated in Figure 4. These case studies serve to capture the contrasting perspectives of the different actors and to showcase their specific area of expertise.

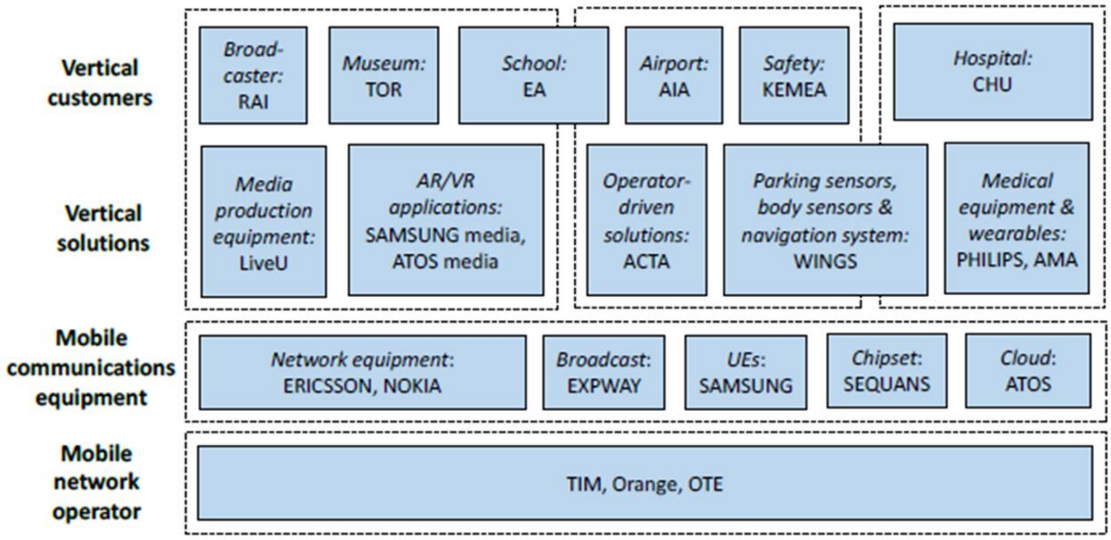

Figure 4. Partners' roles in the 5G-TOURS mobile network ecosystem.

In this period, we have been working closely with WP2 to develop key elements of the framework that aims to establish the value creation potential of the UCs and how that value may be unlocked. Commercial viability of the innovations requires that an assessment of infrastructure costs is evaluated weighed against the commercial, social and economic benefits developed in work package 2. Figure 5 illustrates where T8.1 fits in the overall techno-economic assessment being conducted by RW across the various 5G-TOURS tasks.

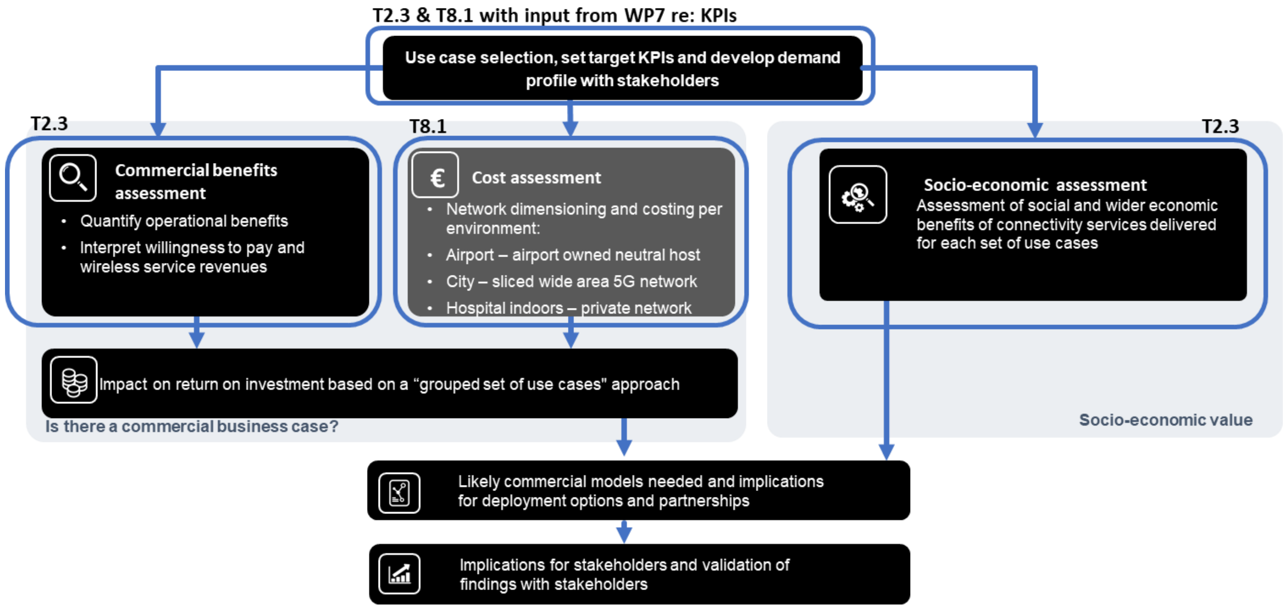

Figure 5. 5G-TOURS Techno-economic assessment approach.

1.4 Document Structure

The remainder of the report is organised in the following manner:

- **Chapter 1** (this section): Introduction to the deliverable and context around the expected economic value of 5G and associated business model frameworks.
- **Chapter 2:** Describes the function and value of 5G from the perspective of the industry verticals. A number of key concepts are presented that serve to equip decision makers within the verticals with the knowledge to engage with the supply-side ecosystem and describes the tools that have been developed for the purpose of optioneering 5G solutions. The benefits of the individual UCs, which have been developed in WP2 are introduced.
- **Chapter 3:** This section considers in more detail the net value of 5G-TOURS within the airport context of the transport evaluation case. Solutions to support the 5G-TOURS Ucs have been comprehensively analysed in terms of their deployment costs which are evaluated against the quantified benefits. Two case studies are presented on smart parking and network performance monitoring.
- **Chapter 4:** Health is the topic of the next section, which introduces a framework to evaluate the net value of 5G innovations in the healthcare vertical. Solutions that have the potential to unlock greater value within the vertical are considered together with the salient features of the most appropriate business models, which will be developed further in the next period. Two further Ucs are presented that consider the practical implications and impact of smart ambulances and remote health monitoring.
- **Chapter 5:** In this chapter the perspective changes to that of a whole city rather than an individual industry vertical or enterprise. This gives us the opportunity to explore the delivery of smart city services over a wider area with a particular focus on the tourism and media sectors. Initial cost estimates have been developed for 5G macro network coverage and these will be used in the next period to validate the commercial, economic and social benefits of each of the 5G-TOURS Ucs.
- **Chapter 6:** Conclusions for the third year of the project from the perspective of WP8.

2 5G Technologies & Ecosystems

This section is intended to equip buyers on the demand side ecosystem with the necessary information required to evaluate 5G technologies, navigate supply side ecosystems, and understand the implications of different 5G business models. The chapter is arranged as follows:

- The first step is to anchor 5G and wireless connectivity in the wider digital transformation landscape and consider the commercial and economic drivers for adoption by vertical industries.
- Next, we consider the technical advances in mobile connectivity introduced by 5G and the characteristics of 5G infrastructure deployment that will facilitate business outcomes and shape investments in connectivity.
- We go on to examine the key business models and principal supply-side actors that will be instrumental in the delivery of 5G solutions into industry verticals, exploring the concept of combining multiple stakeholder interests to deliver economies of scale.
- The chapter concludes by introducing the benefits framework developed in WP2 and the evaluation case settings to which they have been applied. To complete the assessment of commercial viability a number of tools are introduced, which have been developed in WP8 for the purpose of optioneering 5G solutions for the 5GTOURS verticals.

Based on our experiences working with industry verticals, we have identified a gap in the understanding of mobile technology between the wireless industry and other enterprises. Of course, some enterprises are apt to engage with the technology early on, particularly where the benefits are obvious and easily obtainable. This is ably illustrated by the classical diffusion of innovation model, see Figure 6 (Rogers, Diffusion of innovations, 1962). 5G is maturing as a technology but is still in the early stages of adoption. At the leading edge are the innovators, those organisations working in lock-step with the supply-side ecosystem to build upon technological developments and design solutions that create meaningful value. Yet despite the propensity by individual organisations to adopt, when we talk about shared benefit and the inherent value of collaboration, then we see that verticals can quickly run into resistance where other industry stakeholders are on a slower path to implement the technology.

Part of our focus in this deliverable is to provide 5G technology background, but from the demand side perspective. Based on our experience with vertical sectors, what appears to resonate and to influence technology strategy is to focus on those aspects of 5G that affect outcomes within the vertical and the success of wider digital transformation programmes.

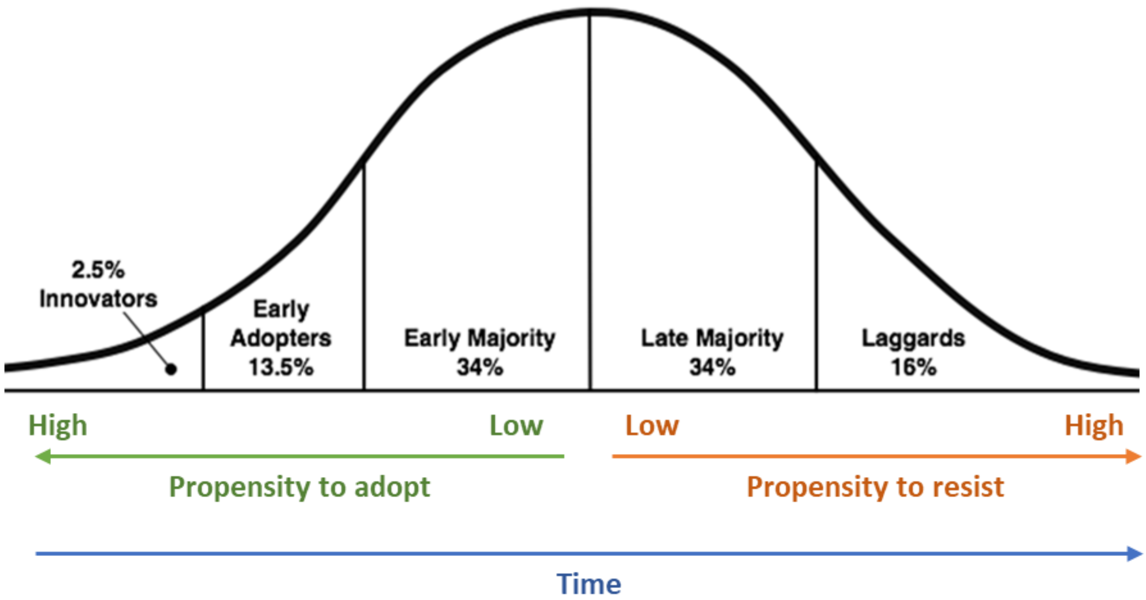

Figure 6. Diffusion of Innovation Model.

2.1 5G & Digital Transformation

Wireless communications underpin a wide variety of applications which are ever more important for citizens, businesses, public service delivery and visitors. Connectivity is central to the collection, transportation and distribution of data and advances in the wider digital ecosystem are forecast to stimulate exponential growth in demand for mobile data. According to the ITU (IMT, 2015), by the end of the decade the increase could be over 80 times the 2020 demand (Figure 7).

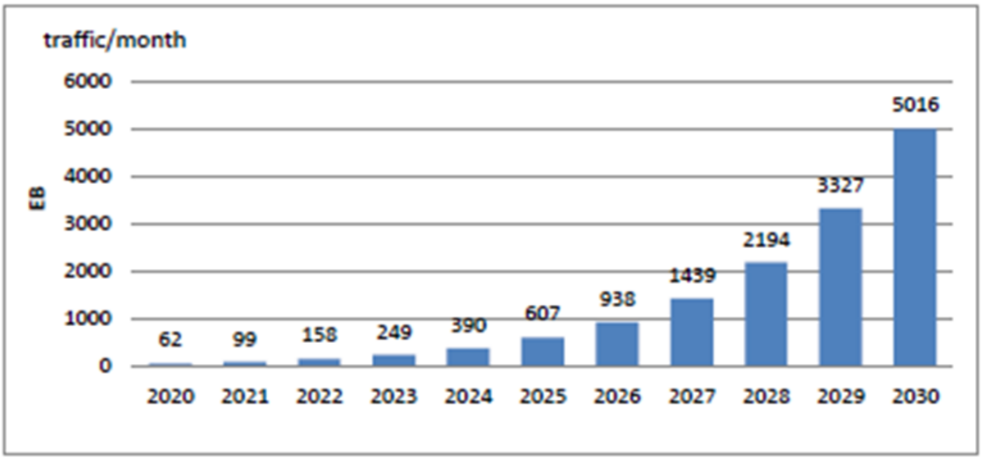

Figure 7. Global mobile traffic estimation.

5G is regarded in many quarters as the centrepiece of a new wave of ground-breaking technologies such as AI, IoT, digital twins, connected vehicles, automation, Decentralised Ledger Infrastructure (DLT), robotics, AR, high-definition video etc. Further innovation in these and other digital solutions will ensure that high quality wireless connectivity will be increasingly vital for the global economy over the coming decades.

2.1.1 Digital Value Chains

Markets for digital solutions can be deconstructed along value chains to illustrate the full range of activities needed to deliver them. At a certain level of abstraction, these functions are common to most digital solutions and services as they currently stand. However, companies can transcend one or more functions as they seek to capture value for themselves. A generic value chain is proposed in Figure 8 for digital solutions within archetypal industry verticals e.g., travel, transport, healthcare etc[2].

Specific solutions may not comprise all functional entities but at a certain level of abstraction, these functions are common to many current digital solutions and services. Companies and organisations can transcend one or more of these functions as they seek to optimise value capture for themselves.

Most functions are highly scalable and exhibit massive economies of scale. Suppliers can take advantage of advanced communications infrastructure to choose locations for their operations that offer certain advantages e.g., access to skilled labour, or low rent or for example. However, communications infrastructure itself requires a physical presence. It needs to be near the devices, objects, and users where the demand is generated and must therefore be distributed by nature and near ubiquitous.

To meet 2030 demand forecasts the wireless industry will need a far greater density of supporting infrastructure than is currently deployed. A recent review in the UK noted that, given the greater number of cell sites likely required for 5G over the longer-term, the traditional model of cell deployment is likely to be too expensive and impractical to adopt" (DCMS, 2018). Whilst traditional towers and rooftop sites will continue to play a part in

[2] The purpose of the model is mainly illustrative. In reality, the definition of such functions is open to interpretation. Therefore, the boundaries can become blurred and significant overlap may exist between functional types. Additional granularity would reveal a greater degree of complexity

providing contiguous coverage, supporting the advanced capabilities of 5G and increasing capacity requires infrastructure to be positioned even closer to the devices and objects that generate data. This means more antennas alongside transport corridors, at street-level and inside buildings.

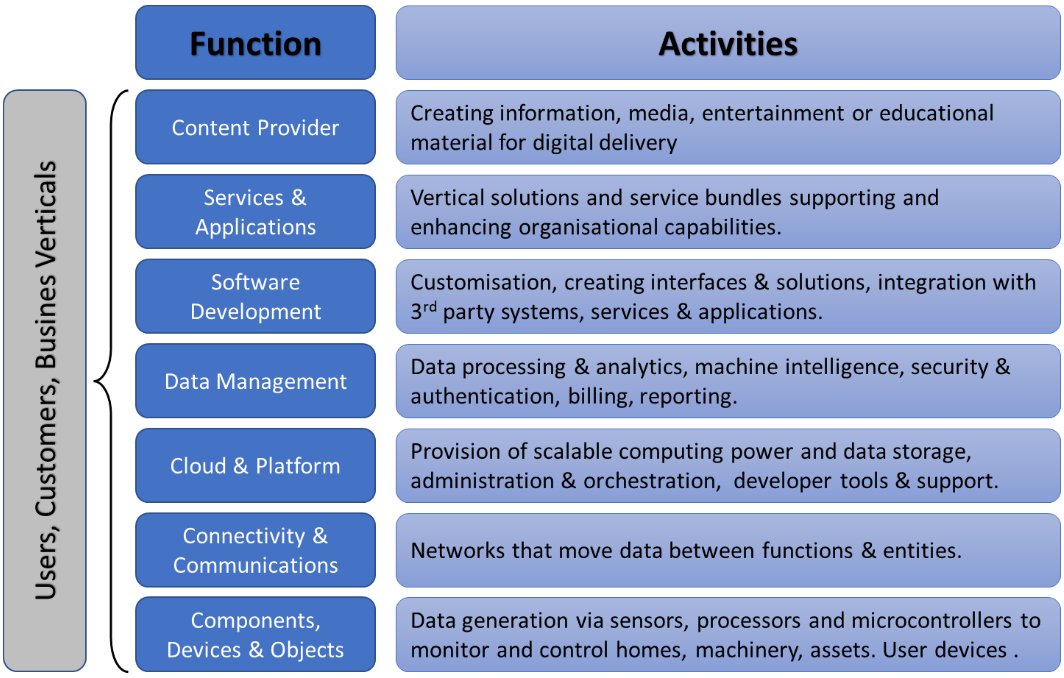

Figure 8. Digital Services Value Chains.

Despite the ubiquitous nature of public mobile services, most industry verticals are yet to engage with wireless connectivity on a **massive scale** to support the imminent wave of new digital technologies that will be required by stakeholders if they are to remain competitive. This deliverable focuses on the deployment of wireless infrastructure into vertical industry settings. Verticals comprise many different stakeholders with different operational focus and digital needs, however, the requirement for connectivity is common if they are to support the diverse array of digital services required to meet those needs. We will illustrate how infrastructure sharing can help achieve economies of scale and deliver greater value. We also aim to demonstrate how investment in 5G infrastructure supports innovation, where entrepreneurs within stakeholder organisations can be lean and agile, create minimum viable products (MVPs) and learn quickly from trials without the need for costly labs or testbeds.

2.1.2 5G Infrastructure Supply Chain

In discussing the role of 5G infrastructure within vertical industry value chains, it is useful to consider the key elements of the 5G infrastructure supply chain.

A traditional view of mobile network supply chain may look like Figure 9 below[3].

Mobile operators have traditionally been at the centre of the value chain, taking revenues from customers and subscribers and using the proceeds to buy access to more spectrum, equipment, infrastructure, and services from the other key parties.

As networks have grown operators were able to reach more customers and generate more income to be re-invested in the network in order to meet burgeoning demand and grow revenues. The growth was mainly driven by the consumer market for public mobile services, and this continues to dominate operator revenues with B2B often contributing much less; as little as 10% in some cases (Techradar, 2021).

[3] This is a generic model for illustrative purposes. In reality some organisations may be involved across multiple domains and some smaller players can have a much narrower scope.

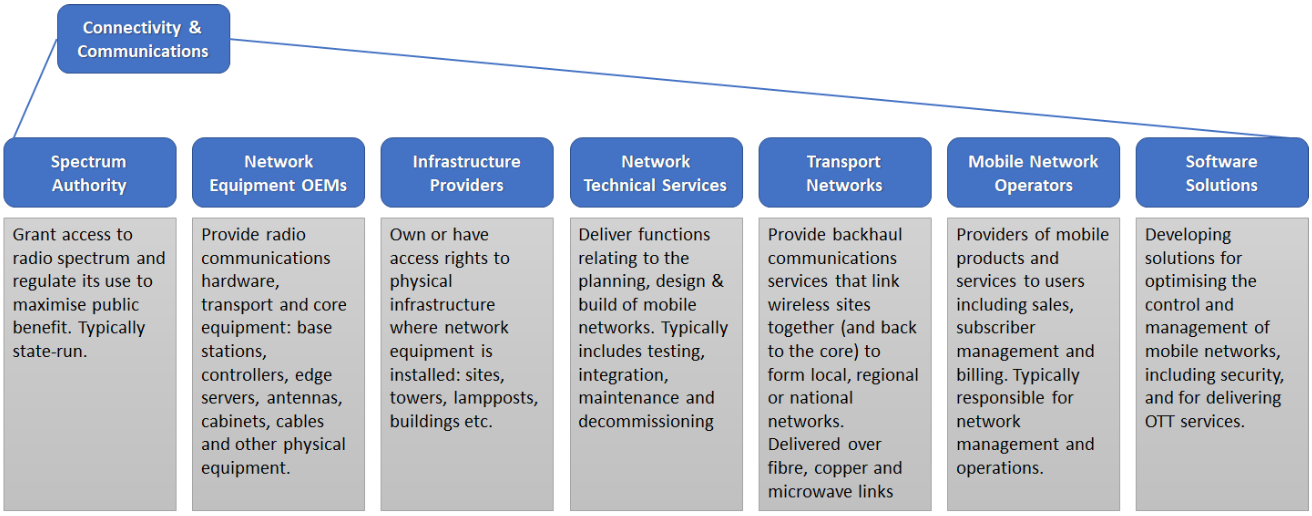

Figure 9. Mobile network supply chain.

Yet revenue *growth* from public mobile is in decline, especially in developed countries. Erosion by regulation, competition, and a desire to pay less has led to increased commoditization of mobile services and a marked decrease in the revenue per GB of data delivered (Figure 10). Costs have been driven down in response with the result that in many *developed markets* revenues have reached a plateau and whilst incomes may receive a boost from premiums charged for 5G. These are expected to be short-lived though.

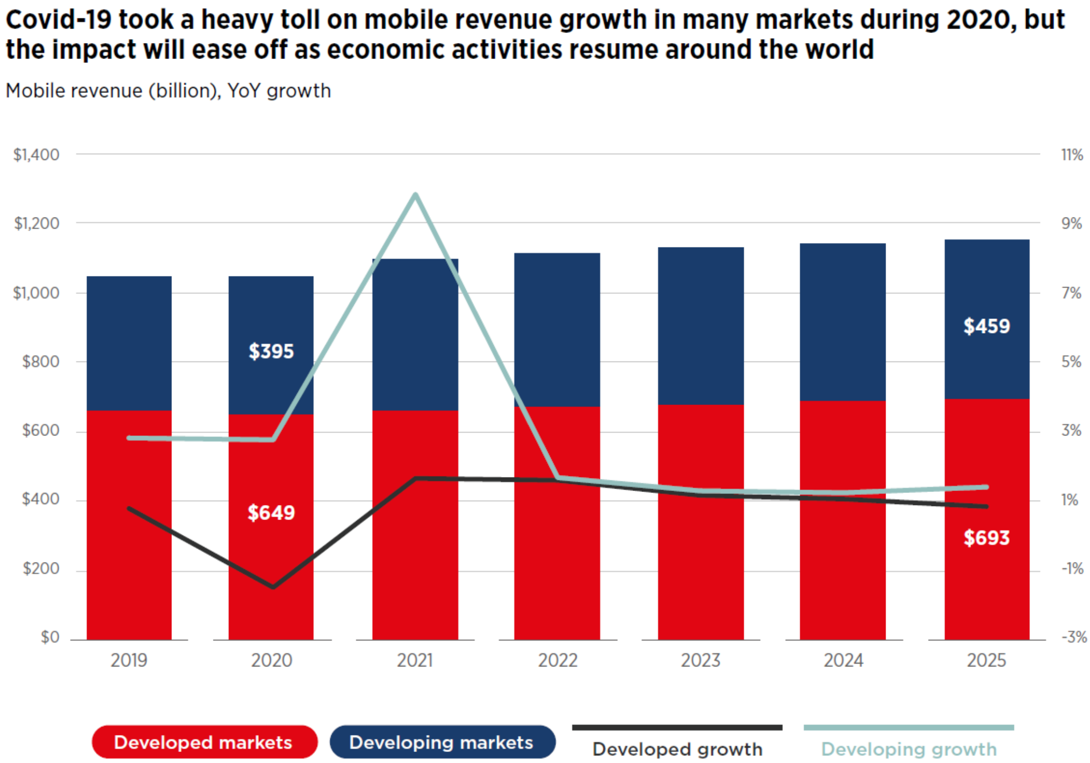

Figure 10. Global mobile revenue growth forecast (GSMA, 2021).

For some time now analysts have predicted that operators will start to focus more on enterprise services and grow B2B revenues. However, operators are still expected to invest in public mobile networks which may limit their ability to grow the enterprise market. This has opened the door for new models of infrastructure deployment with Tower Cos and Neutral Host operators playing a significant role in providing the necessary capital investment.

Meanwhile, advances in the technology together with regulatory developments are facilitating new models of access to mobile services that should, in principle, make it easier to deliver bespoke services into enterprises, by offering more advanced and customisable features. Prior offerings tend to have been derived from consumer-focused products and services, which may be a contributory factor as to why B2B market penetration is perceived to have lagged.

Recent developments, which are expected to benefit industry verticals are:

- **Network slicing:** Allows for operators to create independent logical networks each with dedicated resources and distinct features using a common, shared infrastructure. A logical network, or slice, can be dedicated to one enterprise customer, or shared by a group of vertical stakeholders with the same requirements.
- **Private Networks:** Communications regulators, keen to unlock the economic value potential of connectivity, are taking steps to make spectrum available for organisations to set up their own independent, secure networks. In some territories spectrum is dedicated and licensed for the purpose; in others they have policies that allow for spectrum sharing between local and national licensees.
- **Unlicensed 5G:** Licence-exempt use of harmonized spectrum bands has been embedded in the 5G standards (3GPP, Rel. 16, 2021) but is still in the early stages of development. Nevertheless, it offers the potential to expand the capabilities of enterprise networks and drive down the cost of deployment using unlicensed spectrum for both licensed-assisted and standalone modes of operation (Mobile Europe, 2021).

2.1.3 Finance Dynamics

Another factor that is likely to influence the adoption of wireless solutions by industry verticals is the required investment in infrastructure.

A recent survey has indicated a preference amongst buyers of Private Networks for costs to be incurred as OPEX, whereas wireless infrastructure has typically been capital intensive (Figure 11).

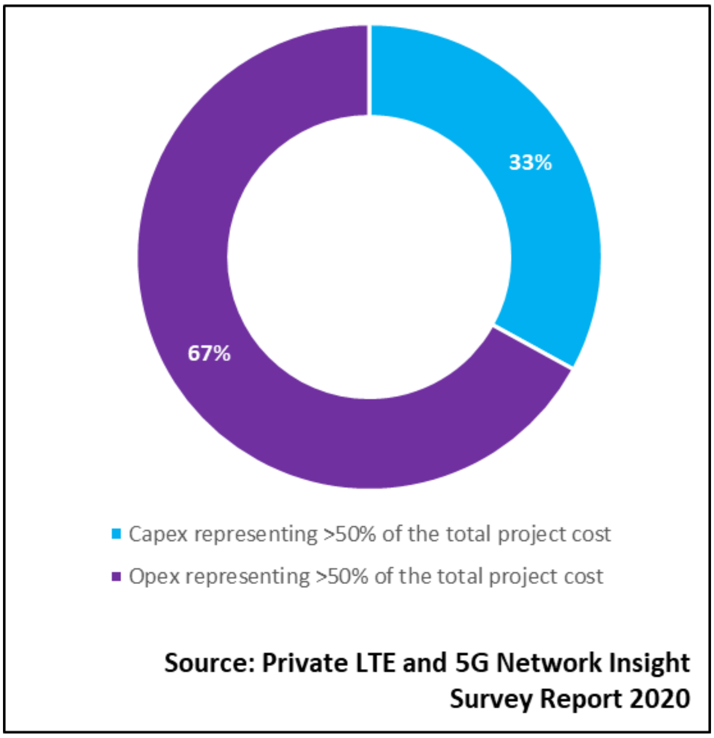

Figure 11. Customer's preferred business model for their mobile private network deployment.

In corporate finance it is generally assumed that investment in technology made as OPEX provides greater flexibility to increase or decrease capacity or capability in response to need or demand. CAPEX asset purchases are considered less responsive and are typically required to provide for the periods of peak demand leaving latent capacity at other times.

Capex investments typically require accurate forecasting to avoid over or under-budgeting, whereas OPEX-based solutions can increasingly respond to changes in demand in real-time.

Certainly, at the platform level there has been a demonstrable shift in corporates' IT expenditure from CAPEX to OPEX, as their use of cloud services increases as a replacement for investing in dedicated date centres.

Advances in wireless technology such as RAN virtualisation seek to exploit advances in computational power and the lower cost base to offer a similar ability that matches capacity with demand across networks. Virtualisation also creates a useful platform for innovation and development, but there is uncertainty around maturity, stability, security, and reliability that could still hinder widespread adoption by industry verticals.

Nevertheless, expenditures on wireless infrastructure will increasingly have a greater proportion of OPEX in them, paying fees to providers of flexible compute capacity rather than investing in physical hardware. However, some physical radiating infrastructure is still required to be located close to where the communications is needed and that can require considerable CAPEX.

The risk of getting budgets wrong persists in many infrastructure projects, across all verticals. Uncertainty about getting the right technologies, ensuring the right capacity, and procuring at the right time the appropriate features and capabilities for future needs can discourage investment. However, engaging with supply side specialists and broadening the pool of key stakeholders can help build confidence that value will be created and de-risk the investment.

2.2 Dimensions of 5G Infrastructure

5G has the capability to deliver up to 100 times the data rates of 4G LTE, at much lower network latency, and to over one million devices per square kilometer. This represents a significant improvement in technical capability over today's technologies and is the basis of a raft of benefits and value attributed to the technology by the supply side ecosystem, Figure 12.

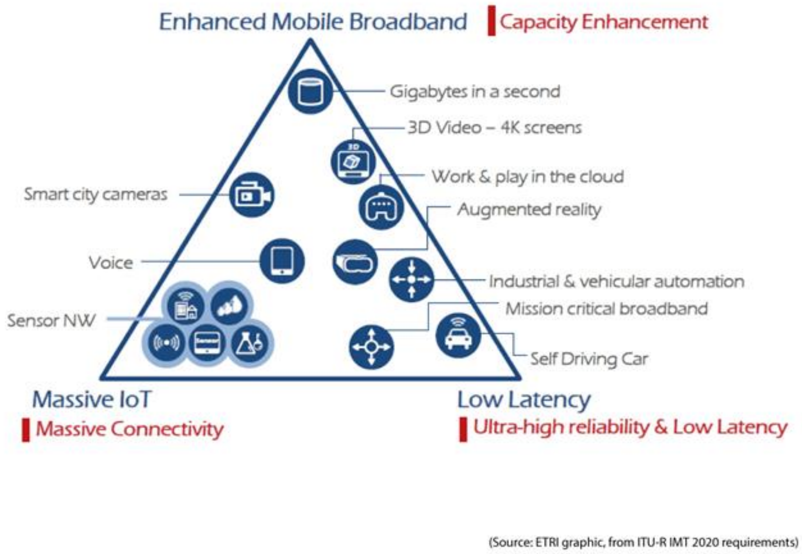

Figure 12. Dimensions of 5G network.

However, from the demand side perspective, verticals will regard 5G as one of a number of technologies that are aimed at improving operational efficiency. Digital transformation is endemic, but technologies will continue to be evaluated against corporate strategic goals and their ability to deliver improved outcomes, rather than being seen as part of the core business. Verticals care more about value-adding products and services that are enabled through a fast, secure, and reliable network connection than about the technical details of 5G, which will be measured against other connectivity solutions as well as other technologies in the digital value chain, Figure 6 and Figure 10.

If verticals are to be convinced of the technology, it is essential to clearly articulate the business value of 5G and demonstrate its potential to underpin a number of practical UCs, which are able to deliver tangible benefits into the organisation and into wider stakeholder ecosystems.

In order to prove the technology, to maximise the direct benefits and realise wider socio-economic value will require both the supply and demand side players to come together (as in 5G-TOURS) and bring their technological expertise and industry experience respectively.

Work has already been carried out in D2.3 5G-TOURS Task 2.3 (D2.3, 2021) to explore the potential benefits from the 5G-TOURS UCs and these will be explored in more detail in the subsequent chapters of this report. The other side of the equation is cost, which is equally important when it comes to investment decisions.

In this section we consider some of the fundamental dimensions of 5G infrastructure cost and how those might impact budgets and decision making.

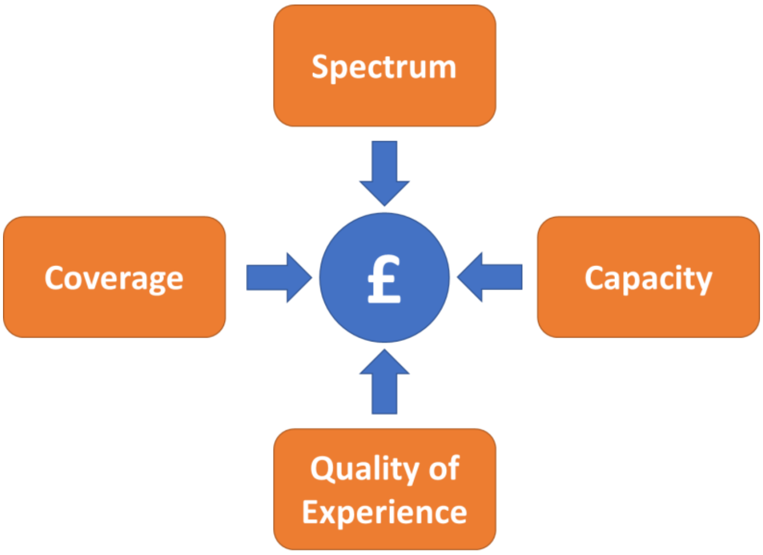

Figure 13. Cost Drivers of Mobile Solutions.

In general, increasing the capability of a given solution along any one of these dimensions will add to the total cost of ownership (TCO). We deliberately take a high-level view and the perspective of buyers of 5G technology on the demand side so they might better understand the trade-offs and implications for optioneering.

2.2.1 Coverage

Coverage in this context relates to the usable footprint of the 5G signal within an area or environment. To provide a signal requires radiating infrastructure (radio equipment, cables, and antennas) to be deployed in or around that environment with the signal directed to where the mobile devices are located. Obviously, if the area to be covered is larger, then all else being equal, it will need more infrastructure to cover it and therefore will come at a greater cost.

Increasing antenna height relative to the mobile tends to increase the coverage footprint although obstacles and features can attenuate or block the signal. Spectrum frequency plays a part too. Low frequency mobile signals (sub 1GHz) travel farther, penetrate obstructions better and bend around obstacles more easily than signals using higher frequency spectrum (>1GHz).

Networks deployed at lower frequencies typically need less infrastructure than those at higher frequencies, which means lower cost on a like-for-like basis. Similarly, to cover a wide area requires less infrastructure for solutions where antennas are mounted higher, however there are practical limits to this in indoor environments whereas outdoor masts and towers are typically restricted to a maximum height depending on local planning rules.

The main drawback is that the amount of low frequency spectrum available for mobile communications is limited and therefore most systems comprise multiple frequency bands. Where multiple bands are deployed together coverage tends to be dictated by the highest frequency band which neutralises any cost advantage due to spectrum selection. This is particularly true for in-building solutions where the lower frequency signals are deployed at lower power to reduce their footprint and match that of higher frequency bands.

It is also worth noting that not all coverage is the same. Different radio services require a particular signal strength, or more accurately signal-to-interference-plus-noise-ratio (SINR). Higher throughput (MB/s) generally requires higher SINR although the signal power diminishes with distance (at a lesser rate for low frequency bands), which means that a high throughput service, e.g., high-definition video, will have a smaller footprint than a low throughput service, e.g., text messaging. Solutions designed for high throughput services require higher density of antennas, which for a given coverage areas means greater cost.

2.2.2 Capacity

At a high level, capacity is the bandwidth available to all users across the coverage area of the network or system. There are three ways of adding capacity to a network: improving the efficiency of the spectrum currently held, buying more spectrum, and through network densification.

Each generation of mobile technology typically sees an improvement in spectrum efficiency through technical innovation and 5G is the best of the standardised mobile technologies. This is one of the reasons that the latest equipment commands a premium.

It is logical that enterprise will want the latest technology not only for optimal capacity but for the latest features and capabilities and, as much as possible, to ensure the investment is ‘future proof’. Therefore, given a 5G solution, the main variables are spectrum resources and network density.

The amount of spectrum is finite, tightly controlled and consequently expensive, therefore the cost of acquiring spectrum to increase capacity has to be balanced against the cost of adding more cells or sites.

Although certain parts of the infrastructure can be shared between spectrum bands other elements are band specific. Therefore, to deploy additional spectrum in different bands requires extra equipment at more expense, on top of the cost to acquire rights to the spectrum.

Densification works by exploiting the nature of signals to cover limited area as we described above. This means that the capacity from a single site is only available to users within that area. Additional radios and antennas can be deployed to retransmit the spectrum in adjacent areas creating an expanse of contiguous coverage made up of individual cells, hence mobile systems are sometimes referred to by the alternative name, “cellular”.

If the cells are more densely deployed then the capacity from each cell can be concentrated in a smaller area increasing the throughput/km^2. It stands to reason that over the greater expanse of the network, the solution with more cells will have more capacity. Or to put it another way, if the number of users or devices is the same each device can have greater throughput.

Densification is expensive in outdoor systems where more sites are needed that require towers, power and more telecommunication equipment. For indoor systems densification can also be costly whether it is the addition of additional small cells or in Distributed Antenna Systems (DAS) systems, the creation of more sectors, which requires more base-station equipment and more DAS hardware.

2.2.3 Quality of Experience

Quality of experience (QoE) is another dimension of cost for mobile infrastructure that is perhaps less intuitive. QoE are those features and functions of the network that impact the perception of users regarding the ability of the system to meet their needs. QoE can be affected by many different elements throughout the system but is typically dictated by that with the weakest performance. If 5G is to be widely accepted by industry verticals it is important that networks and connectivity are able to support those digital products and services at the level expected by enterprise, which is more stringent than that tolerated by consumers.

Of the main cost drivers, QoE is perhaps of greatest importance to verticals. A recent survey has indicated that confidence in the ability of cellular networks to deliver on QoE is low.

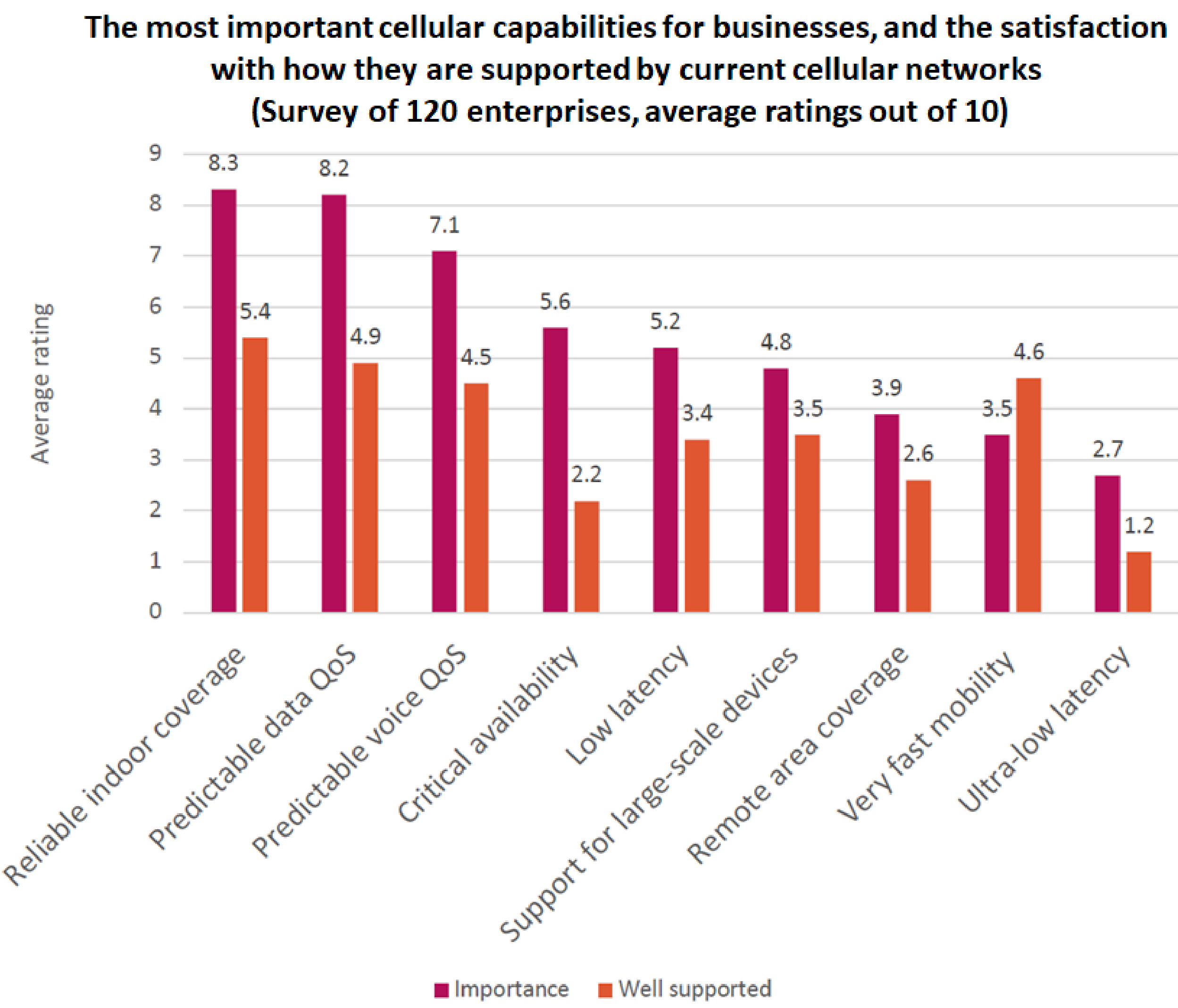

Figure 14. Enterprise view of mobile industry delivery (Real Wireless, 2020).

Some of these have been touched upon above in terms of providing adequate coverage and capacity, which themselves can affect QoE, however, some of the less intuitive ones are:

- **Availability** refers to the ability to access the network and the desired service. Coverage is the main driver of availability, however signals fluctuate across the coverage area of a network for a variety of reasons, which means that certain services may be unavailable in certain locations. Additional infra-structure may be required to address specific availability issues, however to increase confidence over the target coverage area may require densification, both of which will incur additional cost.
- **Reliability** in the context of enterprise solutions indicates the up-time of the network, i.e. where there is no deterioration in the expected performance due to failures or degradation. Issues do happen but reliability KPIs are designed to ensure that they do not happen too frequently and, when they do happen, they can be rectified quickly. More robust KPIs tend to incur higher costs from requiring better quality equipment, increased maintenance schedules and equipment refresh intervals. Solution providers need to be cognisant of KPIs specific to the industry vertical and be capable of understanding and meeting them.
- **Resilience** is the ability of the network to cope in the event of a performance issue or failure. Critical applications may not tolerate any degradation or break in connectivity and require additional monitoring or back-up solutions to ensure continuity of service. These would obviously come at additional cost.

- **Security** in the digital age is paramount for enterprise. Protecting sensitive information regarding, personal identity (customers, staff, suppliers etc), assets, operations, etc, is strategically essential for all digitally engaged enterprises if they are to succeed. Wireless networks, by their nature, are considered more accessible and insecure than their wired counterparts. Measures are required to prevent unauthorised access, damage to computers or the malicious appropriation of data. In many cases, enterprise may express a preference to deploy standalone operational and publicly accessible networks to isolate systems and limit coverage to prevent access. Additional levels of security again come at a premium to the buyer.

2.2.4 Spectrum Access Costs

Radio spectrum is the medium that supports wireless communications and, as a finite and precious resource, is strictly regulated to ensure fair and reasonable access. Regulators are typically responsible for the management, assignment and licensing of spectrum, seeking to ensure optimal technical and economic performance and protection from abuse, malicious or otherwise.

For 5G deployments, access to spectrum is increasingly becoming a key variable, unlike previous generations of mobile technology. The standard supports a much broader range of spectrum than previous generations of mobile technologies, extending from 400MHz to 100GHz. However, as we have seen in Section 2.2.1, not all spectrum is the same. Low-band frequencies (sub 1GHz) tend to be better for longer range and wider area coverage. Mid-band spectrum (1-6GHz) is better suited to areas of high demand where cell densification can deliver greater capacity and it helps if signals are easier to contain, limiting interference. Spectrum in the range 6-100GHz is referred to as High-band and offers much more capacity.

Spectrum for mobile communications is made available to third parties by national telecommunications regulators, who may or may not charge a fee for access rights. An organisation cannot deploy a working 5G solution without access to sufficient and appropriate spectrum. One of the key developments in the standardisation process is that the technology has been developed to facilitate deployments on both licensed and unlicensed spectrum bands.

Licensed spectrum confers exclusive rights to exploit specific sub-bands, subject to the terms and conditions of the licence. Exclusivity offers protection against interference from other parties' systems and allows the licence holder to optimise their use of the spectrum for maximum benefit. Mobile spectrum licences typically have an obligation to provide a nationwide public service and this has been the main focus for the MNOs since the industry matured in the 1980s.

For private enterprise or individual organisations, it is not practical nor economic to bid for national licences. However, if permitted by the regulator under the terms of their licence, holders of licenced spectrum may be able to share access with other parties, subject to any necessary commercial arrangements. This allows the spectrum to be used by multiple organisations within a single territory, although local coordination is essential to avoid interference and optimise performance.

Moving forward, organisations will be able to deploy 5G on the unlicenced spectrum bands that are freely available such as the globally harmonised ISM bands at 2.4GHz and 5GHz, which are extensively used for Bluetooth and Wi-Fi at present. Although the spectrum is readily accessible, there are restrictions placed on the equipment itself, which mainly limits the transmit power and hence the coverage[4]. It is also the case that wireless equipment operating in ISM bands must tolerate any interference generated by other ISM systems nearby. Users have no regulatory protection from ISM device operation in these bands, provided they are certified against the relevant legislation. However, considering the global success of Wi-Fi, 5GU (unlicenced) offers the potential for low cost and low complexity 5G solutions for enterprise.

The nature of the spectrum available, the terms and conditions of the licence (where appropriate) and who holds the access rights all serve to characterise the dominant supply-side business models concerning the delivery of 5G products and services.

[4] Radiating equipment for the ISM bands are certified via local or regional legislation e.g. CE scheme in EU.

2.3 5G Supply Side Business Models

A key objective of WP8 is to develop and validate business models for each of the markets addressed by 5G-TOURS (i.e., touristic, media and entertainment, e-Health, safety, transportation) using contributions from the other work-packages. The business models will help with directing the economic impact of the project, in particular the industrial sectors (market verticals) that adopt 5G as a platform for the delivery and use of products and services.

An initial review of current business models (D8.1, 2020) identified a number of templates that have been used to analyse typical innovations brought by 5G. However, none had been applied to specific UCs such as those considered in 5G-TOURS.

What is clear is that there is no "one size fits all" approach to the delivery of 5G. In D8.2 (D8.2, 2021), we introduced the 5G-TOURS 5G Enterprise Pathfinder Framework for navigating the opportunities presented by 5G (see section 1.2). This framework seeks to align demand-side corporate strategy and individual sector objectives, with a number of supply-side business models, in order to maximise value delivery within the vertical markets and across the wider society.

In line with the ICT-19 mission of "Enabling the Verticals", the 5G-TOURS: 5G Enterprise Pathfinder Framework takes the perspective of demand-side stakeholders who will likely be customers and buyers from the supply-side ecosystem. The intention is that it will better inform 5G technology investment decisions within a range of environments and organisations. UCs are considered to be incremental to a *core service offering* built around a collection of uses and applications for which it should be assumed there is already a degree of infrastructure investment. Therefore, the additional investment that is required to create and capture the value of a specific UC is what is being assessed.

The framework also recognises that the various UCs present opportunities for value creation and capture but that those opportunities may not in themselves be justification enough for the required infrastructure investment. More likely, any investment will be based on the cumulative value afforded by a number of different but co-existent applications. As a result, a number of business models are included that are able to encompass B2C, B2B & B2B2C channels. In addition, it was important to include models that can accommodate vertical specific service characteristics and that can exploit synergies in the coverage, capacity and QoE needs of different demand-side stakeholders.

The sub-set of RAN business models underpinning the 5G Enterprise Pathfinder Framework for 5G-TOURS are described briefly below, however the framework is intended to be flexible enough to accommodate other business models as necessary, particularly those that are yet to be developed or proven.

2.3.1 Private 5G Model

Private 5G is a local or non-public 5G network using 5G technologies to create a dedicated or closed network with vertically optimised services and a secure means of communication within a specific location or area.

Spectrum for private 5G networks is available under the following models, where regulations allow:

- **MNO led sharing:** A public operator provides a private network-as-a-service on a localised basis using dedicated infrastructure and the spectrum bands otherwise allocated for the national public networks.
- **PNO led sharing:** A private network operator sub-leases spectrum from an MNO licensee
- **Dedicated private network:** Using dedicated spectrum that the national regulator has specifically allocated for local private networks.
- **Unlicenced 5G:** Using spectrum that may be shared by other technologies and applications in the locality.

Dedicated spectrum is now starting to be released by national regulators. USA: CBRS (Citizen's Broadband Radio Service), UK, France, Germany.

A number of Private 5G networks have been successfully deployed including, but not limited to:

- **Airports**: Brussels, Paris, Helsinki, Vienna & Hamburg.
- **Hospitals:** Sichuan Hospital.

- **Manufacturing and Industry 4.0:** OSRAM Factory, BMW plant in China, Mercedes Benz facility in Germany and Bosch at a factory in the United Kingdom.

2.3.2 CSP Slicing Model

A CSP delivered service using dedicated network slicing for specific UC services over a particular geographical area. What distinguishes CSP slicing from the private 5G model is that a slice can be provided using the same infrastructure as the public network and spectrum resources are not necessarily provided exclusively for use by the customer or enterprise. Network resources can be allocated as and when required but with a high degree of control over the KPI's making them customisable to suit enterprise applications.

Network slicing enables the most economical model to provide service differentiation and meeting end user SLAs.

2.3.3 Neutral Host Model

The Neutral Host model is primarily about infrastructure. Neutral Host providers offers a shared platform which is open to all mobile network operators (MNOs) and CSPs. They act as an intermediary providing a single managed system for customers who benefit from dealing with a single entity and one serviceable solution. This is important where public access may be desirable alongside operational requirements, e.g.: in a shopping centre, football stadium or airport.

Neutral Host solutions are usually deployed, maintained and operated by a third-party provider and are designed to support a wide range of MNO technologies/spectrum bands. A variety of different architectures are used to provide premium wireless services in different environments, such as Distributed Antenna Systems (DAS) and Small Cells Networks (SCN). Typically, fibre-fed, these networks are designed specifically to cope with periods of peak user demand and scaled to accommodate future generations of technology, including 5G.

A Private 5G network might also be carried over the Neutral host infrastructure.

2.3.4 Hybrid 5G Network Model

The Hybrid 5G Network combines localised private networks with wider area coverage on a public network. This is attractive for UCs that have some overlap in coverage area between requiring dedicated localised resources and being capable of being supported to some degree over a wider area by transitioning onto a shared resource.

2.4 Framework for understanding economic and commercial potential of 5G-TOURS UCs

At the core of 5G technology investment decisions and the assessment of potential value from the 5G-TOURS innovations is a cost-benefit analysis. In this period we have taken significant steps forward toward validating the 5G Enterprise Pathfinder Framework by continuing to work closely with WP2 activities to define the parameters of the benefits analysis such that a comparable set of costs can be generated. We have also made progress in developing a number of Deployment Optioneering Tools to model the uptake of UCs alongside that of core offerings such as public mobile so that we better understand the marginal impact on network dimensioning and costs.

2.4.1 Benefits Assessment

The benefits analysis and economic drivers for the 5G-TOURS UCs has been undertaken within WP2 of 5G-TOURS and specifically T2.3. Figure 15 shows the connection between WP2 and WP8. T2.1, 2.2 and 2.4 all define the service requirements for each of the UC and investigate the implications that these service requirements may have on network deployment. Based on these service definitions, T2.3 then considers who might use and benefit from these services in commercially deployed networks.

We have worked together with T2.3 to ensure that we consider the services provided under the 5G-TOURS UCs extend beyond the project testbeds to where the 5G-TOURS UCs and their related services would be deployed in large scale commercial networks and who, in these settings, would use and benefit from these.

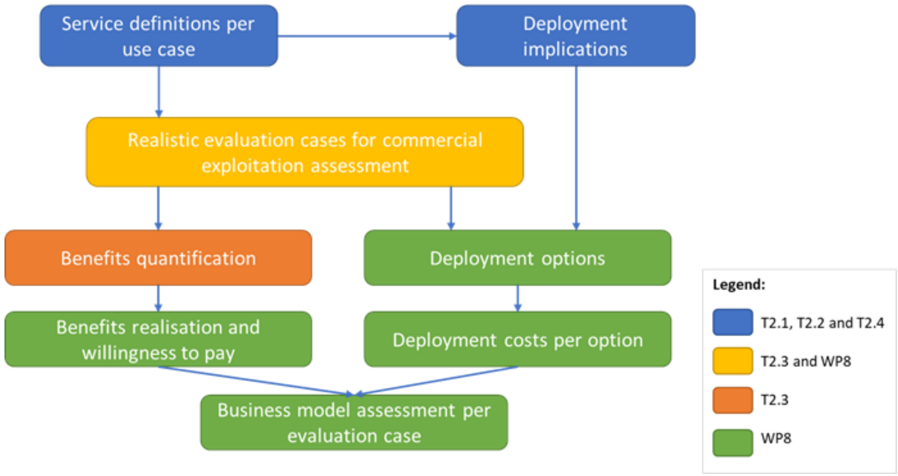

Figure 15. Relationship between tasks within WP2 and WP8.

As a result, the techno-economic analysis by way of the interdependent study between WP2 and WP8 has derived quantification of benefits at a national, regional, vertical user and user benefit level. The UCs have been analysed individually to quantify their specific value to the vertical.

The results of the benefits analysis will be used to validate the selection of business models for the deployment of 5G infrastructure in each of the operating environments (airport, museum city, hospital). These business models describe how organisations in each vertical can create, capture and deliver value, which is derived from 5G, in economic, social, cultural and other contexts. This can then be used by the project partners and other stakeholders to clarify their role in the vertical UC value chain and how this can drive strategies for the commercial exploitation of project results.

The method of the analysis is described in D2.3 and the results will be reported in more detail in the relevant sections to come, but first we consider the context of the 5G-TOURS UCs and the settings they are likely to be used in.

Figure 16 illustrates the mapping for which the benefits have been derived under WP2 and shows the 5G-TOURS UCs aligned to the geographic coverage area and setting that these UCs are most likely to be consumed in.

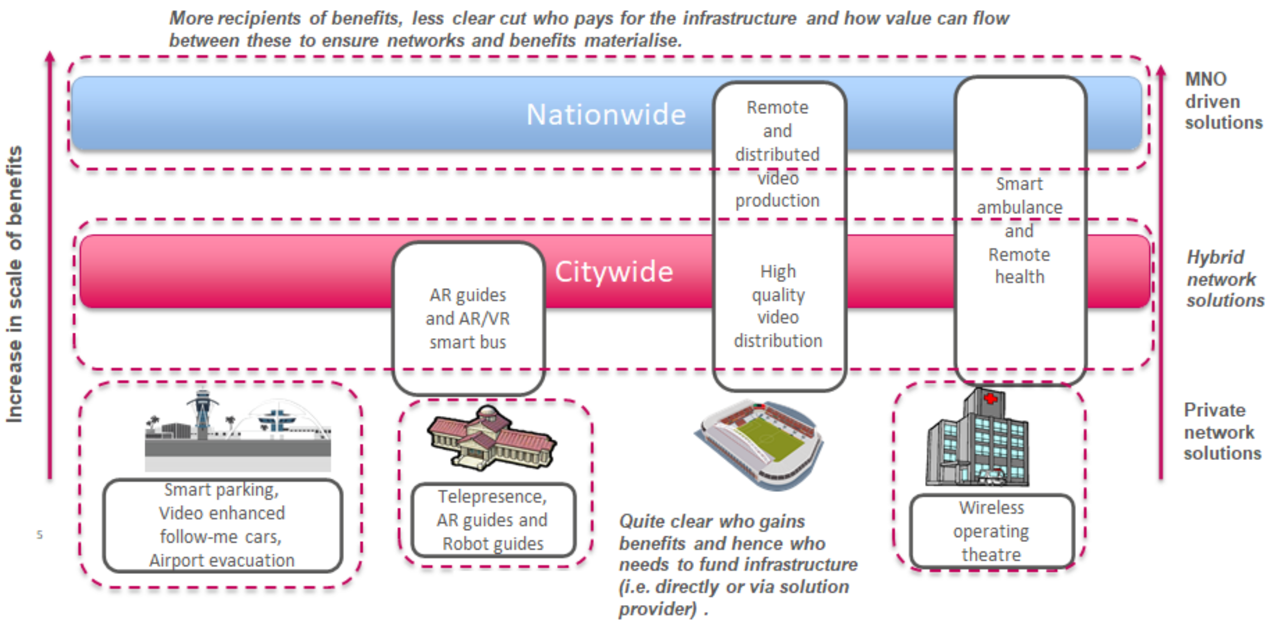

Figure 16. WP8 Mapping of 5G-TOURS UCs to physical settings and evaluation cases.

WP2 has analysed the benefits of a number of scenarios or evaluation cases as listed in Table 1. In WP8, we are, taking the perspective of the vertical, or of organisations within the vertical, at the level at which investment decisions are made. Evaluation case 5, which concerns the nationwide benefits, is more useful for decision making at the political level but less informative from a business model perspective, therefore WP8 is focussed on Evaluation Cases 1 to 4.

Table 1. 5G-TOURS UCs.

	Physical setting	**UCs considered**
Evaluation case 1	Athens airport	• Smart airport parking management (UC10) • Video-enhanced ground-based moving vehicles (UC11) • Emergency Evacuation (UC12)
Evaluation case 2	Museums in Turin	• XR immersive museum experience (UC1) • Telepresence (UC2, UC3) • Robot-assisted museum guide and monitoring (UC3)
Evaluation case 3	Rennes Hospital	• Wireless operating theatre (UC8)
Evaluation case 4	City of Turin	• XR immersive city tour experiences (UC1) • Excursion on an AR/VR-enhanced bus (UC13) • Remote healthcare (UC6) • Smart ambulances (UC9) • High quality video distribution (UC4) • Remote video production (UC5)
Evaluation case 5	Italy	• Remote healthcare (UC6) • Smart ambulances (UC9) • Remote video production (UC5) • High quality video distribution (UC4)

Before we address the individual evaluation case settings, it is worth noting that one of the key elements in the analysis is the take up of 5G services, where it is important to have alignment between WP8 and WP2. In order to ensure that the results and conclusions are directly comparable, the benefits and costs should be derived from the same set of assumptions.

The comparative rates of 5G uptake for the different UCs (B2B) and for end users (B2B2C) are illustrated in Figure 17. The variation by UC reflects, in part, differences in the willingness to adopt 5G by the different verticals as suggested at the start of this section (Section 2). More details can be found in (D2.3 5. T., 2021).

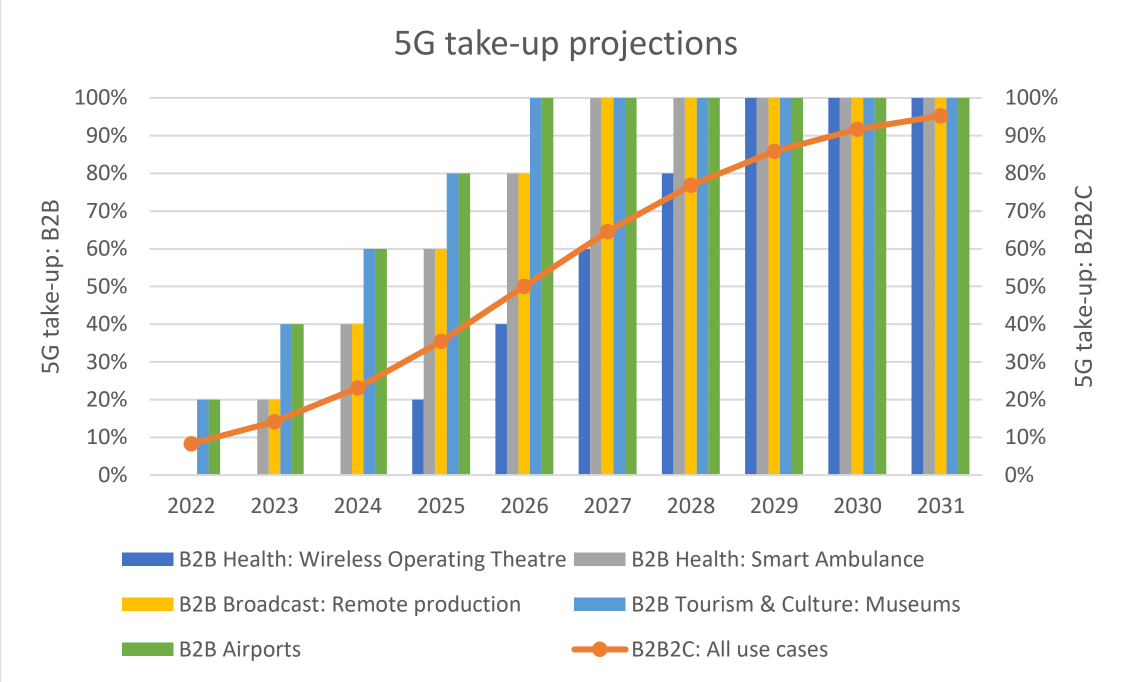

Figure 17. 5G take-up projections: B2B2C and B2B services (campus or citywide).

2.4.2 Deployment optioneering tools

There is a close relationship between WP2 and the commercial exploitation and business model analysis threads of work in WP8. Any business model requires quantification of revenues and costs. Revenues will be linked to willingness of users to pay for a service which in turn are linked to the benefits derived from that service. In this way, WP2 feeds into the business model analysis.

Furthermore, the service requirements and deployment implications developed by the other parts of WP2 are captured by network dimensioning and cost analysis activities of the business model work in WP8. This has necessitated the development of a number of generic cost models that will provide reliable estimates of CAPEX and OPEX over a reasonable lifetime of the investment in the technology. One of the key elements of such an exercise is to quantify volumes of end users for each of the evaluation scenarios. This provides the basis for infrastructure dimensioning and costings.

Real Wireless have enhanced several of their inhouse tools to help answer some key questions in the 5G-TOURS project, these tools are customised to fit the purpose of the project. The main questions that these tools address are:

- What is the capacity and cost required to cover a Smart City with 5G services such as eMBB and AR.
- What is the deployment cost to provide 5G connectivity for an indoor highly populated environment, i.e. an airport.
- What is the cost and capacity required to cover city wide UCs and to provide broadcasting services.
- What is the required dimensioning cost to provide 5G connectivity for an ambulance on transport corridors, e.g. roads.

Figure 18 shows a snapshot of the Real Wireless tools, these are in brief:

- **CPST**: 5G capacity simulator tool that addresses the network dimensioning issue to cover smart city services.
- **Indoor Cost Model**: 5G indoor dimensioning tool to cover highly populated indoor environment.
- **Cost assessment model for city wide UCs**: A Dimensioning tool that analyses the cost of deployment of a 5G network in and around the city. This also includes the broadcasting services.

- **Connected Corridors Capacity Assessment:** A dimensioning tool that analyses the cost of deployment of a 5G network to provide coverage and capacity along transport corridors for smart ambulances.

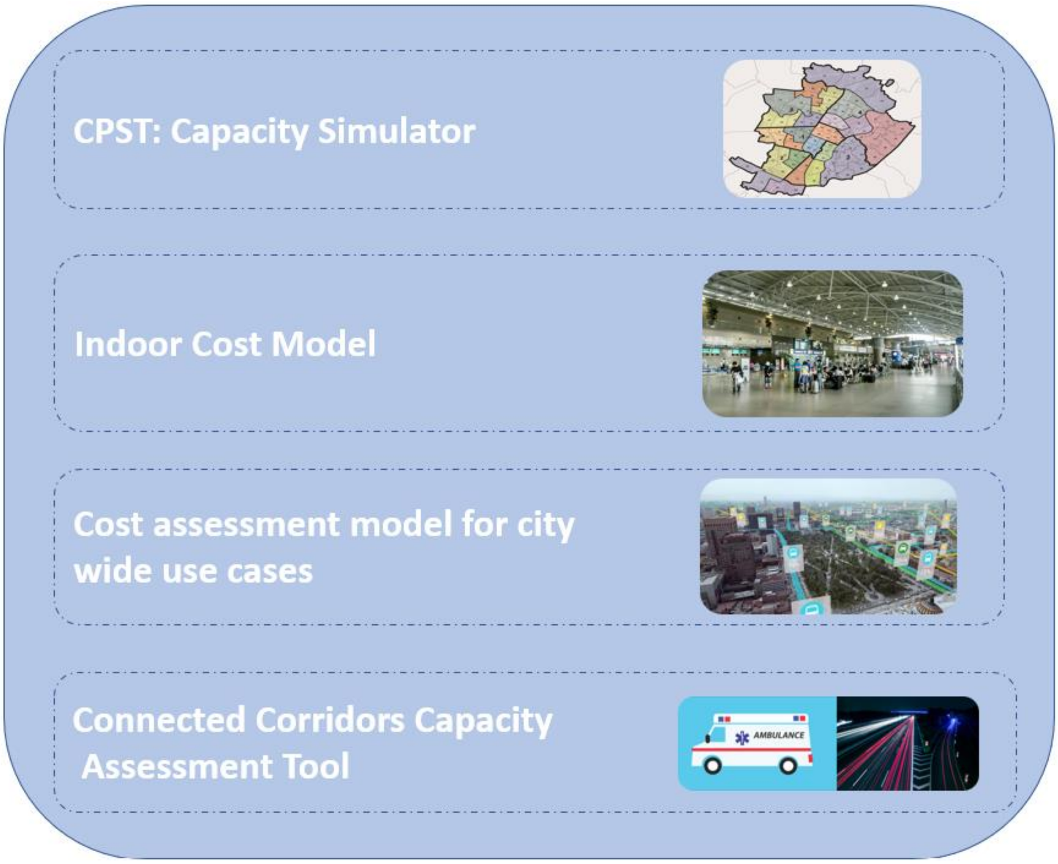

Figure 18. Real Wireless optioneering tools.

In this subsection we describe typical inputs and outputs of each of the tools being developed.

➢ **CPST**

This tool dimensions the network for a wide smart city, some typical inputs of the model include:

- Population and area in km^2.
- Mobile penetration rate and market share.
- User demand/month and overbooking factor.
- Existing site DBs in the city of the MNO taken into consideration in the study

The mobile demand (Mbps) for the busy hour is calculated and the dimensioning of the network is carried out to satisfy user's demand in terms of capacity.

Outputs from the model are shown in section 5 below, this includes analysis of:

- Demand density in $Mbps/km^2$ and capacity offered by the network/strategy.
- TCO of the network for 10-year period per service per strategy.
- Power consumption and CO_2 emissions by the 5G network.

➢ **Indoor Cost Model**

- Typical input of the model includes:
  - Estimation of the indoor data demand/UC.
  - Demand growth for the study period.

  - Population density in the indoor environment.
  - Cost of some key elements of the network.

- This tool estimates the indoor TCO for the study period of deploying a future proofing 5G network in the indoor environment and takes into account that the growth of the wireless demand and number of applications have a significant effect on the estimated cost of the system. There are other factors that affect the cost of the indoor system such as the architecture approach, e.g. DAS vs. small cell, spectrum availability and the technology adopted.
- More details about the tool, the indoor solutions adopted and the detailed elements of the cost are described in section 3.

➢ **Cost assessment tool for city wide UCs**

- This tool analyses the mobile demand in areas of the city. There are several UCs taken into consideration and these are described in section 5. Typical services analysed in that section include:
  - AR/VR for bus services.
  - Broadcasting.
  - Tourism.
  - Remote health.

➢ **Connected corridor capacity assessment tool**

- Providing mobile connectivity across the main road network could deliver benefits to vehicles delivering public services such as emergency vehicles. This tool examines the smart ambulance vehicle UC, its wireless requirements and potential implications for dimensioning of mobile networks on transport corridors. In section 4, further details about the wireless demand that is generated from an ambulance in both DL and UL is investigated and the network cost to serve this demand is also described.

The tools presented above answer mainly the coverage and the capacity questions. However, the QoE which is related to the experience perceived by the end user is not addressed in this deliverable. Figure 19 shows the relationship between Real Wireless tools and Coverage, Capacity and QoE questions. In addition, the availability issue is closely related to the experience perceived by the end user. Work to develop the tools will continue in the next period to include sufficient functionality to fully evaluate the 5G-TOURS innovations from a cost perspective, the results of which will be reported in D8.4.

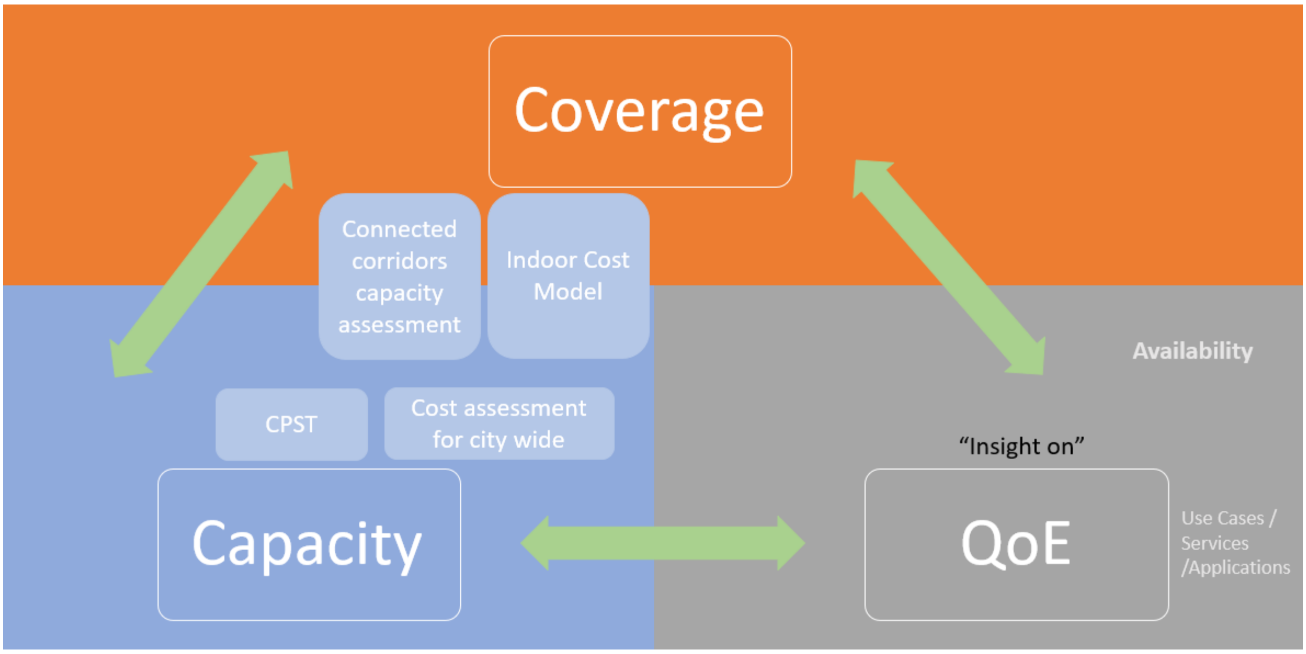

Figure 19. Real Wireless tools vs. Coverage, Capacity and QoE.

3 Airport Sector Business Models, Deployment and Operations

This chapter builds upon some of the concepts developed above and applies them in the airport context of the transport evaluation case. Options for the provision of 5G infrastructure are explored from the perspective of the 5G-TOURS UCs and evaluated in terms of architectural suitability and ease of deployment.

The benefits derived in WP2 corresponding to the airport sector are examined in more detail and evaluated against estimates of 5G infrastructure costs to understand the net value potential of the UC's.

Two case studies are presented on smart parking and network performance monitoring, which look at the 5G-TOURS innovations from the perspective of different providers within the 5G value chain and consider how they might be applied and add value beyond the airport evaluation case setting.

3.1 Innovations & Business Model

The air travel industry is the focus of UCs 10, 11 and 12 as introduced in D8.2 and the specific setting for the cost-benefit analysis is Athens airport, which has been used as the testbed for the trials, workshops, and validation activities.

The innovations in the transport related work package (WP6) are related to improved passenger experiences and seamless movement through the airport setting enabled by 5G and analysed in WP8 as part of the overall passenger journey (Figure 20). These user journeys are intended to support non-5G experts, with limited knowledge of networks, to visualize the operational setting of the innovations within their enterprise. Innovations which have been developed in the context of concrete UCs as follows:

- **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 user under stress. Also, the location accuracy that will be provided from the network will provide the users location precisely.
- **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 (See 4.4.5).

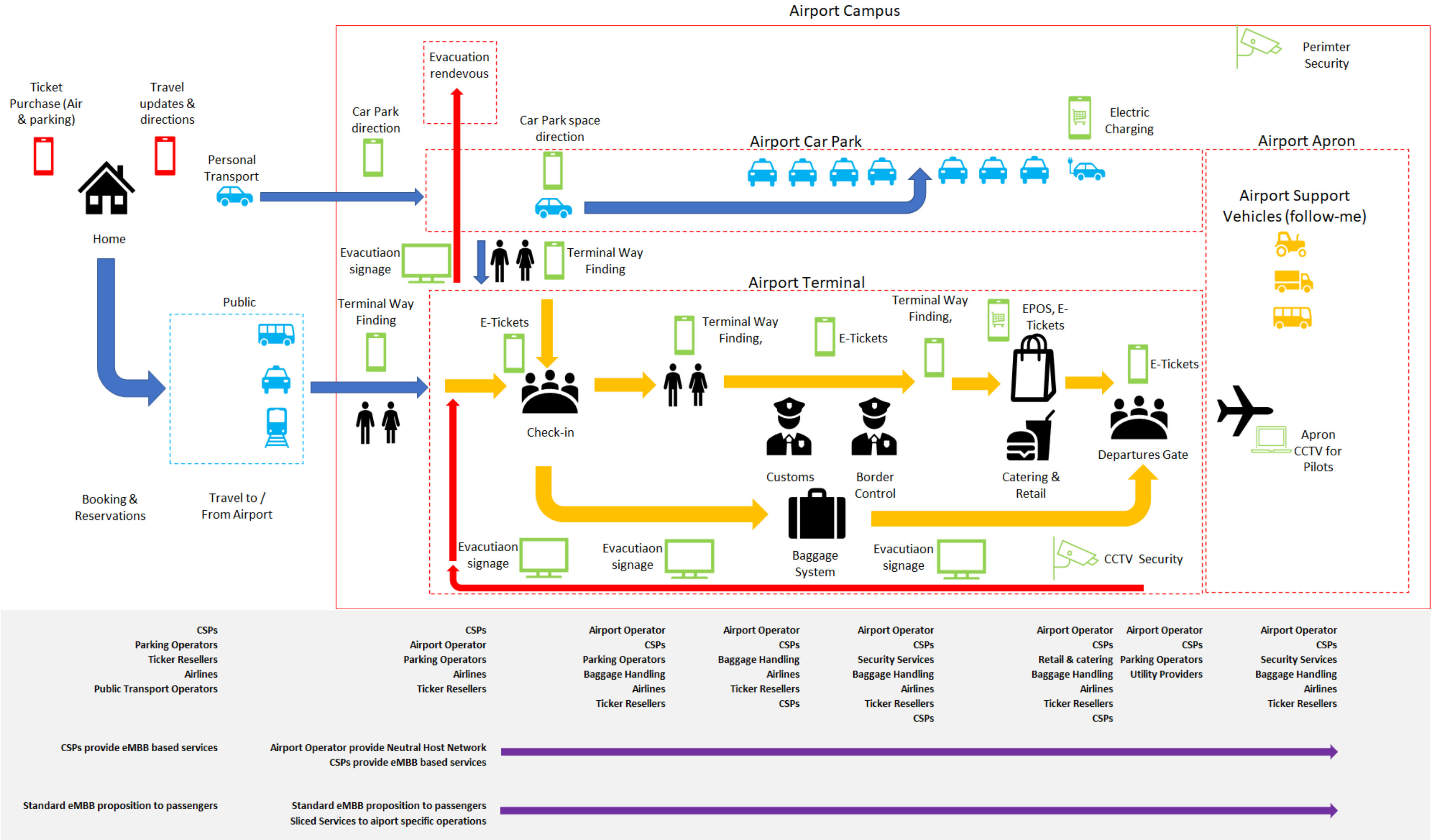

Figure 20. Airport user journeys.

It was established that 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.

3.1.1 Most beneficial innovations for the transport (airport) vertical

During the 5G-TOURS project, several 5G related innovations, pertinent to the transportation/aviation sector were developed. Some of them addressing operational issues, other passenger experience, safety, and security ones.

To identify the most beneficial innovations for the transport/aviation sector, one has to take into consideration the latest development regarding air travel. Since March 2020, airline travel was impacted by the devastating effect from the COVID19 pandemic, where in many countries international travel seized completely whereas in others international travel was reduced up to 98%. Only some relief, medical and cargo flights with medical provisions were operating.

Due to the prolonged effect of the pandemic, governments, airlines, airports, and international travel associations were searching for methods and measures under which air travel could be restarted, while at the same time minimize the risk of the pandemic for passengers and staff, such as the IATA travel pass application illustrated in Figure 21.

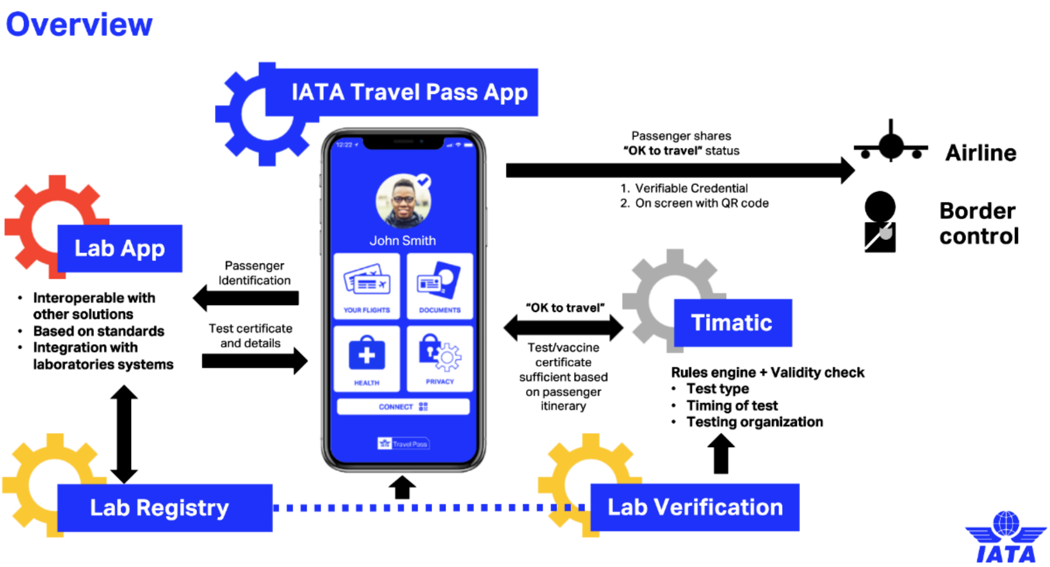

Figure 21. IATA's travel pass app.

Under this prism, all 5G related innovations that could be utilized to fulfil the above-described objective became of primary importance to the industry. Furthermore, the 5G mobile networks advanced capabilities, such as network slicing and multiaccess edge computing, are unique assets that enable connectivity excellence, leveraging reduced latency, faster transmission, network management, a greater number of connected devices, accurate geolocation, and reliable information.

In this context, the innovations identified as the most beneficial ones those that facilitate safe & frictionless travel. COVID-19 underscores the need to enhance airport passenger processing and make it as safe as possible. To achieve this, airports need to minimise direct contact with airport staff or other passengers and therefore it is necessary to fully digitize the entire process to minimize the impact of COVID-19 restrictions on congestion levels. Towards these objectives, 5G plays a pivotal role as it provides the necessary advanced capabilities to facilities advanced digital services in massive scale, e.g., tens of thousands of passengers travelling through an airport terminal such as:

- Thermal imaging and automatic fever detection empowered by a 5G network through a 4K cameras or AR enabled thermal glasses with facial recognition.
- Real time access to and secure transmission of passengers' travel & health records e.g. health passports, may detect critical cases (based on body temperature and travel history).
- Passenger tracking systems and flow management solutions can detect congested terminal areas and alerts for social distancing violations.
- Location based services based on 5G technologies that can accurately calculate the exact position, journey, and interactions of passengers in massive scale to be able to trace interactions of any passengers that is found be infected after their travel.
- Accurate guidance of AGVs for round-the-clock disinfection of strategic points takin into consideration passenger occupancy, journeys to facilitate dynamic and safe routing through passengers.

In this context, other complementary digital initiatives enabled by 5G can be considered and implemented using 5G networks.

Figure 22. Graphical depiction of frictionless travel concept (Politicshome, 2021).

3.1.2 Value to the vertical

The value that these innovations introduce to the vertical comes in many forms. Primarily, it provides a safe and secure framework for the restart of the industry following the COVID19 pandemic era. It helps to economically improve the industry from a complete standstill and stagnation caused by the lockdowns and bans for international travel, tried to reinvent itself in a desperate effort to provide the capability for air travel to become an as safe as possible activity again.

The industry, after the initial shock, quickly gathered momentum to identify those solutions, backed by advanced technology, that would enable the restart of travel again. Many of the solutions - as defined in the previous chapter – that already were in the mature implementation and exploitation state, were gradually put in operation. Innovations such as thermal imaging and automatic fever detection or passenger tracking systems and flow management solutions were quickly embraced as they provided immediate value to airports in their effort to create a safe environment that would facilitate travel without the risk of disease spreading.

As passenger numbers started rising again – AIA experienced high passenger volumes for the summer months of July and August 2021 after almost 18 months of minimum flights, traffic at AIA is forecasted to reach approx. 60% of 2019 ones which was considered a record year – airports are encouraged to invest in these innovations.

Currently innovations around the concept of seamless and frictionless (contactless) travel are of high priority on the investment plans of many international airports. This is especially important as the pandemic seems to persist and COVID19 mutations - such as the Delta one –, can appear at any time.

Those innovations rely on automation, communication and use of advanced features such as geolocation, biometrics, IoT sensors, analytics, AI etc. Furthermore those innovations must be able to provide results in real time to and from large numbers of passengers – even in the order of tens of thousands per hour for mega airports – in an efficient, reliable, secure and timely manner. 5G mobile networks provide exactly this communication framework and infrastructure that is required for these new solutions to work. eMBB, URLLC and mMTC standards provide those capabilities that will enable the above-described solutions to be deployed and utilize their capabilities to the maximum.

Another form of value creation of 5G networks is directly related with monetization by finding smart ways to increase the propensity of passengers to make a purchase at the airport. Customer experience is crucial since the best way to increase non-aeronautical revenues is to increase customer satisfaction. Indeed, according to a study by the Airport Council International (ACI), a rise of 1% in global passenger satisfaction can generate, on average, 1.5% growth in non-aeronautical revenue. Customer experience is a holistic concept that, given increasing numbers of millennial passengers, requires more digital engagement. Therefore, airports must be able to provide a digitally enabled and hyper-connected airport environment that satisfies the passengers who are used advanced digital services.

This is where 5G can be a game changer for airports, triggering a new wave of digitization and innovation in customer experiences while limiting the operational impacts of COVID-19 measures.

3.2 Benefits summary – airport setting

It could be argued that there are potentially multiple benefactors of each UC. However, we assume that as the main beneficiary and the prime stakeholder[5] it is the airport authority, in this case AIA (Athens International Airport), which is in keeping with the overall aim of taking the perspective of a demand side investment decision.

WP2 has calculated the economic benefits for each UC individually but also as a whole, assessing their combined ability to improve the competitiveness of Athens Airport and increase market share. The result is a range of potential benefits as illustrated in Figure 23.

The approach looking at market share is intended to capture the entire value of improved efficiency and additional revenue streams from the UCs rather than trying to identify and quantify specific direct benefits. The more granular approach of assessing each UC separately may therefore be considered as the more conservative approach and likely to be used as the basis of any investment decision. In WP8 we therefore consider the business case for investing in 5G infrastructure to support each UC separately.

[5] The airport authority may be considered a landlord if they own the airfield outright or as a prime tenant if the land or assets are leased. In either case they, or their backers, are likely to be the responsible party for sanctioning telecommunications infrastructure investments of this type.

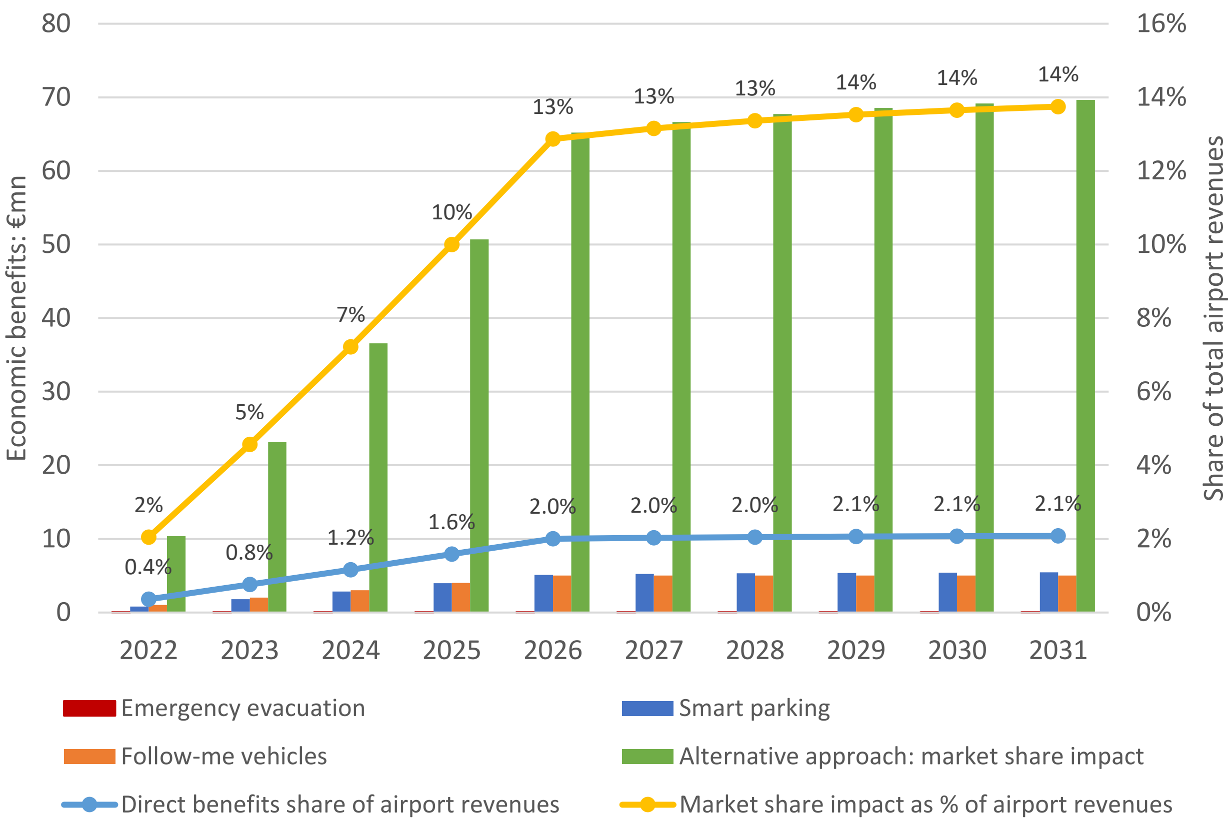

Figure 23. Economic benefits for airport UCs, Athens International Airport (D2.3 5.-T. , 2021).

Social benefits may also be a factor in securing financial support such as government funding where they are deemed worthy of it. This tends to play a role where a clear commercial case for investment is not apparent. Table 2 lists the annualised social benefits developed in WP2, which largely derive from time savings to passengers in the case of smart parking and to the airlines in the case of video enhanced follow-me vehicles.

Table 2. Social benefits from airport UCs (€ millions) (D2.3 5.-T. , 2021)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Time savings for smart parking users	0.6	1.3	2.0	2.9	3.7	3.9	4.0	4.1	4.3	4.4
Reduced costs of delays for airlines	1.5	3.1	4.6	6.2	7.7	7.7	7.7	7.7	7.7	7.7
Total social benefits	**2.1**	**4.4**	**6.7**	**9.0**	**11.4**	**11.6**	**11.7**	**11.8**	**12.0**	**12.1**

3.3 Airport setting solution architecture, business model and cost analysis

In the airport setting, it is assumed that there is a core requirement to support *public* mobile 5G services. In a large indoor setting with such a high density of subscribers, the most efficient means of providing the necessary coverage, capacity and QoE demanded by public CSPs is via an active DAS (Distributed Antenna System)[6].

[6] Active in the sense that key elements of the solution are powered and require a dedicated power supply outlet, which must therefore be provisioned throughout the coverage area.

A conventional macro tower covers a specific area from a central location, using high RF power and a number of directional antennas to create an extended coverage footprint. A DAS on the other hand uses a larger number of smaller antennas, transmitting at low power with a small coverage footprint, but distributed across the area to create a contiguous area of service.

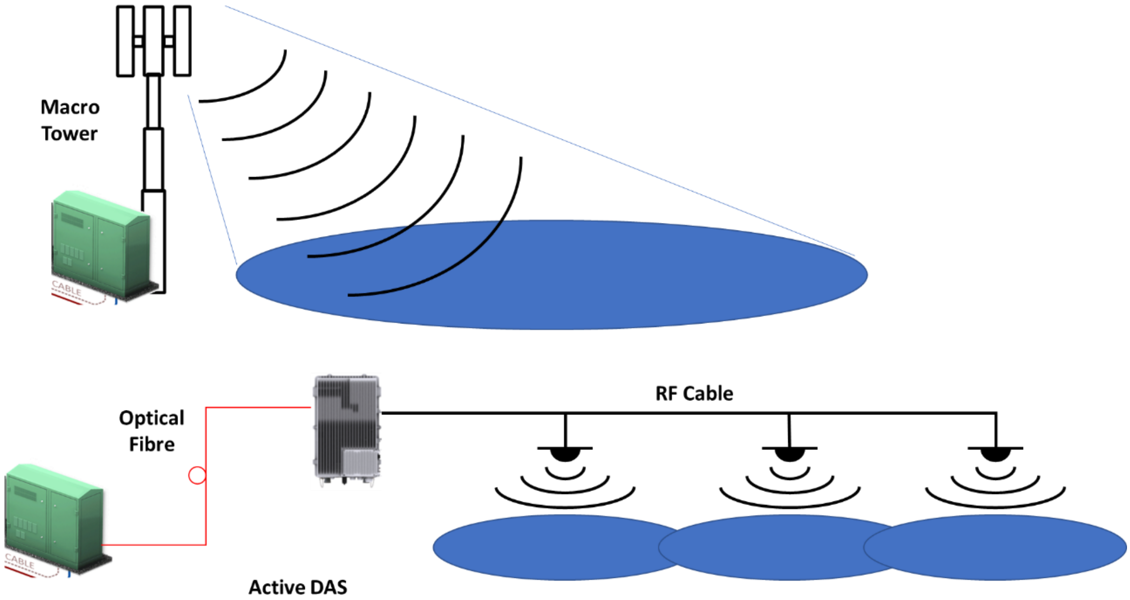

Figure 24. Macrocell vs DAS coverage.

The main advantage of DAS is that the antennas can be positioned close to where the devices are located. Inside buildings, they can be in the same room therefore signals are not attenuated by walls or windows, which can be very lossy and degrade the signal quality. The downside is they require additional hardware and extensive cabling, which drives up materials and installation costs. DAS can support multiple CSPs and multiple technologies but at greater expense.

Under a Neutral Host model, the DAS is typically designed, installed, and commissioned by the Neutral Host Provider. They procure the necessary equipment and materials from suppliers and engage with CSPs to negotiate their connection to the system. In simple terms, a DAS is a transparent conduit for mobile signals therefore CSP’s are required to provide base station equipment, which plugs into the DAS and transmits/receives over their licenced spectrum bands.

There are many different financial models emerging. Traditionally the landlord or tenant would pay the Neutral Host Provider to come and install the system. The landlord could then recover their costs by charging CSPs to connect to the system plus an annual rental fee. Additional revenues may be obtained from tenants or other stakeholders that require access to the system. This model works where there is a strong business case for the CSPs to connect, such as an airport with a large passenger footfall. For other types of venues and industries, where the business case is less attractive to CSPs, the landlord may be expected to cover the costs of CSPs joining the system in addition to the cost of the DAS. Businesses for whom connectivity is vital for operations or who’s customers value connectivity e.g. hotels and multi-tennant office buildings may be willing to pay these costs to remain competitive. More recently, Neutral Host providers have started to assume the role of intermediary, by funding the initial deployment (wholly, or in-part) and recovering their costs by charging landlords and tenants an annual fee under an infrastructure-as-a-service type-model.

Historically, getting the buy-in of one or more CSPs was critical to having a successful DAS deployment as they own the rights to the spectrum. However, more recently, the availability of spectrum for private mobile solutions means that enterprises or NH on their behalf, can deploy their own systems for wireless connectivity, but must pay for the spectrum and the additional radio equipment This could be important to stakeholders if they have particularly sensitive or critical applications that can be separated from public networks for strategic reasons, although they can still benefit from economies of scale by leveraging passive elements of the infrastructure.

CSPs are mainly interested in targeting public coverage as part of their core strategy[7]. They may expect any additional cost, for equipment or infrastructure, required to provide non-public services to be reimbursed. In WP8 airport setting, we have assumed that the airport already has a Neutral Host DAS, which adequately delivers 2G, 3G and 4G services to all of the key public areas. The CSPs want to upgrade the system to 5G and will cover the cost to do so but only to those areas already provisioned by the existing infrastructure.

3.3.1 Key Assumptions & Methodology

In our calculation of costs, we consider that the airport wishes to leverage the planned 5G upgrade to the existing *public* infrastructure in order to support the highlighted UCs. They are able to share common elements of the solution and are assumed to use the same suppliers and sub-contractors. The costs have therefore been derived marginally, that is to say we calculate the cost of providing the *additional* infrastructure required to support each UC. Such an approach makes a direct comparison with the expected benefits more meaningful and representative.

The baseline service is assumed to be the provision of 5G enhanced mobile broadband (eMBB) into all public areas of the airport terminals and piers. To reduce complexity, we consider each UC in turn with the following assumptions:

- **UC10 - Smart airport parking management:** The solution will provide additional coverage and capacity to the external car parks to support a single operator[8] providing a smart parking service only.
- **UC11 - Video-enhanced ground-based moving vehicles:** The solution will provide additional coverage and capacity to the external apron to support a single operator[8] providing a high-quality video service to operational vehicles.
- **UC12 - Emergency Evacuation:** The solution will target the existing coverage areas with the intention to improve the quality (reliability, availability) across the existing coverage footprint for all operators. Additional capacity may be required to support the evacuation service, but the expectation is that in such a scenario some of the planned public eMBB capacity can be repurposed in the event of an emergency.

The evaluation of cost aims to capture the total cost of ownership (TCO) to 2031 in line with the benefits reporting. Costs comprise CAPEX items such as: solution design; equipment room fit-out; DAS equipment; fibre radiating infrastructure (RF cabling & antennas); BTS equipment; installation and commissioning[9]. OPEX items include the cost of power; transmission, management, monitoring and reporting; maintenance and annual inspections.

It is assumed that all scenarios modelled are independent of any prior infrastructure that has been installed to deliver legacy mobile systems i.e. 2G, 3G, 4G, however it is assumed that there is suitable space available to house the new equipment.

Synthesis of the above scenarios within the Real Wireless suite of tools is ongoing. The basis for the airport evaluation case is Athens airport for which a generalized model has been developed using the indoor modelling tool. Efforts to-date have concentrated on developing Baseline costs for the public 5G upgrade within the terminal buildings and for the cost to implement UC10 & UC11. UC12 is yet to be implemented.

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[7] . CSPs will support their large corporate customers by providing equipment and resources to improve the delivery of mobile services into their premises, but they tend to do so unilaterally and sparingly.

[8] This can be either a public CSP who would be engaged and remunerated to provide the service or deployed as a private network for the airport or NH to manage.

[9] The scenarios assume that the cost of spectrum will be met by the CSP.

3.3.2 Results

Results have been developed for 3 scenarios that are intended to demonstrate the economies of scale in deploying infrastructure solutions that are able to address the requirements of multiple UCs and applications compared with a more piecemeal approach.

- **Scenario 1:** Implementation of each UC as a separate standalone solution.
- **Scenario 2:** UC10 & UC11are supported by a combined solution. Public 5G is separate.
- **Scenario 3:** All UCs addressed by a single solution

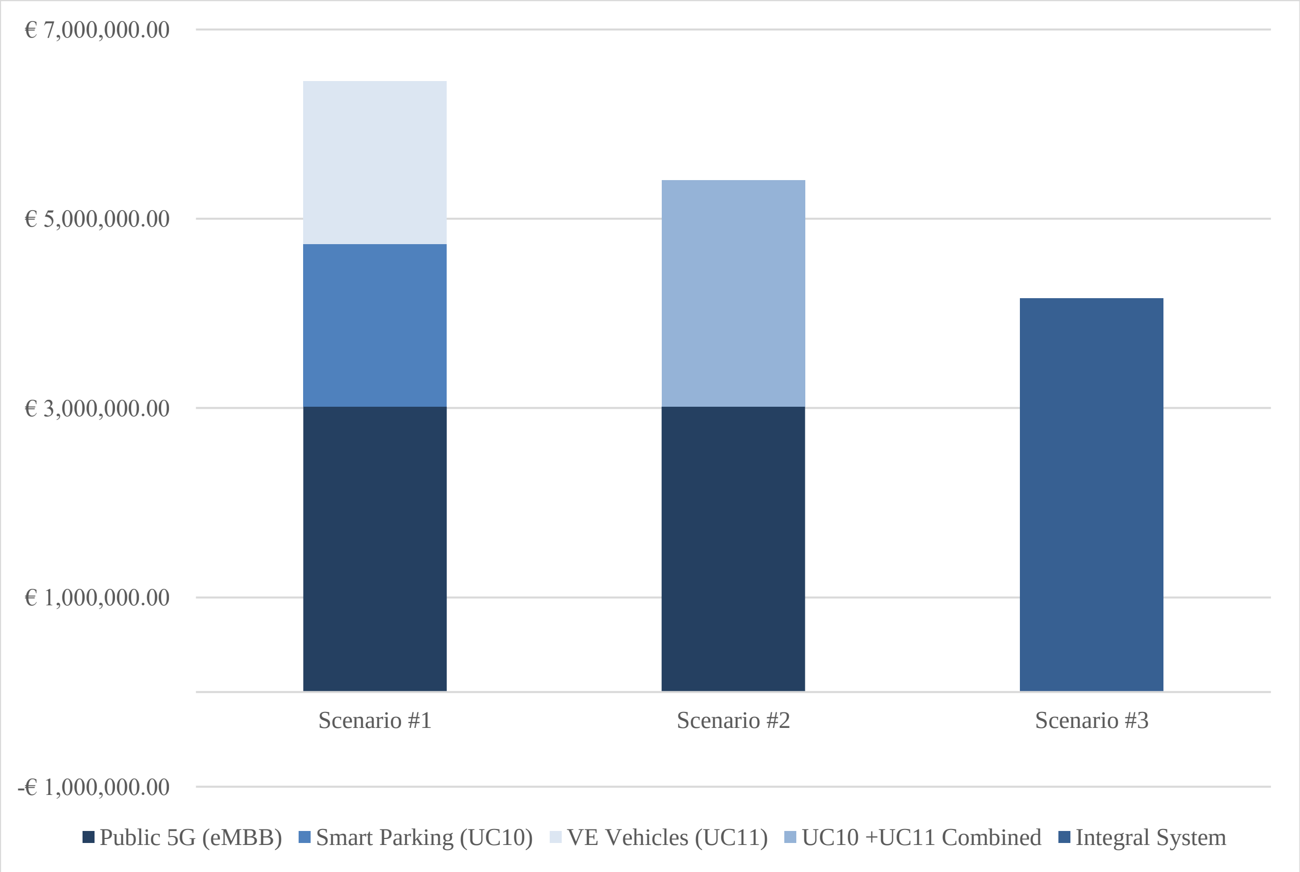

Figure 25. Airport DAS Deployment Costs.

The total cost of ownership for each of the scenarios is presented in Figure 23 for the period 2021-2031, which includes an estimate of the upgrade costs after 5 years to cater for the growth in demand for 5G services. Data is also presented in Figure 25 to illustrate the additional cost to support UC10 and UC11 over the baseline TCO in each case.

Over the same period Work Package 2 found the aggregate direct benefit of UC10 and UC11 to be €81.7m with a combined social benefit of €92.8m. The net benefit of implementing 5G is therefore very significant irrespective of the specific deployment scenario, however, it is important to recognize that there are many more stakeholders whose requirements and UCs could be supported on the same infrastructure but who may be more reliant on such economies of scale to deliver a viable cost-benefit quotient.

As modelled, the unified approach of scenario 3 represents a 35% cost saving over the discrete implementation of scenario 1. Whilst the potential for cost savings may seem obvious from the perspective of a single stakeholder, the airport authority in this case, it stands to reason that greater economies of scale and greater overall benefit would be realized by capturing the 5G connectivity requirements of many more stakeholders such as airlines, emergency services, aircraft manufacturers, public transport, car rental firms etc.

The cost model has been validated against the cost to deploy similar systems in other airports, for which Real Wireless has several data points. In the next period we will develop the model further to consider UC12 and to estimate the cost of additional infrastructure, which will support a greater number of services in the same coverage areas as UC10 and UC11. This will reflect the impact of catering for the requirements of more stakeholders.

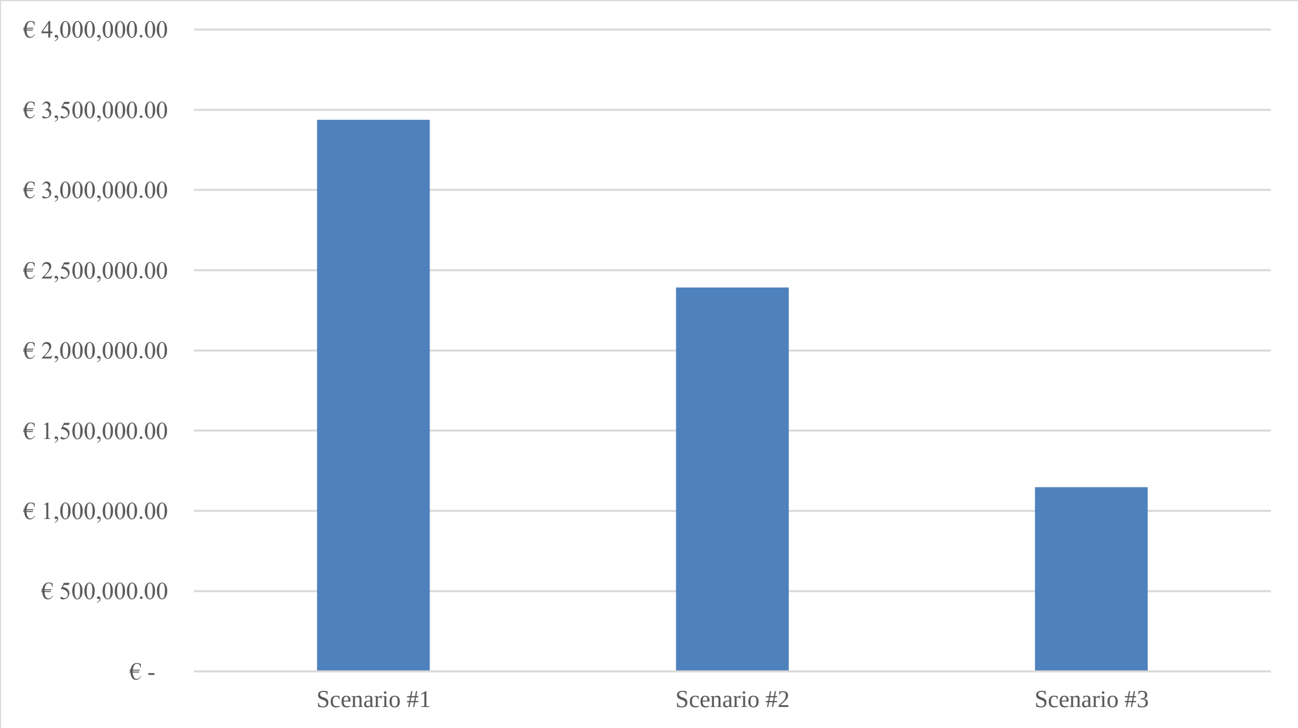

Figure 26. Athens Airport DAS Deployment Costs (Public Mobile Service).

In addition to the cost-benefit analysis, two contrasting case studies have been developed to illustrate the potential for 5G to unlock greater value in both the demand and supply side ecosystem. They provide a more qualitative view of the wider market potential for the solutions being showcased at the Athens Airport testbed, which will be validated during the planned workshop.

3.4 Airport Case Study 1: Smart airport parking management (UC10)

3.4.1 Analysis of market context / Market needs

The global smart parking market was valued at $6.05 billion in 2019, and is projected to reach $11.13 billion by 2027, registering a CAGR of 12.6% (Research, 2020). Increase in parking concerns across the globe, growth in demand for IoT based technology, and high adoption rate in number of vehicles drive the demand for the global smart parking market. However, high employment cost & configuration complexity and low rate of internet penetration in developing regions restrain the market growth. Moreover, rise in investment on building driverless vehicles and increase in government's initiative in building smart cities across the globe are expected to create tremendous opportunities for the growth of the market.

However, the COVID-19 pandemic has significantly affected parking facilities worldwide due to quarantine and work from home national policies that eventually resulted to closures of parking facilities. The same applies to airports, where parking is one of the largest revenue sources, which were forced to shut down many services due to travel restrictions that severely reduced the revenues generated by their parking facilities. This also affected construction works for new facilities that we put into halt or were shut down due to budget limitations.

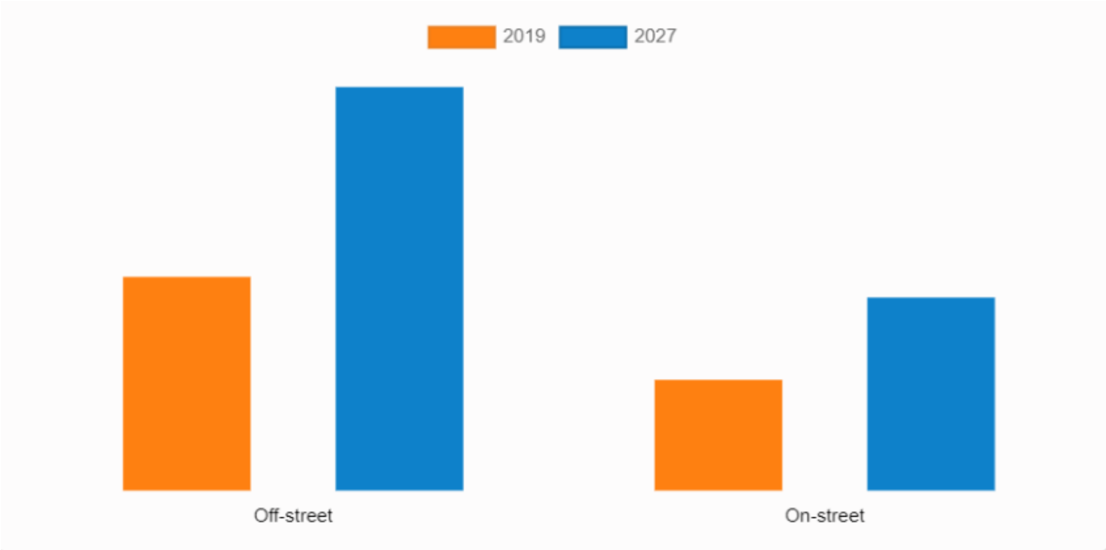

Figure 27. Smart Parking market by type. Off-street parking is projected as the most lucrative segment (Allied Market Research, 2020).

On the other hand, we are currently evolving to the "new normal" as they call it, where more and more people prefer using their cars instead of public transport in their everyday lives. Thus, the need for smart parking systems is justified as 60% of emissions and air pollutants come from cars while 50% of road traffic is due to drivers looking for a parking space, and an average driver spends 54 hours per year in traffic jams.

WINGSPARK is a smart parking solution developed by WINGS ICT Solutions, through which the following can be achieved:

- 30% reduction in the distance a driver travels looking for a parking spot.
- 40% reduction in the time it takes for a driver to park in a parking spot.
- 10% reduction in traffic in urban areas.
- 40% reduction of pollutants and exhaust gases.

3.4.2 Service description / Purpose of the service

WINGSPARK aims at reducing unnecessary driving, since with its advanced forecasting algorithms there will be safe predictions about whether or not there is a free parking space in the area of interest. This will consequently also contribute to emission reduction, which is a great environmental benefit. Furthermore, WINGSPARK will help in reducing the time spent looking for parking places in the area of interest. This will be feasible as drivers will be directed to areas with free parking spot and will not need to roam randomly looking for possibly available spot, spending time and gas money. It is composed of a parking occupancy sensor, a user-friendly Dashboard where all live measurements and historical data are depicted, a suite of AI and predictive analytics algorithms, based on which prediction of the possibility the driver to find an available parking spot as well as optimised routing to the spot is provided, and a mobile application for the drivers which depicts the aforementioned information.

To sum up, WINGS's Smart parking product added value is:

- **Optimized parking** – Users find the best spot available, saving time, resources, and effort. The parking lot fills up efficiently and space can be utilized properly by commercial and corporate entities.
- **Enhanced User Experience** – A smart parking solution will integrate the entire user experience into a unified action. Driver's routing, spot identification, location search, and time notifications all seamlessly become part of the destination arrival process.
- **Reduced traffic** – Traffic flow decreases as fewer cars are required to drive around in search of a free parking space.

- **Reduced pollution** –An optimal parking solution will significantly decrease driving time, thus lowering the amount of daily vehicle emissions and ultimately reducing the global environmental footprint.

The proposed solution also aims at the easy monitoring and management of the parking space in real time, but also the possibility of maximizing its use, through the exploitation of the data coming from smart parking sensors. The management software and the utilization of the data collected from the individual systems that make up the proposed solution, make it possible to offer value-added services for facility managers and for the benefit of the end users (drivers) utilizing the possibilities offered by the Internet of Things and AI. Therefore, there are 2 categories of users who can benefit from the WINGSPARK solution: drivers and the parking facility management staff.

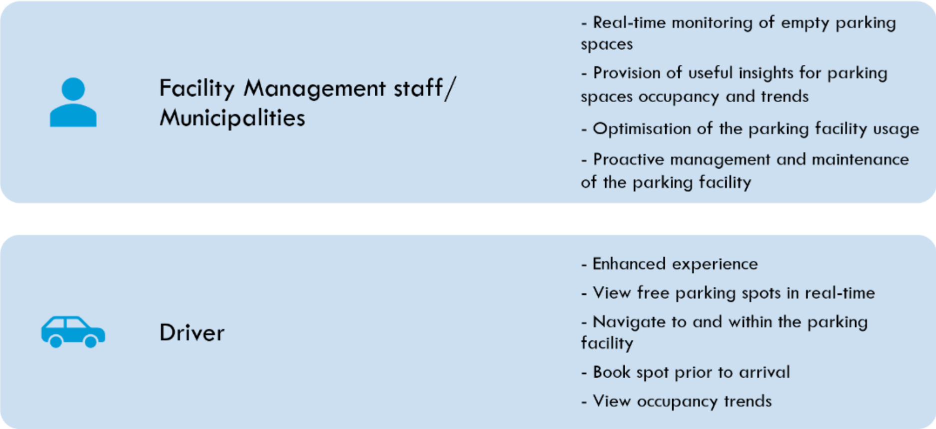

Figure 28. WINGSPARK addressing the user needs.

WINGSPARK comprises of:

- Parking Occupancy Sensors, for vehicle detection
- Intelligence, for
  - forecasting parking availability at a dedicated time
  - calculation of the available parking slot according to the criteria specified by the user
  - optimal routing of the user to the spot
- A Mobile application for the drivers (different for on-street and off-street scenarios) and a web-based dashboard for the parking facility management staff.

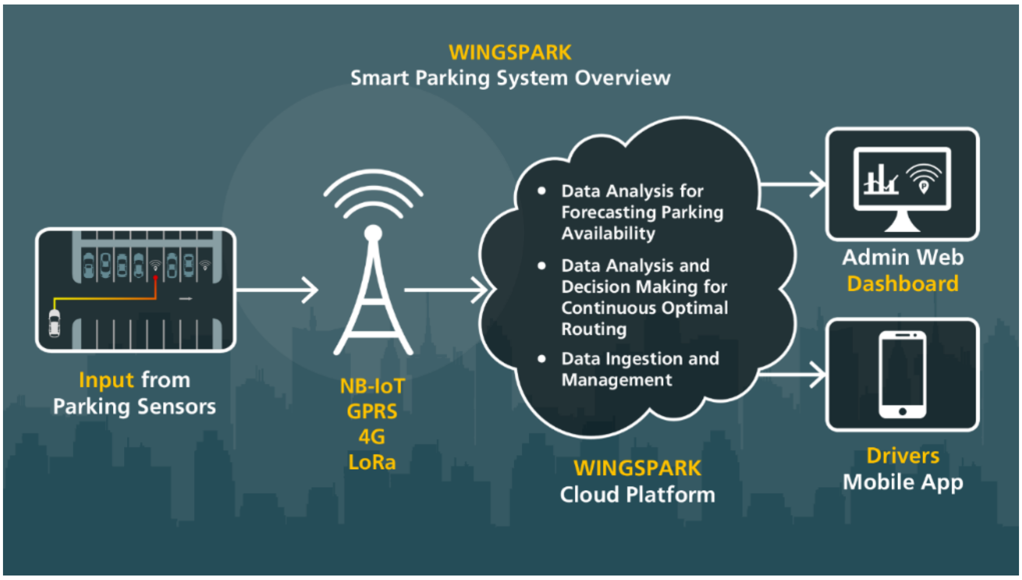

Figure 29. WINGSPARK overview.

3.4.3 Potential customers and value chain actors

Parking facilities in public and private sector as well as municipalities will be the potential customers who will pay for the "Smart Parking Management" system.

This kind of services may open new opportunities for stakeholders of the healthcare sector value chain. There are several of actors influenced by the "remote health monitoring and emergency situation notification":

- **Parking facility management staff:** Parking facility management staff both in private and public facilities who have direct contact with the system interface through which they can a) have a real time picture of the vacancies and occupied positions b) have a real time picture of the positions that are occupied without the expected fee being paid c) have a single payment management infrastructure. The service aims to assist the parking facilities to optimize the management and monitoring of the facility.
- **Municipal staff:** Municipal staff who have direct contact with the system interface through which they can: a) have a real time picture of the vacancies and occupied positions b) have a real time picture of the positions that are occupied without the expected fee being paid c) have a single payment management infrastructure.
- **Drivers/Visitors/Citizens/ People with disabilities:** The actors interact with mobile application for the drivers, through which they can: a) locate the vacancies in the roads of interest b) be guided through the optimal route to the nearest vacant position of their interest c) pay through the driver's application the fees for the time period that his car will be parked d) to plan his travel based on targeted forecasts for finding empty parking spaces.
- **Network Provider:** The actor that provides the network/communications infrastructure.
- **Platform Provider:** The actor that provide the required infrastructure/platform components to support the solution (cloud platform, devices, analytics, etc.).

3.4.4 WINGS business model and Go-to-market strategy

The smart parking solution will be offered to parking facilities both in the public and private sectors, and municipalities will also be reached as potential clients as well to integrate WINGS solutions.

The proposed system promises an enhanced drivers experience, though a) visualisation of the parking spots based on category (e.g., spots for disabled people) and status (free / occupied), b) interactive maps, c) identification of occupancy patterns based on predictive analytics, d) optimal routing to the selected spot/block, e) intuitive guidance to the closest available spot, f) drivers reporting on parking events, payments, g) account, vehicle, favourite spots management, h) driver authorisation and i) support for payments. The drivers application is available for Android and iOS systems.

The proposed system promises to support municipalities and parking facilities through: a) the provision of parking spaces availability in real-time; b) predictions of occupancy trends in the area of interest in a selected time slot; c) useful insights for parking spaces occupancy and trends based on predictive analytics on daily, weekly and monthly basis which will lead in optimized usage and savings; d) the definition and monitoring of different zones within the parking, with different time-based rules to support various policies; e) events detection in real-time, regarding overtime parking, violations, sensors events, and warnings and f) remote operation of hardware components.

The system's innovations will be highlighted through the a) active performance measurement while the service is running; b) resource allocation, deployment, and migration of Network Services in an automatic and optimized way using various metrics (infrastructure, VNFs, Applications, etc.) and verticals' requirements; c) correlation of user QoE with Active Service KPIs to identify relation between network performance, Quantitative Service KPIs and QoE.

WINGS plans to exploit the outcomes of the project, towards enhancing the company's software solutions, but also other solutions in different vertical domains, so as to extend the supported set of connectivity options and to be able to offer the platforms services over a wide area connectivity offering, with certain quality guarantees. The solution, as such, will be included in the WINGS portfolio of products, and will provide WINGS with new business opportunities. Through 5G technologies and the innovation developed in the context of 5G-TOURS, WINGS is enabled in maturing its products and consequently expanding its portfolio and becoming more efficient in its offerings. In the Smart airport parking management UC WINGS aims at extending its WINGSPARK platform in order to monitor in real-time the parking facility at Athens International Airport by leveraging on its 5G-enabled Smart Parking Occupancy sensors. WINGS also provides a mobile app utilizing 3D graphics, that will assist the users in finding and navigating in the spot leveraging on AI. The smart parking management contributes to the emission reduction by reducing unnecessary driving to locate a parking space. This process will also add to the travelling efficiency of tourists through targeted parking spot suggestions. This is a solution that relies on the mMTC capabilities provided by 5G. The WINGSPARK solution will be offered as platform as a Service (PaaS), and a penetration pricing will be followed for the solutions, the price of which is set artificially low to gain market share quickly. The prices will be potentially raised once the promotion period is over and market share objectives are achieved.

The go-to-market strategy for WINGS solutions is split in three different phases:

Phase 1 "Promotion and Awareness": Normally, the first three months after the end of the project will mainly focus on promoting the results of the project and its solution performance/innovation comparing to currently existing solutions to parking facilities and municipalities, and other potential stakeholders/customers (e.g. companies looking to optimise their employee parking). This will allow WINGS to attract stakeholders' interest and possible customers. Promotion and awareness activities will take place before the end of the 5G-TOURS project.

Phase 2 "Pre-sales: Customized solutions and pilots": The customers attracted during the "Promotion and Awareness" phase may be interested either in the exact solutions that were designed and tested during the lifetime of 5G-TOURS project or to similar solutions that need to be adjusted to their needs. This phase involves all those actions that will allow the customization of the solutions to the customers' needs. These may include but are not limited to:

- Identification of new requirements.
- Adjustment of monitoring, predictive mechanisms.
- Testing and validation in a lab environment.
- Pilots of the designed mechanisms on their real environment and real users (e.g. parking facilities, municipalities, and respective drivers, etc.).

Phase 3 "Sales": This phase refers to the selling of the mechanisms and the services derived both from the 5G-TOURS and the Phase 2 to specific customers based on principles for licensing, business models, pricing, and distribution briefly presented above and further enhanced after the first launch of the WINGSPARK solution.

Communication channels with broad reach (e.g., social media, project's website, newsletters) but also workshops, webinars, conferences, and other campaigns already have (during the lifetime of the project) and will be taken into consideration for the promoting activities. Social media accounts for promoting WINGS solution and its functionalities, enabling stakeholders and end-users to interact, share their opinion, their concerns and their quality of experience, view news and announcements and pose questions to the project team.

Towards the above, WINGS has already started to pursue valuable synergies with vendors, Telecom Operators and OEMs, so as to set up a collaborative infrastructure that will enable the delivery of the previously described advanced services. With respect to WINGSPARK platform, WINGS has already deployed 50 sensors in the Athens International airport. WINGS has also collaborated further with OTE and has achieved the deployment of WINGSPARK cloud platform and its 5G-enabled Smart Parking Occupancy sensors in OTE parking at Psalidi and at Ilissos building, in Athens. Furthermore, WINGS has already achieved the commercial exploitation of the platform via a commercial smart parking project at Central Greece.

3.5 Airport Case Study 2: Network Performance Management

3.5.1 Market Requirement

If 5G is widely adopted by industry verticals and their stakeholders, then it is increasingly likely to underpin many functions that are critical to the success of the enterprise, by way of either operational excellence or customer satisfaction. For that to happen the enterprise requires a high level of trust in the ability of the technology to deliver as expected. That trust must also extend to the supply side ecosystem who need to be prepared to focus on the vertical and understand the key challenges and opportunities in detail; to collaborate with stakeholders and create joint approaches towards a set of common goals; to be prepared to cultivate relationships for long-term value and not short-term gain; and finally, to cultivate a culture of transparency in all their dealings with each other.

Performance has to be measurable to be fully understood. Therefore the role of technical solutions in the measurement of 5G network performance are key to cultivating the high levels of trust we aspire to. This is particularly important for UCs such as airport emergency evacuation (UC12), where the network needs to be in a state of readiness to cope with rare events. The airport operator needs to have high confidence, in advance of such events, that the network will perform when called upon. In a safety of life situation, it cannot be left until after the event to decide whether the network performance is fit for purpose or whether improvement is necessary. Therefore, it is important to have state-of-the-art performance monitoring solutions and for the data to be comprehensible and accessible for all key stakeholders and authorities.

3.5.2 Business proposal to 5G network implementers and customers

Target customers, for a *network performance monitoring solution*, are MNOs, network equipment providers, and verticals. Global Enterprises can also use such tools to monitor the performance of their network as being deployed and operated in different countries and by different network operators.

Such a solution provides information on the performance achieved while the service is being offered. The results can be compared to the targeted or anticipated performance metrics. Weak points or network segments of less than expected performance can be detected and diagnosed to identify an acceptable resolution. Diagnosis can be applied to a variety of critical network elements, i.e. the RF part, the L3 IP implementation and routing, the physical and virtual/logical paths.

In the context of the Athens airport setting the network performance monitoring solution has been implemented across all UC's as illustrated in Figure 30, showcasing the versatility and applicability to meet industry specific performance criteria.

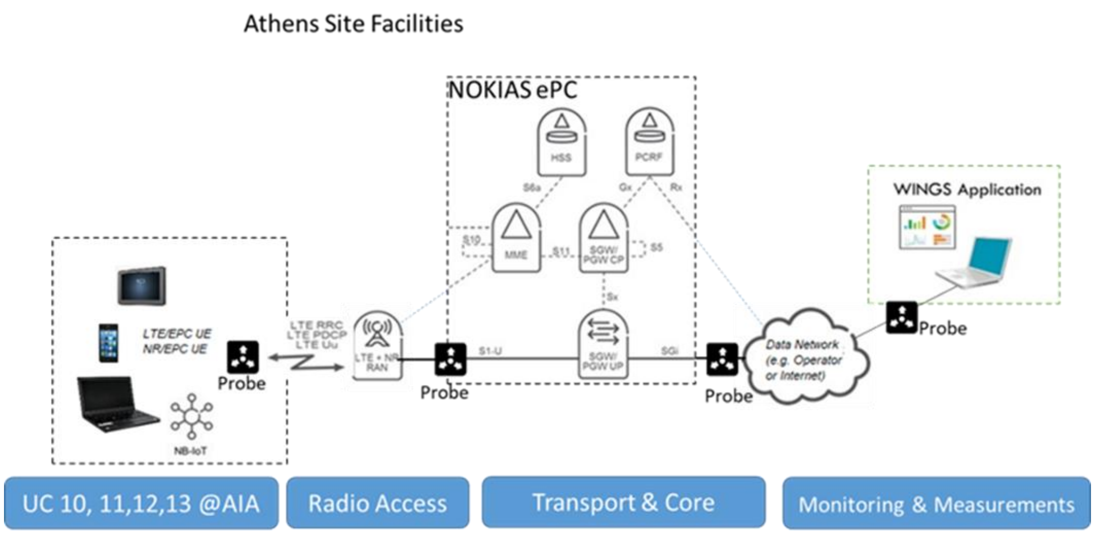

Figure 30. Network performance implementation.

Key activities for promoting such solutions is to present the results achieved in the 5G-TOURS project that indicate the value added from a 5G network. Channels to reach out to the customer segments of the solution are the typical contact teams, workshops, proof of concept, 5G and SME Industry Associations and conferences.

The developed and suggested solution can be operator driven, in the case where the MNO has such a system and utilises it to support customer services. It can also be network operator enabled, in the case where the MNO cooperates with a system integrator. Finally, it can even be a non-operator solution, where the vertical can decide to have such an implementation e.g., in a private 5G network. An Enterprise can also choose to use such solution in order to monitor SLA agreements. The solution can be provided by a “telecom operator supporting company on network performance issues”.

Features of such a solution are to monitor identified network key performance indicators (KPI’s) during the setup of the network, or during operation. The advantages of using a 5G network are to achieve very low latency, high bandwidth, and reliability, i.e. much higher performance of the network compared to previous mobile technology generations. Often such KPI’s will form part of the contractual agreement to supply 5G products and services, therefore it is important to be able to demonstrate to enterprise customers that their operational systems and applications are supported by infrastructure that is capable of fulfilling the business and operational requirements of the vertical.

Figure 31. Indicative monitored network KPIs.

The end user can have cockpit views available, tailored to their requirements, for monitoring network or service performance from their Operations Centre, similar to Figure 32 below.

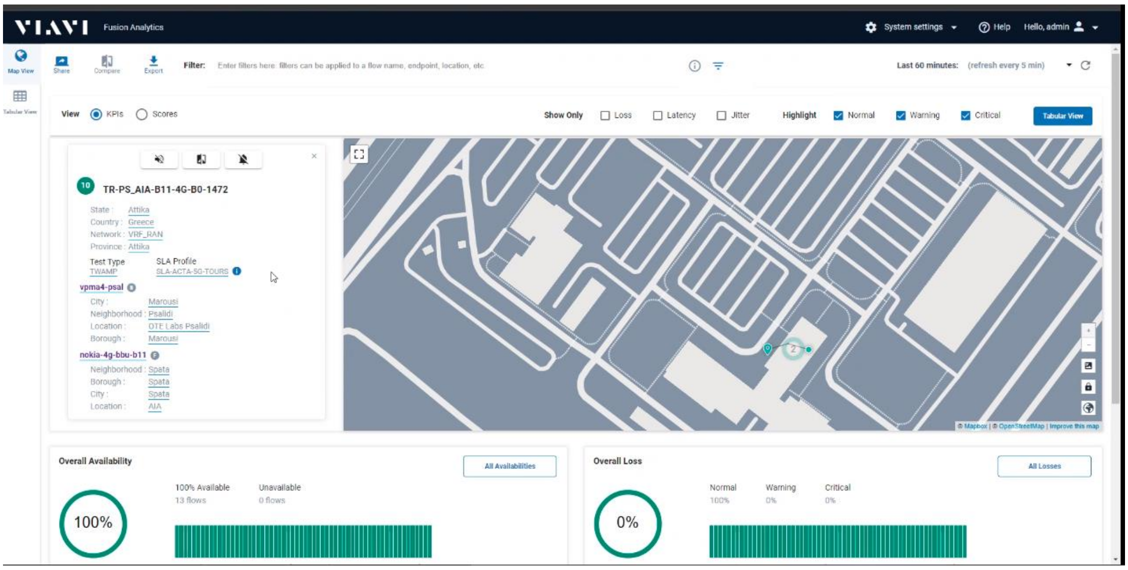

Figure 32. User view of network performance scores.

3.5.3 Commercialization of the developments achieved during the project

The cost of a *network performance monitoring solution* can be provided as on a standalone basis or can be modular, with some parts offered in the form of a SaaS.

The required components are:

- Hardware or software probes.
- A central application gathering.
- Analyzing and presenting the performance metrics gathered from the network.
- A speed-test application, within the network, provides information of the expected (during the deployment) and the actual user experience (during the operation).
- The synchronization of the network components is essential for precise correlation of the raw data.
- Finally, RF measurement equipment are supportive to precisely identify the strength of the RF signal in the coverage area and the areas of interest (where the service is being deployed).

Costs of operating the network performance SaaS are more than offset by savings from faster response time to identify and resolve data network bottlenecks, and eventually revenue safeguarding and customer satisfaction and loyalty.

5G deployments into industry verticals are at the early stages therefore such savings remain qualitative. Over time it will be possible to quantify the added value of network performance measurement solutions like this in terms of ensuring that the QoE is preserved by maintaining network reliability and availability. Moreover, as demand increases it puts greater pressure on network resources and one of the main benefits of this solution is to have visibility of performance impacts before they become problematic. By analysing historical data and identifying key trends upgrades can be rolled out seamlessly and in a timely manner so as to maintain those KPIs.

During the promotion of the solutions to customers, via the planned 5G-TOURS workshops, it is intended to collect feedback that will help to identify their willingness to invest in such solutions. The results from the project and the qualitative analysis of the benefits will be important to persuade customers and stakeholders that the network performance monitoring solutions contribute to ensuring the quality of service and quality of experience of their end customers.

4 Health Sector Business Models, Deployment and Operations

This chapter builds upon some of the concepts developed in chapter 2 and applies them in the context of the healthcare sectors. Options for the provision of 5G infrastructure are explored from the perspective of the 5G-TOURS UCs and evaluated in terms of architectural suitability and ease of deployment.

The benefits derived in WP2 corresponding to the health sector are examined in more detail and evaluated against estimates of 5G infrastructure costs to understand the net value potential of the UC's.

Two case studies are presented on smart ambulances and remote healthcare, which look at the 5G-TOURS innovations from the perspective of different providers within the 5G value chain and consider how they might be applied and add value to the wider healthcare community and to stakeholders across the value chain.

Work to develop the suite of tools required to model the cost structures of 5G deployment in healthcare is ongoing. Some preliminary cost estimates are provided for the support of smart ambulances however further development is needed to synthesise the wireless operating theatre UC as the solution architecture and hospital setting is quite distinct.

4.1 Innovations and Business Models

The healthcare sector is the focus of UCs 6, 7, 8 and 9 as introduced in D8.2. There are two distinct settings for the cost-benefit analysis, namely the Rennes Hospital testbed at CHU to support hospital-based functions and the wider city area, which deals with mobile, ambulance-based functions. UC 8 is centred on the CHU testbed and specifically, the setting of a wireless operating theatre, which is a highly controlled and complex environment. It was decided that the delivery of 5G into the hospital setting would be best served way of a private network and/or neutral host provider mainly due to the critical nature of the scenario. Safety of life issues require robust solutions and, in this case, dedicated in-building infrastructure was deemed necessary to support the technical requirements of the application.

In terms of the infrastructure required to support it, UC7 is distributed across two settings. Expertise is assumed to be based in the hospital but dispensed to the ambulance, which is out in the wider city environment. In a similar manner, elements of the Connected Ambulance UC (UC 9) have also been implemented at Rennes as part of the testbed. These address the provision of coverage and services to the external areas of the hospital and facilitate the coordination of ambulances at despatch and arrival.

The remaining UC6, and part of UC7 and UC9, concern the delivery of healthcare solutions over a wider area. These have been integrated into the Turin, city-scale test bed and are based on 5G services being delivered by an external macro network by way of CSP slicing. This can help ensure that resources can be prioritised for healthcare applications and affords greater control over capacity and quality of experience.

Note that UC6 and UC9 are grouped under health use cases but they have been implemented and deployed in Athens as a consequence of changes made to the programme as a result of the COVID pandemic. Nevertheless, cost modelling and business model assessment is being developed in the context of the city of Turin as it is complementary to the tourism sector analysis, which considers city wide 5G infrastructure. This approach streamlines the modelling effort and is entirely consistent with the benefits analysis developed in WP2 (D2.3 5. T., 2021).

4.1.1 Market position and Innovation Potential

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 UCs:

- 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.

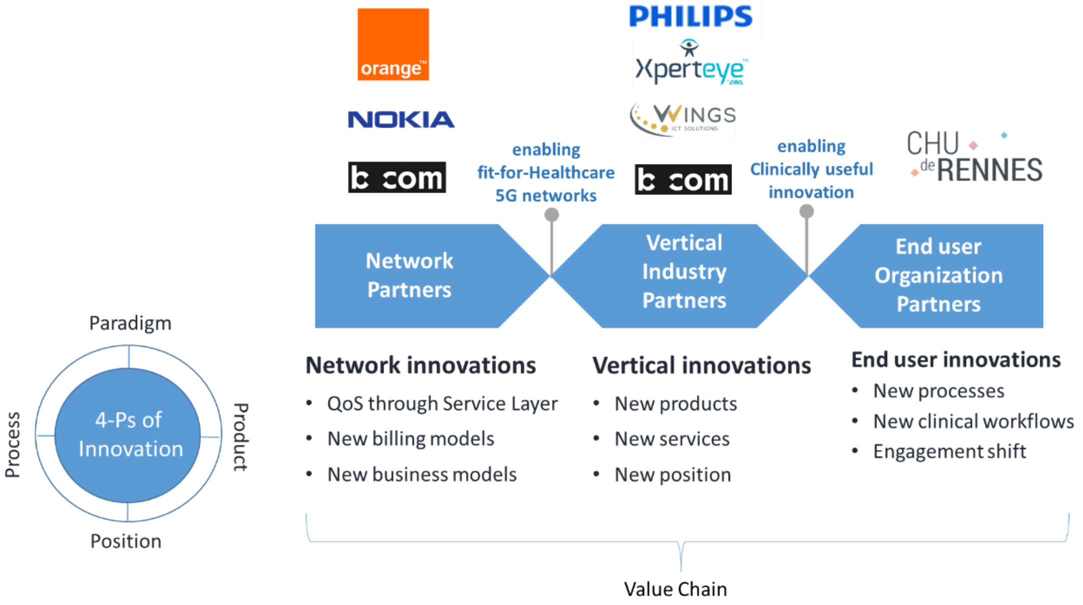

Figure 33. Healthcare innovation value chain in 5G-TOURS.

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 innovations is provided in Table 3.

Table 3. Benefits of health innovation in 5G-TOURS and enabling 5G features.

Innovation feature	**UC6 Patient Monitoring**	**UC7: Teleguided ultra-sound**	**UC8: Wireless OR**	**UC9 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.	Anywhere anytime best medical care Expert only contacted when needed	Reduction of wiring clutter Easier config and & prep of OR	Provide medical assistance ASAP Transfer patient to hospital ASAP

	Timely response possible	Less trained doctors can do exams	Better sterility, easier cleaning	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

4.2 Benefits Summary – Healthcare setting

As mentioned previously the healthcare UCs have been split across two environments, CHU at Rennes and the City of Turin. Work Package 2 has calculated the economic benefits for each setting as illustrated in Figure 34 and Figure 35.

Within the business model context, the benefits represent the value that 5G has the potential to create within the vertical and across the wider society. That value can be direct and easily realised by way of additional revenue or cost savings or it can be indirect such as improving social or environmental conditions or enabling broader economic value in other sectors or enterprises.

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

In the hospital setting, the sources of value that are considered to directly benefit the hospital are:

- Cost savings from reduced surgical complications (also promoting team well-being by expert back-up through telepresence)
- Cost savings from a reduction in 30-day emergency readmissions post-surgery
- Greater efficiency through faster operating theatre set-up
- Cost savings and improved training and education through telepresence.

Additionally, wider social benefits arise from the impact on patient quality of life. 5G enabled interventions can reduce the rate of surgical complications which in turn leads to a reduction in mortality and post-operative readmissions to hospital for further treatment.

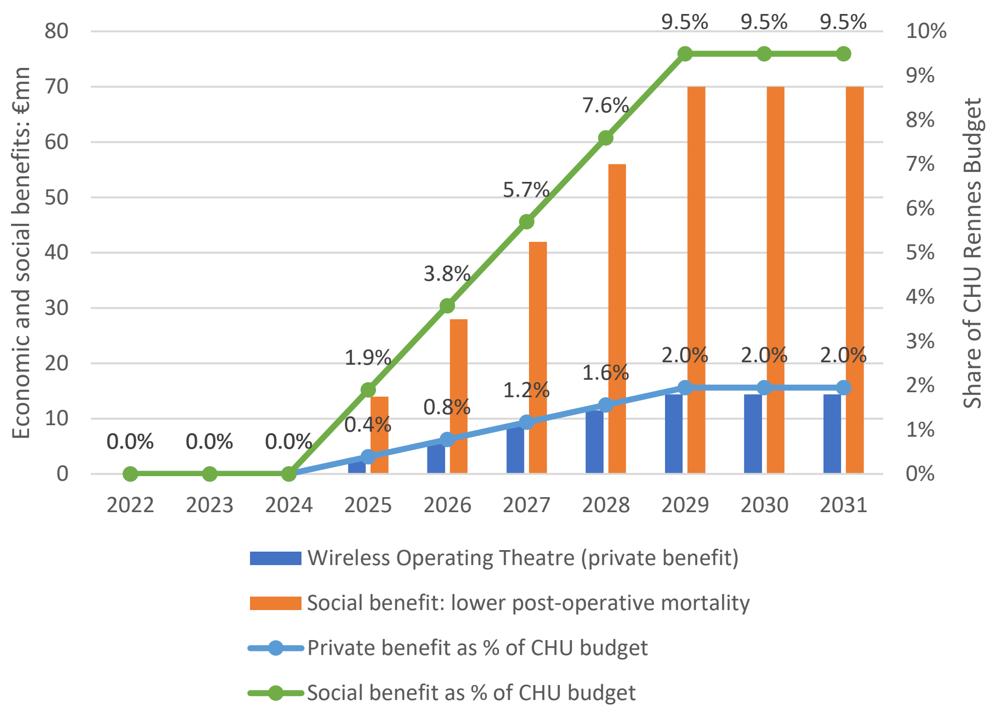

Figure 34. Socio-economic benefits for wireless operating theatre, CHU Rennes (D2.3 5.-T. , 2021).

Remote healthcare and smart ambulance are covered in evaluation cases 4 and 5, which look at healthcare in a city or nation rather than a hospital setting. The proposed benefits that directly accrue to the healthcare provider as a result of 5G enabled remote healthcare include:

- Reduced General Practitioner (GP) appointments resulting in more efficiently run clinics and better patient outcomes.
- Fewer missed appointments that otherwise impact productivity.
- Reduced outpatient appointments.
- Cost savings: delaying the average time of entering residential care.
- Greater efficiency and cost savings in home-based care settings.

Wider sources of value include the benefits to individuals who need fewer appointments in a clinical setting and therefore spend less time on average attending appointments.

The benefits that are adjudged to directly accrue to the healthcare provider as a result of 5G enabled smart ambulance services are

- Teleguidance for better patient assessment and initial treatment on arrival or in transit.
- Smart routeing for faster ambulance journeys.
- Better patient outcomes: reduction in subsequent re-admission for emergency patients.
- Cost savings/greater efficiency: reduced patient transfer times to hospital.

Social and environmental benefits are also evident in terms of better patient outcomes and reduction in mortality from better and faster treatment as well as savings in CO2 from reduced patient to hospital transport times.

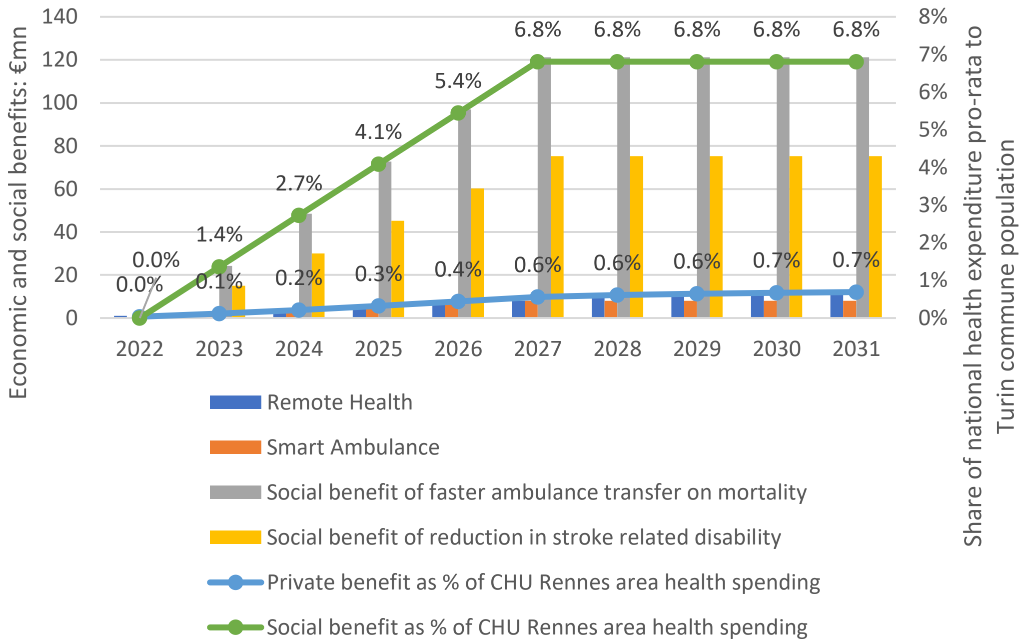

Figure 35. Socio-economic benefits for remote health and smart ambulance, Turin (D2.3 5.-T. , 2021).

Within the context of WP 8 and taking the perspective of demand side investment decisions within the healthcare sector, greater importance is placed on the direct, more tangible benefits. Where value resides outside the vertical, the challenge is to bring in other stakeholders who stand to gain, or their advocates, and find a way to work that ensures the maximum value is delivered across the board.

Discussions with such stakeholders are better justified where clear and transparent data exists to support the requirements and expectations of all concerned. By coming together to create a greater value pool, individual stakeholders can claim more absolute value for themselves and enable others to do likewise. A key step in understanding the practicality of liberating any intrinsic value in 5G UCs is to understand the cost and complexity of deploying the infrastructure to support it and is what has driven the development of the cost side of the 5G-TOURS 5G Enterprise Pathfinder Framework. The following section details the approach taken to develop the tools to support a better understanding of the feasibility of 5G value creation in the healthcare sector.

4.3 Healthcare setting solution architecture, business model and cost analysis

By the nature of the physical environment and the nature of the UCs, the two healthcare settings have very distinct solution architectures. Unlike the airport environment, where demand for public mobile services is expected by visitors and consequently drives the investment in mobile infrastructure, 5G infrastructure in the hospital environment is primarily driven by operational needs. There are similarities however, particularly in the case of the wireless operating theatre. Signal integrity is paramount and therefore an in-building solution is required that can deliver high quality of experience on all fronts (see 2.2.3).

A public mobile service requires the presence of all operators, which in the airport environment justifies the selection of a DAS system. However in the hospital operating theatre, the UC may be supported by a single CSP contracted to provide the service or it may be delivered using private 5G spectrum. It follows that in 5G-TOURS the solution under consideration is that of a small cell network, which is dedicated to the provision of 5G connectivity that enhances the effectiveness of the staff and resources. Small cells are similar to DAS systems in that they can be positioned close to where the devices are located and avoid signal impairment from passing through walls etc.

Small cell solutions can be more compact, cheaper, and easier to install than DAS systems, but they tend to have limited bandwidth capabilities and typically support only one or maximum two CSPs. Where more CSPs need to be present, then multiple small cells are required and this adds the cost and complexity of the system as well having a greater impact in terms of aesthetics, installation and maintenance.

However, small cell solutions can easily sit alongside DAS systems and benefit from shared elements such as equipment rooms and cable routes. If planned together, some of the design and installation costs can also be shared. In the next period we will further develop the Real Wireless in-building tool to enhance the small cell functionality and consider several deployment scenarios within CHU Rennes to understand the economies of scale in deploying public and private 5G within taking into account those additional elements to facilitate the smart operating theatre and connected ambulance UCs.

For the provision of wide area connectivity to support the other healthcare UCs, we have based our analysis on the delivery of 5G over a conventional macro network of towers, poles and rooftop sites. The roll-out of 5G networks requires operators to upgrade existing mobile base station sites and build new base stations. However, the current focus is on extending public coverage as cost-effectively and quickly as possible, within capital expenditure constraints. Hence the MNOs are currently investing in upgrading or creating new rooftop sites and 'streetworks' sites in urban areas such as those illustrated in the photos below.

Figure 36. Typical macro network infrastructure.

However, 5G, powered by network virtualisation and network slicing, gives mobile network operators unique opportunities to offer new services to enterprises and verticals to address their various KPIs.

This is the basis for the delivery of 5G services to support the wide area healthcare UCs such as smart ambulances and remote health monitoring. Section 5.6 looks at the city scale implementation of macro networks to support a range of UCs using the Real Wireless toolkit. However, work is ongoing to fully develop the range of scenarios required to understand the supplementary costs to provide additional infrastructure that is needed to support the healthcare UCs.

Smart ambulances and remote health monitoring are the subject of 2 case studies that have been developed to showcase the potential for 5G to create value in the healthcare sector. They provide a more qualitative view of the market potential for the technologies being showcased at Turin, which will be validated using the model.

4.4 Healthcare Case Study 1: Impact of smart ambulance on 5G dimensioning and deployment for transport corridors.

A frequently quoted UC for 5G is providing connectivity for vehicles on transport corridors with a tendency to focus on services for private vehicles such as infotainment, assisted driving, logistics and semi-automated driving. However, improved mobile connectivity across the main road network could also deliver benefits to vehicles delivering public services such as emergency services. In this section, we examine the smart ambulance vehicle UC, its wireless requirements and potential implications for dimensioning of mobile networks on transport corridors.

4.4.1 The promise of 5G for services to professional vehicles on transport corridors

While manufacturers already include cellular devices in their vehicles under today's 4G networks, it is anticipated that the following characteristics of 5G will unlock a new level of applications beyond current offerings:

- Improved reliability and lower latency
- Wider bandwidths (facilitating higher throughputs per device and higher overall capacity)

In the case of public service vehicles, these additional capabilities delivered by 5G could help to transform the level of service received by patients in ambulances.

For example, the wider bandwidths offered by 5G could facilitate video streaming from ambulances at the scene of an emergency back to a consultant or specialist at the hospital to allow paramedics to get remote support and expertise immediately. Additionally, the continuous collection and streaming of patient data could begin when the paramedics arrive at the incident scene right up until delivery of the patient to the emergency department at the destination hospital. By doing so, doctors will be able to gather information on the patient's situation and make preparations before the patient's arrival at the hospital. The low latency of 5G has also been cited as an enabler for applications such as a consultant remotely guiding a paramedic's hand to the right area when taking an ultrasound via haptic feedback.

The smart ambulance would have a single connection with the 5G network with the vehicle acting as a hub to distribute services to users onboard. This places a different set of requirements on mobile networks in terms of coverage and capacity. Traditionally on mobile networks users are individuals with handsets and distributed widely across the cell area. In contrast these public service vehicles have the potential to generate localized hotspots of demand in a cell that the network will need to cater for.

4.4.2 The challenge of mobile connectivity on road networks and emerging deployment options

According to Ofcom (Ofcom, Connected Nations, 2018) in September 2018, only 64% of the UK's motorways and A roads had good in-car 4G data coverage from all operators. Good 4G coverage here is unlikely to mean throughputs high enough for many of the vehicular services envisaged, such as video streaming for infotainment. This highlights how commercially challenging extending coverage to these major roads is for Mobile Network Operators (MNOs) based on traditional macrocell deployment models and raises questions over how realistic it is to expect operators to provide the near 100% 5G coverage on roads that would underpin the smart ambulance visions described earlier.

Until recently, providing coverage to a nationwide and largely rural area made use of nationwide licensed spectrum and macrocell focused deployments. However, new deployment models are being realised, rather than each MNO deploying their own networks, a hyper-dense network of small cells could be deployed by an independent neutral host network infrastructure provider potentially in partnership with the relevant transport authority, at least along the busiest sections of motorway. All MNOs would then have the opportunity to utilise the shared independent network on the major roads to extend their existing coverage. As the cost of the network is effectively shared by the MNOs, this approach should lead to cost savings for MNOs and make improved mobile coverage on major roads more feasible.

These new deployment ideas are also being boosted by changes in the availability of mobile spectrum in Europe recently. Many regulators in Europe made spectrum available between 3.8 and 4.2GHz for low and medium power localised deployments and also announced sharing and reuse of existing mobile bands where these are currently unused by existing operators. This opens up spectrum options for a neutral host deployment on major roads and removes one practical barrier to such a neutral host approach – the availability of spectrum.

In this section we ask, "*How much more cost effective will new neutral host driven shared infrastructure deployments be in providing 5G connectivity and new services for public service vehicles to major roads compared with MNOs acting individually to upgrade their existing networks*?".

4.4.3 Mobile applications expected on major roads and their requirements

The start point for this analysis is to understand the types of mobile applications likely to be in use on main roads. We consider two groups of vehicle types generating mobile traffic on the roads:

1. "Business as usual" traffic from private vehicles
2. Smart ambulance applications

In this section, we highlight the applications that we have considered for each of these user groups and the comparative requirements across user groups (in terms of throughput, reliability, and latency). We consider this from both an uplink and downlink perspective as, while most applications are downlink centric, many of the applications discussed for public service vehicles are likely to require high uplink throughputs also.

4.4.3.1 "Business as usual" traffic from private vehicles

Table 4 lists the main groups of mobile applications likely to be used by private vehicles. Figure 37 compares the data rates required across these. From a data rate perspective, infotainment services will dominate as this can include streaming video. We also assume that mobile phones within private vehicles will connect to the in-car infotainment system so that all existing mobile phone usage by passengers in cars is accounted for under "Infotainment". The other applications considered have much lower data rates as are mostly receiving or reporting status updates from either the roadside infrastructure or the vehicle. However, in some cases these updates, such as warnings of upcoming hazards, are of a safety critical nature and will be relied upon by drivers and hence need to be delivered at high reliability and potentially low latency.

Table 4. Mobile applications from private vehicles.

Application	Description	Reliabil-ity	Latency
Infotainment	In car network and entertainment system for music, video streaming, web browsing, navigation aids etc.	Consumer grade	<50ms
Safety & Security	Warnings of upcoming hazards and other safety critical aids to drivers relying on communication with roadside infrastructure.	High	Potentially sub 10ms
Maintenance and Diagnostics	Reporting of vehicle status to manufacturer to help foresee issues and schedule preventative maintenance.	Consumer grade	<50ms
Fleet services	Services to commercial vehicles to track status of the fleet.	Consumer grade	<50ms

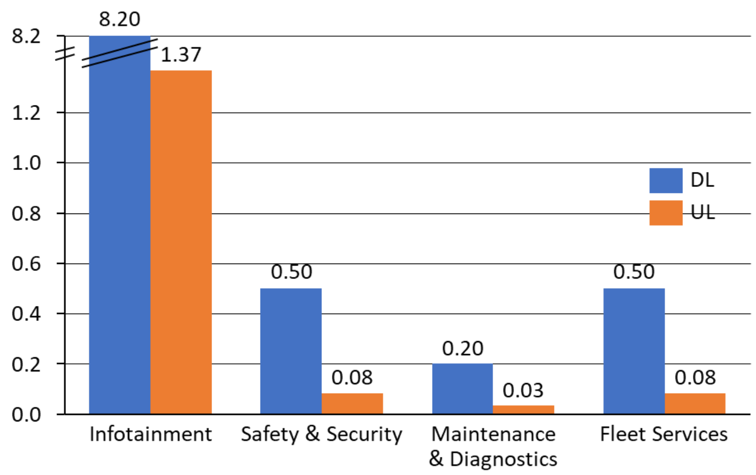

Figure 37. Data rates required per wireless application per private vehicle [Mbps].

4.4.4 Smart ambulance demand analysis

Table 5 lists the types of services anticipated for a smart ambulance with data rates given in Figure 38. All services will need to be delivered at a high reliability level which the mobile network will need to be dimensioned before. An additional challenge is the high uplink requirement to stream high quality video back from the ambulance to a remote consultant. Mobile networks are typically dimensioned for users mostly downloading data, however, in the case of smart ambulances high uplink data rates will be essential. In the future, smart ambulances may also include AR for remote surgery and triage, but we have not considered this in our analysis here.

Table 5 - Mobile applications from smart ambulances

Application	Description	Reliability	Latency
HD video conferencing	Live feeds from cameras in the ambulance so that remote support can be provided by a consultant.	High	<50ms
Patient monitoring and intelligent routing	Real-time sharing of patient diagnostics such as patient's blood pressure, temperature, pulse, etc. and updates to the ambulance on traffic conditions, best hospital to be routed to due to patient condition and availability of the right expertise.	High	<50ms

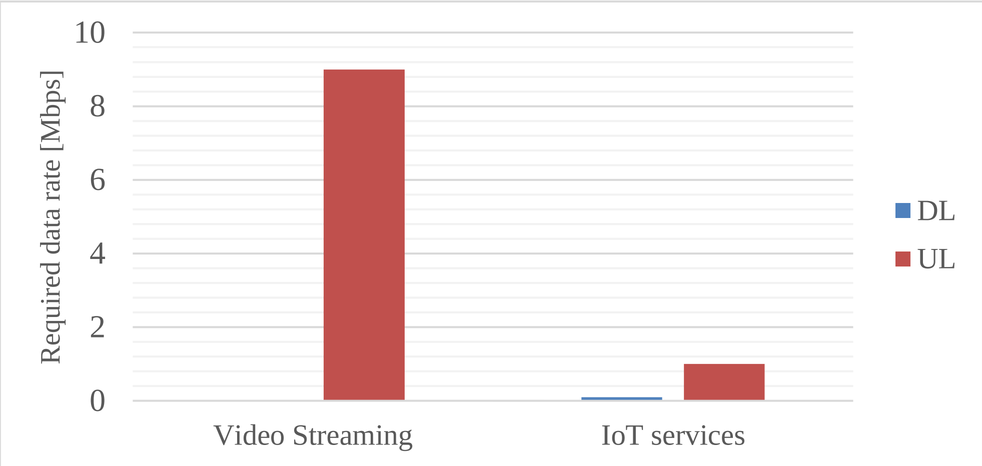

Figure 38. Data rates required per wireless application per smart ambulance [Mbps].

4.4.5 Mobile network options for major roads and factors in their dimensioning

Having determined the services that a mobile network will need to support on major roads, we next look at the dimensioning of such a network. We compare two deployment approaches:

- An MNO macrocell driven approach.
- A neutral host hyper-dense network.

The volume of sites and equipment needed under each approach is set by a combination of the coverage and capacity requirements of the mobile services to be accommodated. In this section we compare, at a high level, the impact on site spacing of adding smart ambulance and smart bus services to the existing "business as usual" traffic and try to understand how these new services might challenge existing networks from a coverage and capacity perspective.

4.4.5.1 Traditional MNO driven macrocell vs neutral host hyper-dense network approach

A hyper-dense radio network topology is characterised by a combination of fibre and mmWave mesh networking for high capacity backhauling from small cells that are deployed in very close proximity to the transport route (see Figure 39). The distance between small cells will typically be around 300m, although this distance is affected by a number of factors such as density of vehicles, traffic demand, and spectrum availability. The mesh backhaul offers a multi-Gbps connection and alleviates the "line-of-sight" requirement that is typically associated with mmWave links. This allows the cells to be closer to the end-user. Each cell site will host a variety of radio access technologies and frequency bands to deliver services to the moving vehicles and other equipment across the network.

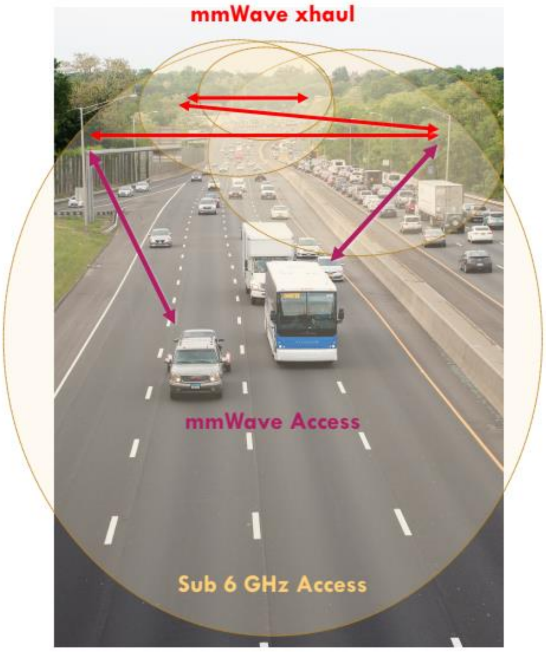

Figure 39. Typical hyper-dense small cell deployment.

In our analysis we compare the network dimensioning of a hyper-dense small cell network with that of a traditional macrocell driven approach. Key differences between the two approaches are:

- Transmit power and antennas:
  - Macrocells have a maximum EIRP of 64dBm/10MHz and up to 16 antennas
  - Small cells are assumed to be limited to a maximum transmit power of 25dBm per antenna and up to 8 antennas
- Spectrum:
  - Macrocells are assumed to access 2x20MHz at 700MHz and 1x40MHz at 3.5GHz
  - Small cells are assumed to only have access to 1x40MHz at 3.5GHz
  - For TDD spectrum, we assume a 50/50 downlink/uplink ratio
- Height:
  - Macrocells are assumed to be 20m high whereas small cells are assumed to be at 10m height

Given the higher transmit power, number of antennas, antenna height and access to the lower frequency bands we expect macrocells to have a much larger range and hence require less cells in a coverage limited deployment. However, a small cell network, dimensioned against similar coverage requirements, will have a higher capacity density due to the higher density of cells deployed.

4.4.5.2 Coverage requirements for smart ambulance services compared with existing mobile services

To understand the dimensioning of the two network options from a coverage perspective, shows the estimated maximum distance from the macrocell or small cell sites (or cell range) at which different combinations of wireless services required on roads could be delivered. These are based on link budget calculations for a single vehicle being able to receive their required combination of services at the cell edge. For simplicity we assume that smart ambulances have the same antenna installed as on private vehicles. Demand from multiple vehicles across the cell is considered in the next section.

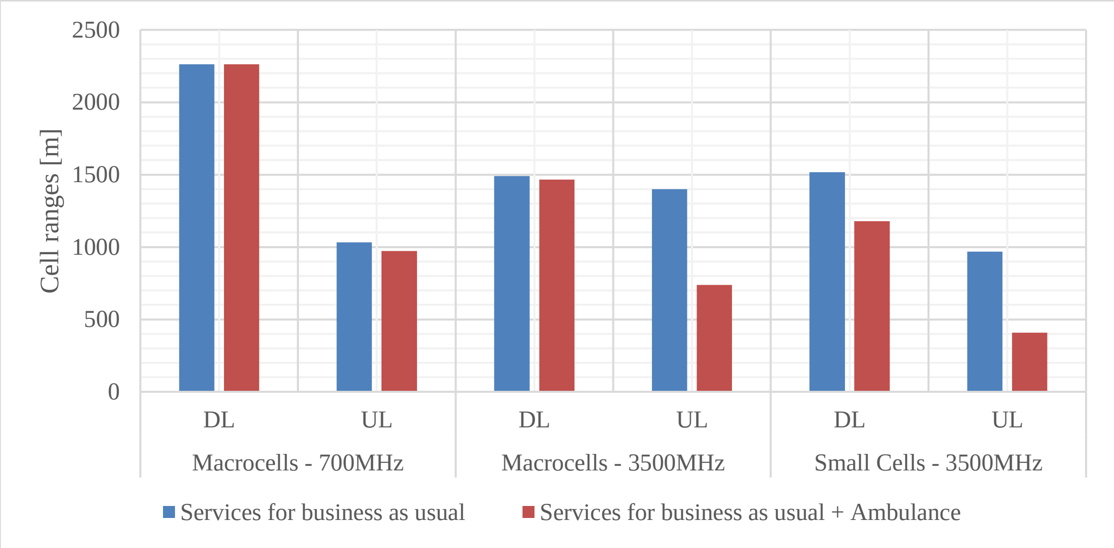

Figure 40. Estimated cell ranges for different combinations of wireless services on roads.

Figure 40 shows that:

- As expected, macrocells cell ranges are larger than small cell ranges, implying less sites required.
- The largest ranges are achieved when providing coverage solely for the "business as usual" services to private vehicles. Adding either support for smart ambulance services on top of this reduces cell range.
- Adding smart ambulance services to the "business as usual" network shrinks the achievable cell range for both the macrocell and small cell cases and across all frequency bands. While this vehicle type is not so challenging on the downlink, its high uplink data rate requirements and overall requirement for higher reliability can be seen to have a very noticeable impact on achievable uplink cell ranges. We note that on the uplink the transmit power advantage of the macrocell will not come into play as both deployment types will be limited to the user device's transmit power for uplink transmissions (assumed at 23dBm). The larger height and number of antennas of the macrocell though still gives it some advantages over small cells even for uplink reception.

In practice, depending on the availability of fixed fibre backhaul to the small cell sites along roads, the distance between small cell sites may be limited by the mmWave backhaul link between them. If this is the case, an inter site spacing of approximately 300m is anticipated which is less than the cell ranges shown above. Therefore, a truly hyper-dense small cell network using mmWave backhaul and deployed at this density would also meet the coverage requirements of the services considered above.

4.4.5.3 Demand smart ambulance services compared with existing mobile demand

Next, we consider the capacity dimensioning of the two network options. Figure 41 and Figure 42 show the maximum capacity that is provided per cell in the case of the macrocell network and small cell networks (dashed yellow line). Taking the networks and site spacings required to deliver just the "business as usual" traffic, we consider:

- How much capacity per cell is already taken up by the "business as usual" services.
- How much additional capacity per cell is required for the smart ambulance services. For simplicity, we assume accommodating one smart ambulance per cell. Where this exceeds the maximum capacity per cell this indicates that the existing "business as usual" network will need to be densified to meet these capacity requirements.

Additionally, we partition the major roads into groupings based on vehicle density as the volume of vehicles to consider varies between the groupings and hence wireless demand will vary between quieter and busier sections of the roads. We have identified four such groupings: 1) the “Low Traffic” with an average daily traffic of 15,000 vehicles, which corresponds to 52% of the major roads; 2) the “Medium Traffic” with an average daily traffic of 70,000 vehicles and it characterizes 30% of the major roads; 3) the “High Traffic” with an average daily traffic of 125,000 vehicles and close to 17% of the major roads; and 4) the “Extremely High Traffic” with an average daily traffic of 180,000 vehicles, which represents approximately 1% of the major roads.

From Figure 41, we can see that, prior to the addition of smart ambulance traffic, the macrocell network is already near downlink capacity in all but low traffic areas. Adding the smart ambulance services does not exceed this maximum capacity as the DL requirements for the ambulance is not relatively high.

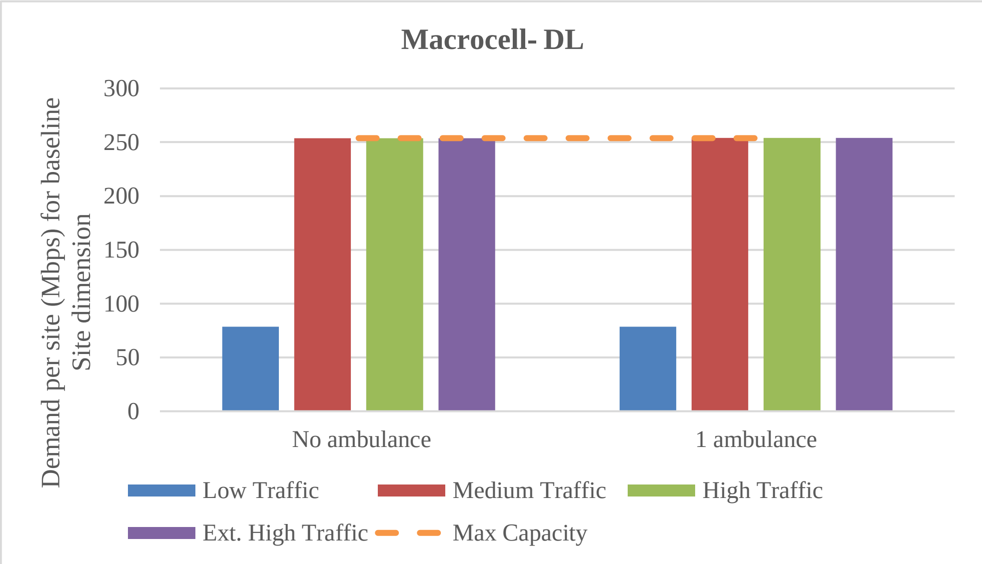

Figure 41. Downlink demand per site for different service combinations for macrocell “business as usual” network.

In contrast, Figure 42 shows that the hyper-dense small cell network, with smaller cell ranges and hence a higher number of sites, has more spare capacity in the “business as usual” scenario. The smart ambulance services again do not exceed this spare capacity in the DL.

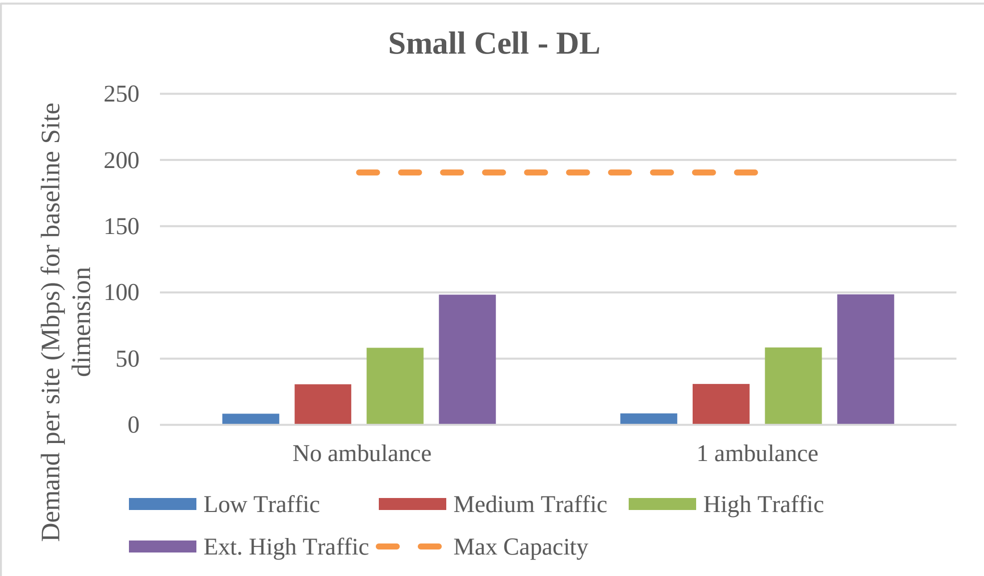

Figure 42. Downlink demand per site for different service combinations for small cell “business as usual” network.

Figure 43 and Figure 44 show uplink capacity and demand per cell for the “business as usual” macrocell network and small cell network. This shows both the macrocell and small cell networks having spare uplink capacity and readily being able to accommodate the additional uplink demand of the smart ambulance services. This abundance of spare capacity on the uplink is more evident in the case of the hyper-dense small cell network, as in fact, for the given TDD configuration of 50:50 up to 6 smart ambulances could be accommodated in a single cell (as might be the case in a major incident).

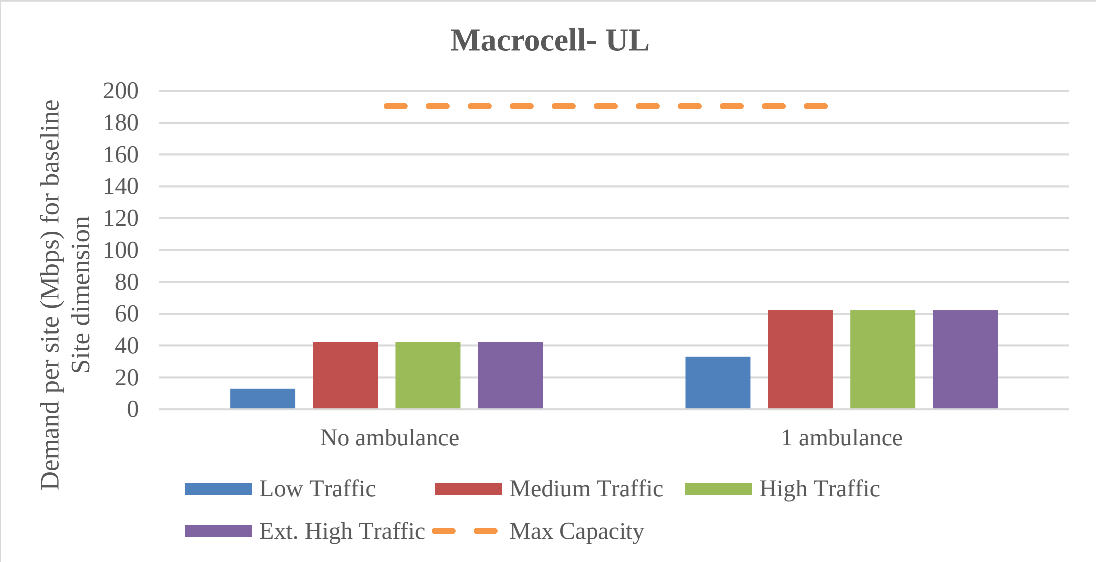

Figure 43. Uplink demand per site for different service combinations for macrocell “business as usual” network.

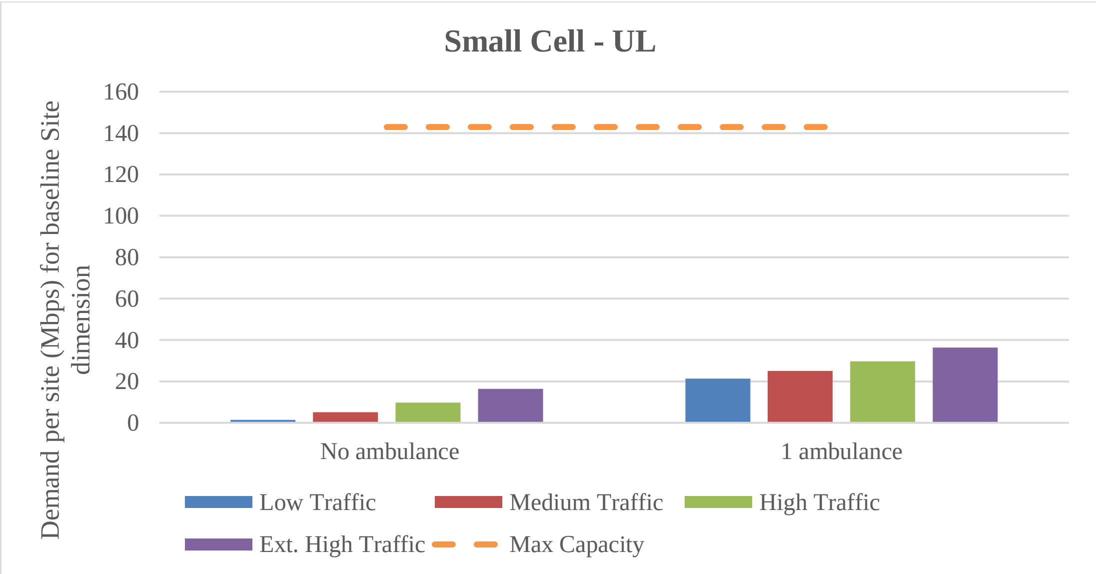

Figure 44. Uplink demand per site for different service combinations for small cell “business as usual” network.

4.4.6 Network dimensioning and costs results

In this section, we perform a network dimensioning exercise for providing coverage to parts of the major roads that we anticipate would not be currently covered by all MNOs to the signal level required to support the vehicular services envisaged in this section. Combining both coverage and capacity considerations in a model, we can determine the number of sites required via the macrocell and small cell deployment options. These site volumes can then be translated into cost.

4.4.6.1 Macrocell compared with small cell with mmWave backhaul limitations

As mentioned earlier, a fixed backhaul connection might not be available to all roadside small cell sites. This analysis proposes the use of a mmWave mesh network between sites for backhaul instead, so that the fibre connection to one small cell site can be distributed to multiple sites. Figure 45 and Figure 46 compare the site volumes and 10-year TCO respectively for the macrocell deployment strategy compared with using small cells with the limitation of mmWave backhaul. This represents a truly hyper-dense small cell deployment with extremely high volumes of small cell sites required. However, having deployed this high volume of small cells for the "business as usual" network, we can see that this hyper-dense small cell network is much less sensitive to additional services being added compared with the macrocell network. This is because the small cell network has a high capacity density and, within the limits of the bandwidth available per cell, it can relatively readily accommodate new services being added to the network (as illustrated by the capacity per cell plots earlier). Despite the high volume of small cells in this hyper-dense deployment, the 10-year TCO is still very much less than a macrocell approach.

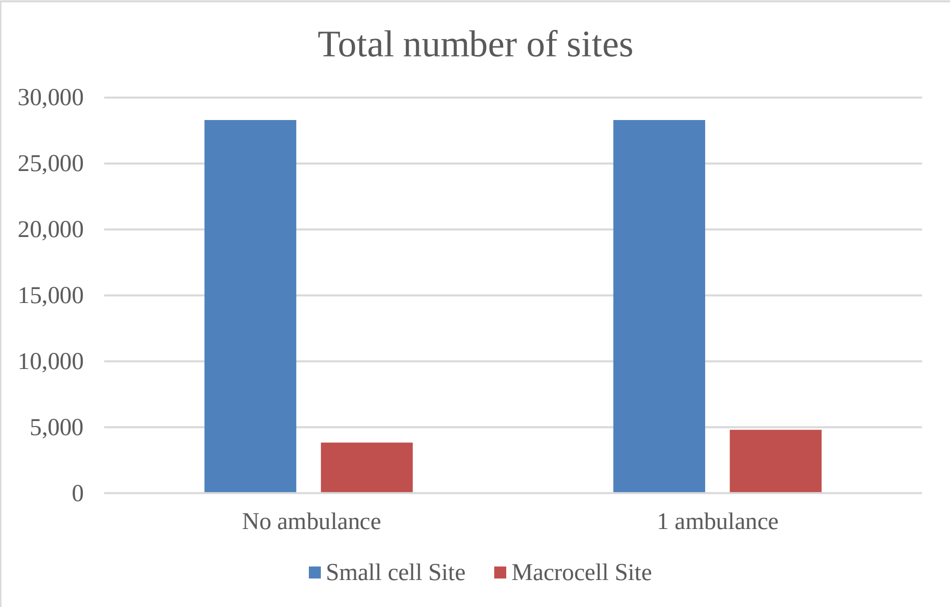

Figure 45. Number of sites required on major roads for small cells and macrocell deployment strategies and considering different service combinations.

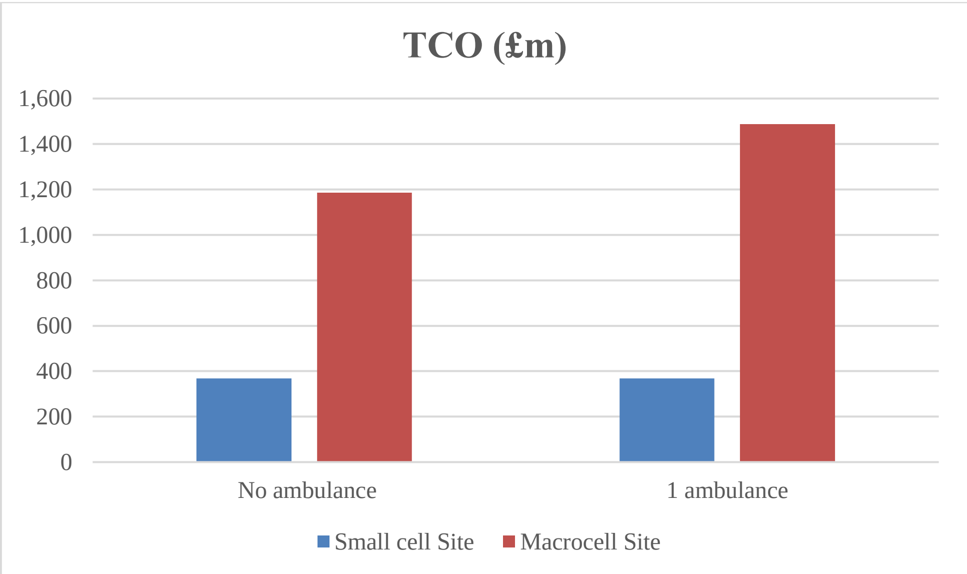

Figure 46. 10-year TCO for small cells and macrocell deployment strategies and considering different service combinations.

4.4.6.2 Site volumes and costs - Macrocell compared with small cell without mmWave backhaul limitations

The hyper-dense small cell network owes its high density to the limitation of the mmWave links, which, as shown, comes with some pretty beneficial advantages, such as higher offered capacity density and insensitivity to demand variations. It is interesting to explore though the case when this density is relaxed, by assuming that the neutral host network is deployed in an area with an extensive optical fibre network which the neutral host provider can utilize. This may not be feasible in reality, due to the lack of enough optical fibre on the major roads in Europe, and also due to the impact that the decreased number of poles may have to the neutral host's business model.

In such a scenario, the small cell network exhibits the same behaviour as the macrocell network (Figure 47), due to the fact that it is not over dimensioned, but optimally deployed to meet the required demand, and therefore, any increase in the demand will lead to densification.

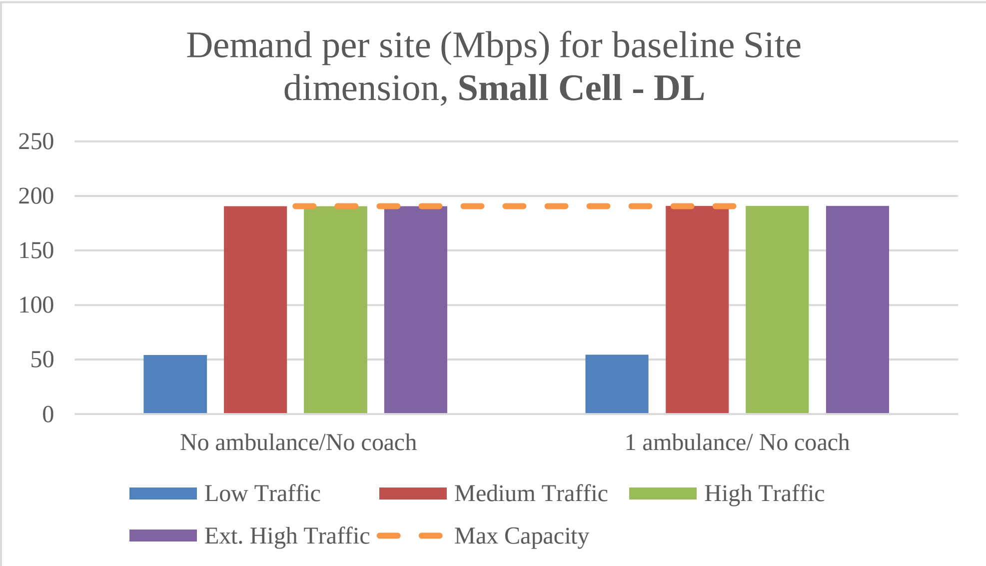

Figure 47. Downlink demand per site for different service combinations for small cell "business as usual" network with available optical fibre.

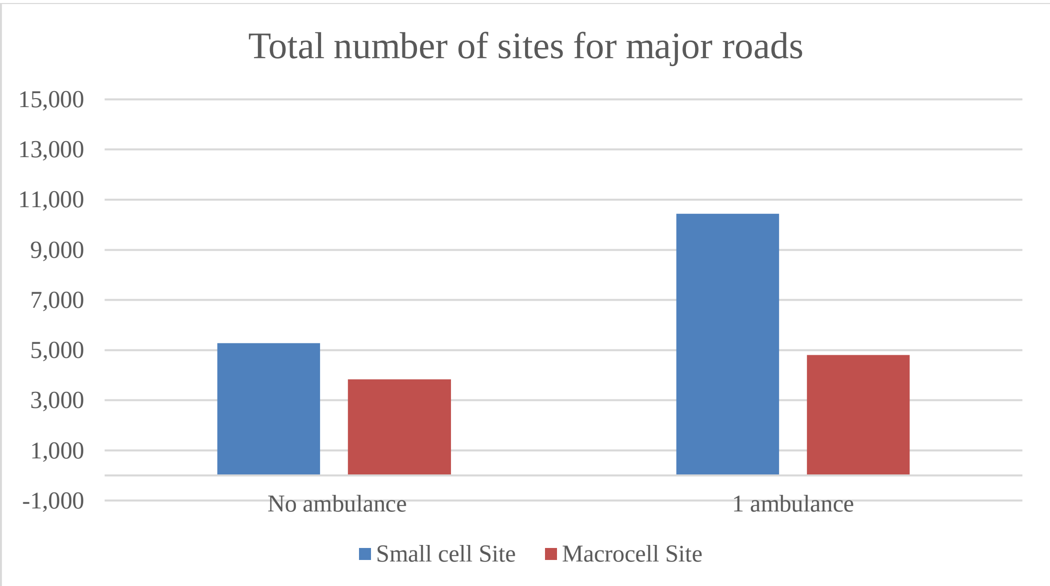

Figure 48. Shows the difference in site volumes required for the two deployment strategies and different combinations of services.

This shows that adding the smart ambulance service to the "business as usual" network creates coverage rather than capacity challenges and site volumes are increased in line with the decreases in uplink cell range seen earlier.

Figure 48 shows the number of sites required on the major roads for a country like the UK for small cells (with no mmWave limitation) and macrocell deployment strategies and considering different service combinations.

In Figure 49, we translate the site volumes into a TCO over 10 years. While the small cell network has a much higher volume of sites than the macrocell case, the cost of deploying each small cell site is much less than that of a macrocell. These leads to significantly lower TCOs for the small cell deployment option. The cost benefits of the small cell network also improve when considering that this cost will ideally be shared amongst multiple MNOs over time in the form of access fees. It should be noted though that in this scenario, any cost for the usage of the optical fibre network has not been incorporated in the calculation of the small cell TCO.

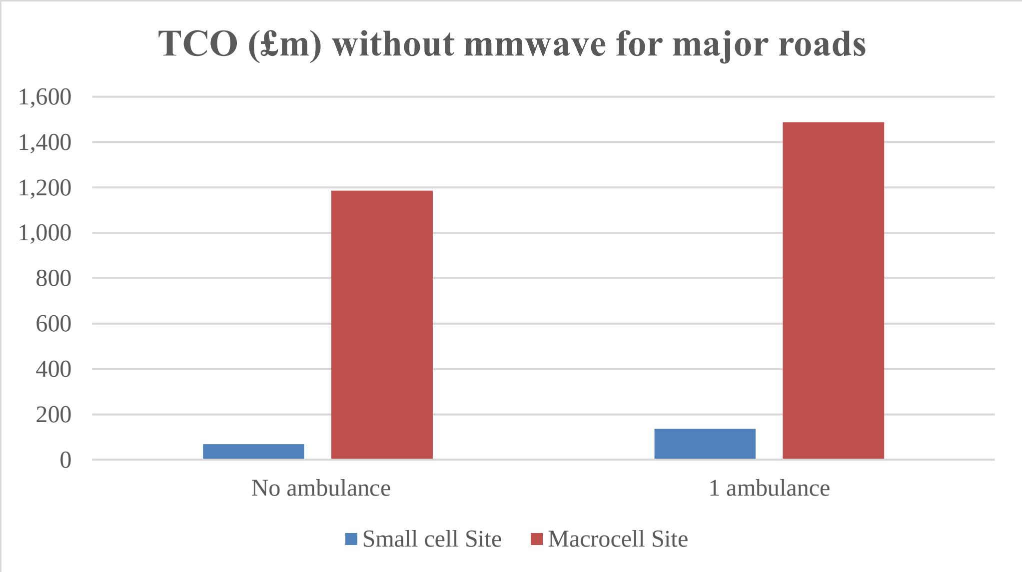

Figure 49. 10-year TCO for small cells (without mmWave limitation) and macrocell deployment strategies and considering different service combinations.

Smart ambulance services are likely to be challenging compared with accommodating wireless traffic from private vehicles. This is because they:

- Generate very localized demand hotspots with high throughput requirements which need to be accommodated even at the cell edge. This is challenging from both a capacity and coverage perspective.
- Have demanding uplink and high reliability requirements which shrinks cell ranges from a coverage perspective.

Considering a hyper-dense small cell network using mmWave backhaul, we find that these more challenging services can be much more readily accommodated. This is because, compared with macro-cellular networks, these hyper-dense networks have high volumes of capacity built in from initial deployment and so are less sensitive to requiring network expansion as new services are added. Additionally, the hyper-dense nature of such networks improves their reliability and hence ability to support high reliability services such as those required for professional vehicular services. While the volume of macrocells is much less than small cells, we find that, with a much lower cost per site, the small cell strategy still has a much lower 10-year TCO in all cases with savings of up to 83%.

4.5 Healthcare Case Study 2: Remote health monitoring and emergency situation notification

4.5.1 Market context

The COVID-19 pandemic has dramatically changed the telehealth and telemedicine market, with technology providers and healthcare professionals adopting or expanding healthcare platforms and tools to meet the growing needs of remote care.

In 2020, the global telehealth and telemedicine market was reached USD 38.7 billion and is expected to grow at a CAGR of 37.7% over the forecast period, reaching USD 191.7 billion by 2025 (Market, 2020).

A bridge to care was offered through telehealth during the pandemic crisis. Today, it provides the foundations for the permanent adoption of virtual and hybrid virtual/in-person care models in order to achieve improved healthcare access, outcomes, and affordability. A justification of these numbers is the sufficient percentage of physicians (58%) who still believe that telehealth solutions are more necessary than they did before the pandemic, despite the fact that this number was slightly higher in September 2020 (64%). Accordingly, more than half of physicians still believe that virtual visits should be continued (Mckinsey, 2020).

4.5.2 Service description and purpose

The main goal of the proposed solution is to offer improved, more efficient, and accessible remote care and, consequently, improving the quality of life of affected citizens, especially when already diagnosed with a critical disease still compatible with home care (e.g., some form of cardiovascular disease, hypertension, diabetes, etc.). The main features 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 solution leverages wearable devices tracking a patient's vital signs and having them aggregated inside an IoT-based platform named STARLIT (Smart living platform powered by AI & robust IoT connectivity). STARLIT offers a dashboard for medical professionals enabling them to monitor the vital signs and status of several patients at the time. It also provides the option of setting up a virtual call with a certain patient. Alarms are raised notifying of current or potential future issues and more specifically, in case of: (a) main vital signs such as heart rhythm, heart rate, blood pressure or oxygen saturation are critical or are out of range (based on certain predefined thresholds) (b) recorded values show a trend towards a potential problematic situation leading to health emergencies, or (c) the patient leaves a specific predefined geographical area (geofencing).

4.5.3 Potential customers and value chain actors

Hospitals and other healthcare organisations in the public and private sector as well as municipalities in the context of social services will be the potential customers who will pay for the "remote health monitoring and emergency situation notification" system.

This kind of services may open new opportunities for stakeholders of the healthcare sector value chain. There are several of actors influenced by the "remote health monitoring and emergency situation notification":

- **Healthcare professionals:** Healthcare professionals in healthcare organisations, private and public hospitals who have direct contact with the system interface.
- **Municipal staff:** Municipal staff involved in social services who have direct contact with the system interface.
- **Patients/Visitors/Citizens:** The actors that do not interact directly with the user interface of the system, but they still affected by it as they may have access to the functionalities provided, such as visualisation of their real-time or historical data, etc. (patients, citizens visitors - subjects being monitored or their relatives).
- **Network Provider:** The actor that provides the network/communications infrastructure.

- **Platform Provider:** The actor that provide the required infrastructure/platform components to support the solution (cloud platform, devices, analytics, etc.).

4.5.4 WINGS business model and market strategy

The remote health monitoring and emergency situation notification will be offered to healthcare professionals in public and private hospitals, healthcare organisations and businesses, insurance companies or others. Municipalities will also be reached as potential clients as well to integrate WINGS solutions to the social services.

The proposed system promises a) awareness and real-time access to health-related information, b) reliable disease detection and immediate response in case of emergencies based on the suite of AI and predictive analytics algorithms, c) enhanced user experience for disease management and rehabilitation issues, and d) flexibility and usability to support the efficient communication with other Electronic Health Records (EHRs) or platform components already existed in different premises/settings.

The system's innovations will be highlighted through the a) active performance measurement while the service is running, b) resource allocation, deployment, and migration of Network Services in an automatic and optimized way using various metrics (infrastructure, VNFs, Applications, etc.) and verticals' requirements, c) correlation of user QoE with Active Service KPIs to identify relation between network performance, Quantitative Service KPIs and QoE.

The solution, as such, will be included in the WINGS portfolio of products, and will provide WINGS with new business opportunities. The remote health monitoring and emergency notifications system will be offered as platform as a Service (PaaS), and a penetration pricing will be followed for the solutions, the price of which is set artificially low to gain market share quickly. The prices will be potentially raised once the promotion period is over and market share objectives are achieved.
The go-to-market strategy for WINGS solutions is split in three different phases:

- Phase 1 "**Promotion and Awareness**": Normally, the first three months after the end of the project will mainly focus on promoting the results of the project and its solution performance/innovation comparing to currently existing solutions to healthcare organisations, public and private healthcare settings, municipalities, healthcare businesses, and other potential stakeholders/customers. This will allow WINGS to attract stakeholders' interest and possible customers. Promotion and awareness activities will take place before the end of the 5G-TOURS project.
- Phase 2 "**Pre-sales: Customized solutions and pilots**": The customers attracted during the "Promotion and Awareness" phase may be interested either in the exact solutions that were designed and tested during the lifetime of 5G-TOURS project or to similar solutions that need to be adjusted to their needs. This phase involves all those actions that will allow the customization of the solutions to the customers' needs. These may include but are not limited to:
    - Identification of new requirements.
    - Adjustment of monitoring, knowledge building and predictive mechanisms.
    - Testing and validation in a lab environment.
    - Pilots of the designed mechanisms on their real environment and real users (e.g., hospitals with real patients, municipalities with real citizens, etc.).
- Phase 3 "**Sales**": This phase refers to the selling of the mechanisms and the services derived both from the 5G-TOURS and the Phase 2 to specific customers (e.g., public/private hospital, municipalities, insurance companies, etc.) based on principles for licensing, business models, pricing, and distribution briefly presented above and further enhanced after the first launch of the WINGS solution.

Communication channels with broad reach (e.g., social media, project's website, newsletters), but also workshops, webinars, conferences and other campaigns already have (during the lifetime of the project) and will be taken into consideration for the promoting activities. Social media accounts for promoting WINGS solution and its functionalities, enabling stakeholders and end-users to interact, share their opinion, their concerns and their quality of experience, view news and announcements and pose questions to the project team.

5 Tourism Sector Business Models, Deployment and Operations

This chapter applies the concepts developed in chapter 2 in the context of the smart city. Unlike the previous chapters that are specific on the Airport and Health sectors, this section covers two contextual settings. On one side, the Tourism sector specifically for the museum setting and secondly, the city environment, as aggregation of tourism, media plus health cases specific for the city. Options for the provision of 5G infrastructure are explored from the perspective of the 5G-TOURS UCs and evaluated in terms of architectural suitability and ease of deployment.

The chapter considers the wider commercial appeal of the innovations that have been developed to support the specific use cases. To that end some preliminary cost estimates are provided for the delivery of 5G services at scale. Work to develop the suite of tools required to model the cost structures of city-wide 5G deployments is ongoing. The framework for this development is outlined later in the chapter with the intention of reaching the point where it is possible to understand the marginal cost of providing additional infrastructure to support individual use cases. In the next period we will exploit this capability to understand the net benefit of the individual use cases.

5.1 Tourism Innovations & Commercial options

Innovation is the Engine of the Transformation of Tourism into Smart Tourism: the “Touristic city node” built by 5G-TOURS in the city of Turin creates a framework where products and services are created, targeting the 5 A’s of Tourism, i.e.:

- Attraction: It includes all those factors which attract a tourist. It could be a place, nature, lakes, beach, monuments etc.
- Accessibility: It is how to access or reach to that place of attraction. Ways to reach.
- Accommodation: Place to stay or accommodate while travelling for rest or overnight stays.
- Amenities: All the other services which we require while travelling for good and comfortable living such as food, drinking water, sanitary, etc.
- Activities: It includes activities which a place or attraction holds such as nature walks, history & architecture, boating, views, health, etc., empowered by the use of the most advanced technology.

The Touristic City of 5G-TOURS is a place where visitors are provided with 5G-based applications to enhance their experience:

- AR/VR for immersivity.
- Gamification to involve the youngest and promote connections and social inclusiveness.
- Robot-assisted services to improve employees work/life balance and productivity.
- Telepresence to allow for remote visits.
- Media distribution and production to further improve the visitors’ experience with additional content.

The 5G-TOURS innovations allow the development of services and products to cope with the COVID-19 emergency, offering services to tourists on site and to local residents that guarantee a safe experience. Social distancing could be provided by the use of robot-assisted visits that control the number of visitors at a touristic site or in front of an attraction. Use of personal devices instead of those rented by the museum for guided 5G-TOURS could be another means for reducing social distancing issues.

The 5G-TOURS innovations, however, also represent important tools to accompany the Touristic sector in its evolution, the post COVID-19 era: the immersivity experience offered by VR/AR can allow the creation of a new virtual tourism opportunity, to improve, complement or even replace the physical tourism experience. The 5G-TOURS UCs represent examples of products and services for these new types of tourism.

5.1.1 Commercial options for the sector

During the last decade, museums all over the world witnessed a decrease in visitors. AR can help in reversing this trend, acting as an attraction in its own right and motivating particularly the youngest tourists to visit a museum through technologies they are familiar with. 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 service can be provided 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.

On the other hand, high quality video service distribution and remote or distributed video production 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. In Turin it is planned to produce a bespoke professional 4K-HDR video for both testing and promotional activities about the city and its culture. The expected return in this sense is related to the use of innovation technology to improve the strategy market for the promotion of tourism.

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.

There are several socio-economic drivers for Telepresence: reduction of travel spend, 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).

Robot assisted museum guide improves employee’s work/life balance and productivity. The robot will not replace employees, of course, but will offer them an insight on some activities on one hand. On the other, it will allow visitors to get more information about museum locations and additional details.

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.

5.2 The value of the 5G-TOURS Innovations for the sector

5.2.1 Tourism sector: product and service characteristics

Tourism is one of 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-pandemic “hit-and-run” tourism, to match the interest of people to travel with the need of sustainability.

Slow Tourism means responsible and sustainable tourism, 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 encourages people to value their cultural and natural heritage (BNB, 2017).

Never-ending Tourism comes as a specific proposal to respond to the COVID-19 pandemic, to allow travellers 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 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.

5.2.2 The museum

The Municipality of Turin and FTM have expressed, since the beginning of the project, their interest in the innovative aspects of the project case studies with the aim to give uniqueness to the cultural offer of the City. The interest of other various local and national actors operating in the cultural and tourism fields has been confirmed by the recent Industrial Workshop which took place in Turin, on the 30th of September.

For the first UC, *Augmented Tourism experience*, the level of interest for the innovation proposed is high: the UC provides 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 only a 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.

The innovation forecast in UC 2, *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. Furthermore, the aspects related to the use of telepresence for surveillance purposes 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.

In UC 3, *Robot assisted museum guide*, the innovation is guaranteed using robotic technology to provide an enhanced museum visit experience. As for UC1, the interest is high aiming to present a new way of visiting a museum and to add value to the museum itself. The guided tour, performed autonomously by the robot following a precomputed path, can accompany visitors inside the museum independently. The benefits can be represented by being able to provide new or additional content through the robot, by being able to use it for rooms surveillance too or simply as an additional autonomous guide.

Finally, both the innovations presented in UC 4, *High quality video services distribution* (UC4), and UC5 *Remote and distributed video production* (UC5) are interesting 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. The Itinerant Orchestra event that was performed in November, the 9th, it's a prime example of new innovative cultural offer.

5.2.3 Media sector: product and service characteristics

Since the beginning, 5G technologies promised to be a great opportunity for the media sector, both in the field of production and distribution of audio-visual media content and services.

5.2.3.1 Distribution of media content

For distribution, 5G offers a suite of standard tools 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 on the HPHT network and 5GMS operated by the MNO on the LPLT 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.

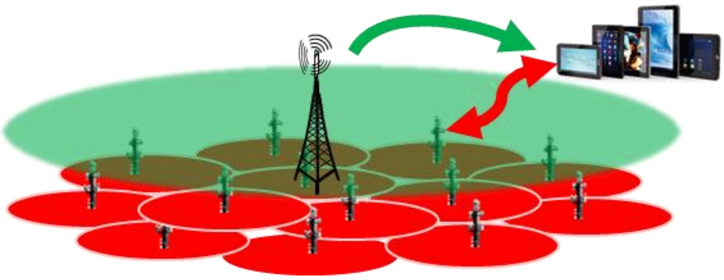

Figure 50. Service - level cooperation.

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 50 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 5G-TOURS UC4 has the scope to test this technology in the field, to verify its maturity and the potential interest of the users.

The main risk regarding the provision of the innovation into the media verticals is due, however, to the fact that only prototype receivers are available implementing 5G-Broadcast, while so far, no commercial terminal is available, thus preventing the commercial introduction of the service.

5.2.3.2 Content production

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. In this direction, UC5 exploits 5G technologies to obtain a new elastic and efficient production model. The considered UC is very challenging, with stringent requirements in terms of huge data volumes, very low delay requirements as well as minimal jitter, to allow perfect synchronization of a multitude of sources that are far apart from each other.

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.

5G ultra-low latency and high bandwidth are crucial in the implementation of XR technologies, say VR, AR, and MR. UC1 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.

5.2.3.3 Media Acquisition

Cellular bonding technology invention changed live newsgathering by providing easy and cost-effective tools to do media acquisition from the field.

The players on this domain today (like LiveU) provide 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 UC 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 UCs.

5.3 Benefits Summary – Smart City setting

The smart city UC's are split across several environments within the city of Turin, Italy. Work Package 2 has calculated the economic benefits for each setting as described in the following sections.

For tourism, the setting is a museum. Benefits have been derived based on the proof-of-concept testbed in Palazzo Madama and then aggregated across all of the major Turin museums (Museo Egizio, Museo del Cinema, GAM and Fondazione Torino Musei) to give an estimate of the benefit to the city as a whole.

Benefits to the broadcasting sector have been derived under UC's requiring wide area coverage across a city (as opposed to more local coverage in the case of museums). In the related network cost analysis in WP8, we assume that these services are delivered across a common city area. Although they can be provided by different organisations, most of whom operate nationally, the major investment in 5G will be at the city level. One of the key stakeholders will be the city authority who will play a key role in facilitating the deployment of infrastructure therefore the cost-benefit analysis has been purposely set at the city scale.

5.3.1 Tourism sector: benefits in a museum setting

For the tourism sector analysis WP2 has calculated the economic benefits for each UC individually but also as a whole, assessing their combined ability to improve the attractiveness of Turin museums and increase ticket sales. The result is a range of potential benefits as illustrated in Figure 51.

Within the business model context, the benefits represent the value that 5G has the potential to create within the vertical, which can be direct and easily realised by way of additional revenue or cost savings. Economic benefits are assumed to accrue to the commune of Turin taken together rather than for a single museum which gives a broader perspective than considering just one museum. The UC's considered, and the corresponding sources of value are as follows:

- Touristic City – Telepresence (UC2, UC3).
  - Direct charge for immersive remote access to museum collections.
- Touristic City – XR immersive museum experience (UC1).
  - Increase in visitors because the immersive experience makes the visit more attractive.
  - Direct charge to the user.
- Touristic City – Robot-assisted museum guide and monitoring (UC3).
  - Direct charge for guiding service.
  - Museum security after closing hours.

Increasing reach and access for underrepresented groups, which is an objective for many museums, is considered to be a significant social benefit of these services. However, as these are nascent applications with no comparable precedent WP2 has not been able to quantify the scale of their value to society.

Within WP8, the cost to provide ubiquitous 5G services across the city scape at scale is being developed. The next period will analyse the marginal cost to provide any additional infrastructure required to support these services so that the net value can be derived to aid optioneering and investment decisions within the vertical.

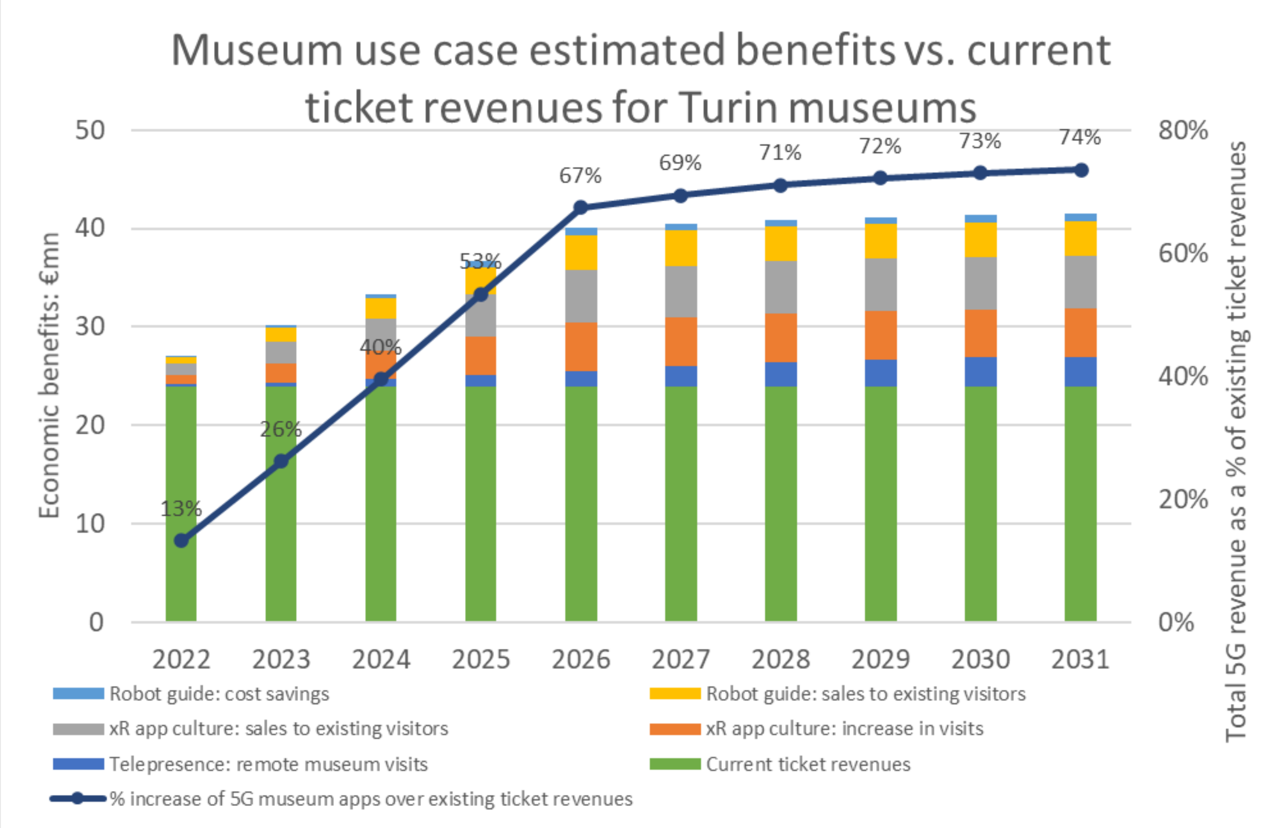

Figure 51. Socio-economic benefits for museum and culture use cases, Turin (D2.3 5.-T. , 2021).

5.3.2 Broadcast sector: benefits in the city setting

Within broadcasting, the benefits represent the value that 5G has the potential to create within the vertical, which can be direct and easily realised by way of additional revenue and cost savings. Commercial benefits are assumed to accrue to actors within the broadcast sector, whilst any wider social value that is create will benefit the commune of Turin. The UC's considered, and the corresponding sources of value are as follows:

- Remote Production (UC5)
  - Cost savings (net of additional costs) in equipment, transport, and personnel
- Content distribution (UC4)
  - Advertising; subscription ser-vices
  - Licence fee payments

In terms of social benefit, WP2 has identified that Public Service Broadcasting (PSB) has the potential to create additional value associated with the distribution of video content (Figure 52).

Remote production will also bring forward new creative opportunities, enriching the services offered to viewers over traditional broadcast and 5G networks. Enabling the production and distribution of immersive content at live events in venues and sports stadia for example would add to the potential for wider economic value creation. However, such services would involve venue owners, who would be the principal stakeholder in deciding the level of investment in 5G infrastructure. Currently this is beyond the current scope to analyse, however the tools and methodologies being developed under WP8 will have the capability to do so.

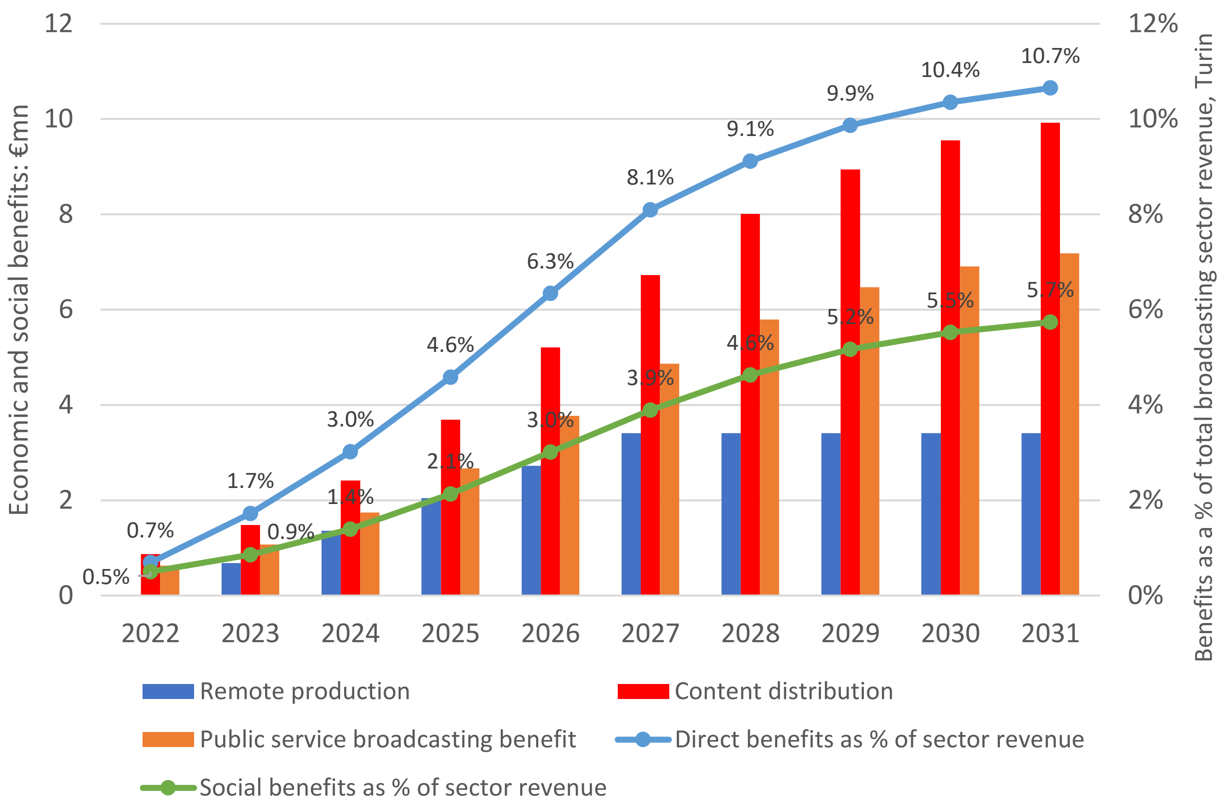

Figure 52. Socio-economic benefits for broadcasting applications, Turin Airport (D2.3 5.-T. , 2021).

As with the tourism UC's, WP8 has commenced the derivations of costs to provide ubiquitous 5G services across the city scape at scale. The next period will analyse the marginal cost to provide any additional infrastructure required to support these broadcast services so that the net value can be derived to aid optioneering and investment decisions within the vertical.

5.4 Media role in the mobile network ecosystem

5.4.1 Market context

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.

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 avoid especially now.

We live in an increasingly digitalized society where new technologies such as XR will make it 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. With actual networks, those requirements can´t be fulfilled and here is where 5G can help. 2021 has been the year when the 5G rollouts have begun to be available, as well as compatible devices supporting these types of scenario, 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.

5.4.2 Service description and purpose

The main goal of the proposed solution is to offer any kind of art centres the possibility of enhancing and enriching their offering and engaging the visitor through active interaction with the are 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 is proposed is an affordable means to overcome the current limitations so that users can access extended information with their own mobile device. Visitors will be 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.

These kinds 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 infrastructure owner's 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 digitalized the cultural content.
- **IT Integrator:** Organization that integrates the whole solution.

5.4.3 Business model and Go-to-market strategy

In 5G-TOURS, ATOS is acting 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, as such, might be included as part of a wider business media portfolio of products, which would create new business opportunities.

However, having in mind the profile of the organisation, instead of just providing the app, developers could play several of the above-mentioned roles, such as the IT integrator one.

On the other hand, in order 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 would have to be in-depth evaluated once the results of the project after the proof of concept in Palacio Madama in Turin are available.

One possible go-to-market strategy might consist of creating a set of additional innovation pilots of these new experiences in other the cultural centres in the tourism sector, early adopters as Palacio 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.

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 UC scenarios could be done.
- The **Barriers** to entry 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.**

5.5 Cost of providing Smart City services in Turin

In this section, the mobile data demand in the city of Torino is estimated for eMBB and AR services, the cost of a 5G network to cover these services are calculated. In addition, the power consumption and the emissions due to the 5G network utilisation are estimated.

The different zones used during the simulation of Turin are shown in Figure 53, where the mobile demand density is estimated per zone, hence the dimensioning of the network is also calculated per zone.

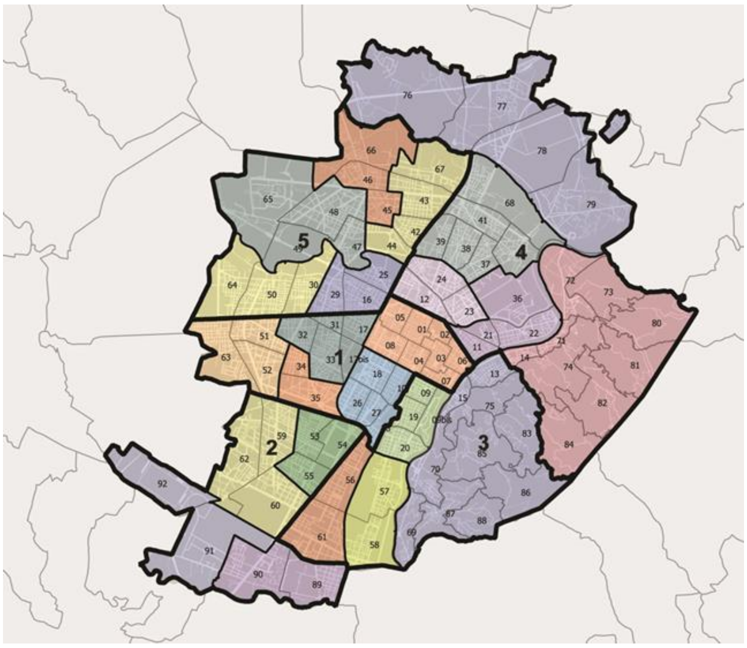

Figure 53. Zones of Torino considered in the simulation.

The graphs in Figure 54 show the population density in Turin per zone. For each range of population density, a specific clutter geotype is specified in the simulation approach.

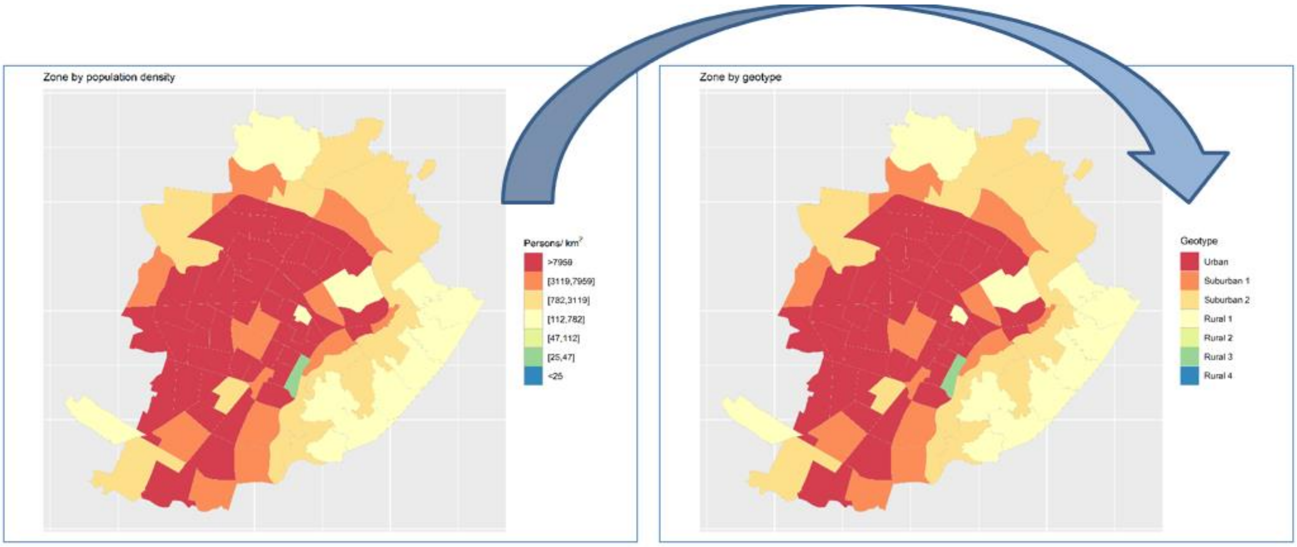

Figure 54. Population distribution and geotypes in Turin / Year 2021.

The population density bands for these geotypes follow Ofcom's Mobile Call Termination model (Ofcom, Mobile call termination market review: 2018-21, 2018) including:

- Urban: > 7959 persons per km^2
- Suburban 1: 3119 < persons per km^2 < 7959
- Suburban 2: 782 < persons per km^2 < 3119
- Rural 1: 112 < persons per km^2 < 782
- Rural 2: 47 < persons per km^2 < 112
- Rural 3: 25 < persons per km^2 < 47
- Rural 4: persons per km^2 < 47

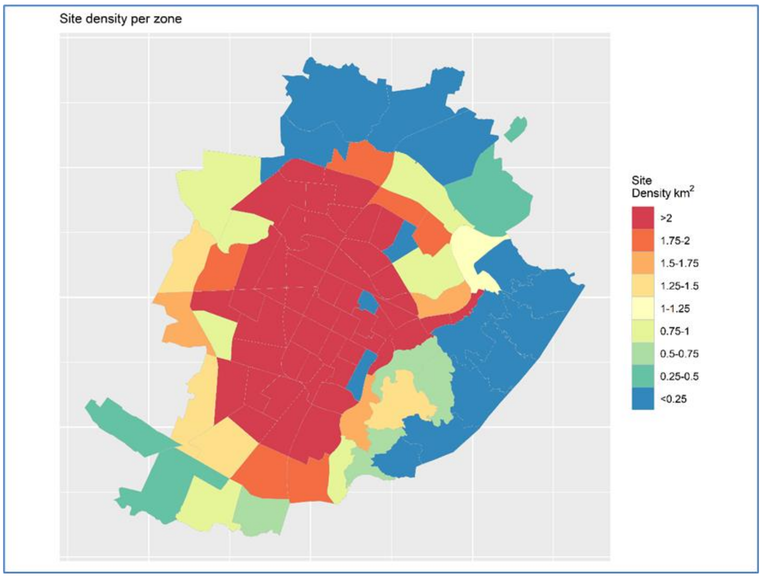

Figure 55. Site density per zone in Turin / Year 2021.

Figure 55 shows the density of TIM 4G sites in Turin ((https://www.cellmapper.net/map, 2021)). Toward the center of the city the density of sites is higher. However at the outskirt of the city, in particular the east side, the density is relatively low as the population is lower in these areas (see Figure 54).

In this simulation, the mobile services assumed are:

- **eMBB:** For mobile data users

  The enhanced mobile broadband (eMBB) is actually what most mobile users consume for 5G since it defines a minimum level of data transfer rate, it promises to deliver both vastly increased bandwidth and decreased latency compared to existing 4G services. eMBB services in this simulation are used for mobile data users.

- **AR:** In Touristic places

  AR is known as the interaction of data, graphics, audio, and other types of sensor's enhancements which are presented in a real-world environment and are displayed in real-time. The simulation was based on AR services for touristic places since it can radically improve the navigation experience and increase the safety of people's journey.

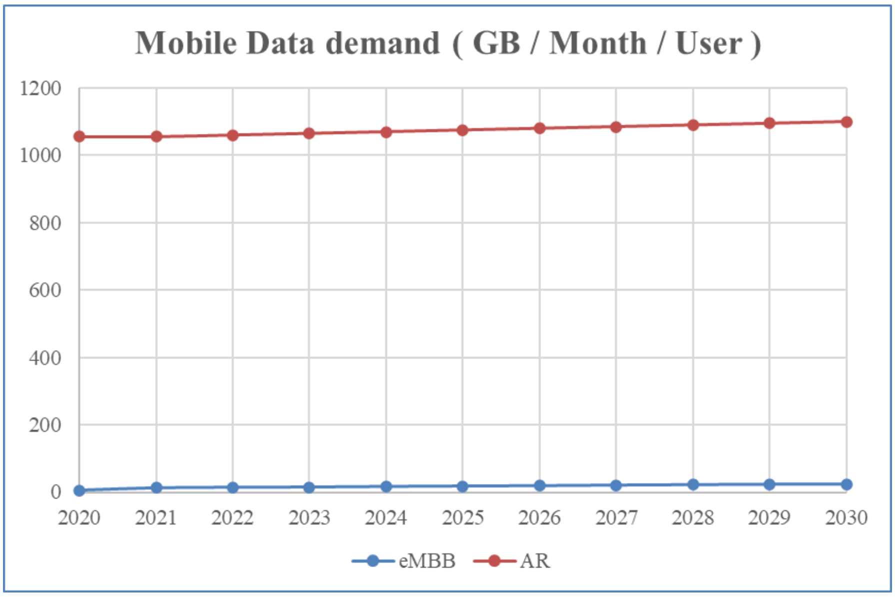

Figure 56. Mobile data demand per user.

The prediction of data consumption of eMBB and AR users are shown in Figure 56. These values are expressed in GB/month/user. It is expected that the mobile data demand for AR user is many times higher when compared to an eMBB user due to the high requirement of the former technology in terms of connectivity. On the other hand, the penetration rate of AR and eMBB services into users is:

- 80% for eMBB services
- 25% for AR services

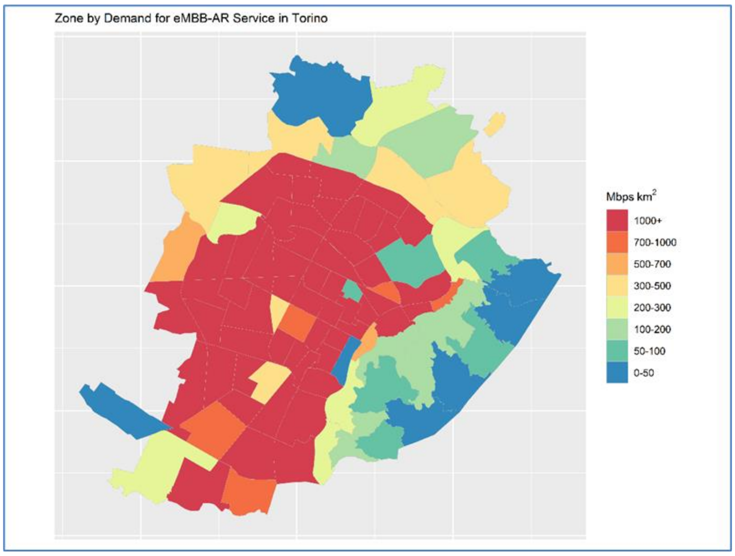

Figure 57. Demand distribution per zone in Turin.

By combining the population and mobile demand services, Figure 57 shows the estimated mobile demand density in the city for 2021. For a high population density, the mobile demand density is also high.

To be able to serve the high density of demand, there are four different strategies that could be applied:

1. <u>Minimal:</u> Initial capacity of the existing asset without any intervention. This way there is no spectrum or additions of sites.
2. <u>Adding 5G spectrum</u>: Adding more spectrum, i.e. 0.7GHz, 3.7GHz and 27 GHz for macro cells sites.
3. <u>Small cells</u>: Deploying new small cells to meet the demand. By following this strategy there is no additional spectrum added to the macrocell sites.
4. <u>Small Cells and spectrum</u>: Adding the 5G spectrum at first to marcocell and then small cell to meet the demand.

The graph below (Figure 58) shows details about the total cost of deployment depending on the services and strategies chosen. The costs are calculated for the period of 2021-2030 and it represents the total cost of a 5G deployment in millions of Euros depending on the service and the strategy chosen. As the graph shows, there is no cost in case the MNO decides to follow the "minimal" strategy, however the cost is the highest in case the "Small cells and spectrum" strategies are followed. By choosing "small cells" strategy, we obtain the lowest total cost for all the services. In addition, the cost values increase with the increment of the additional services.

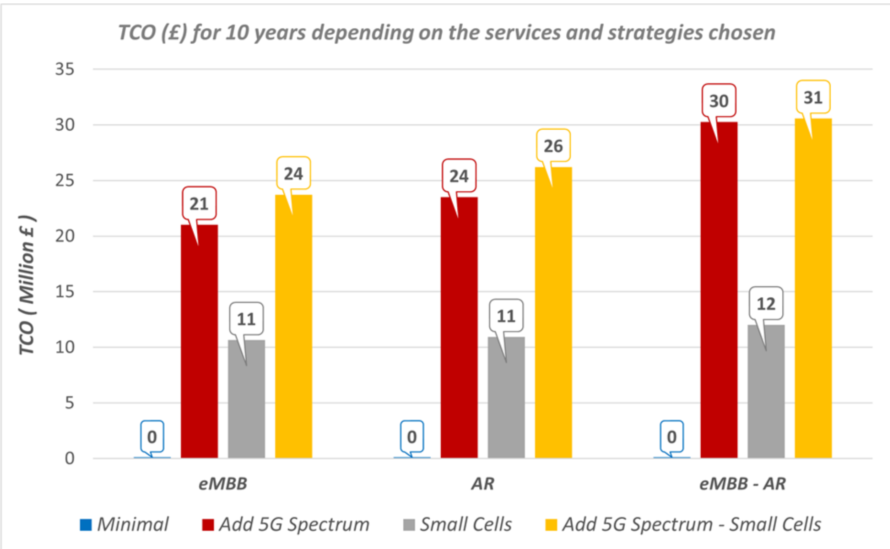

Figure 58. Cost of a 5G network for the city of Turin.

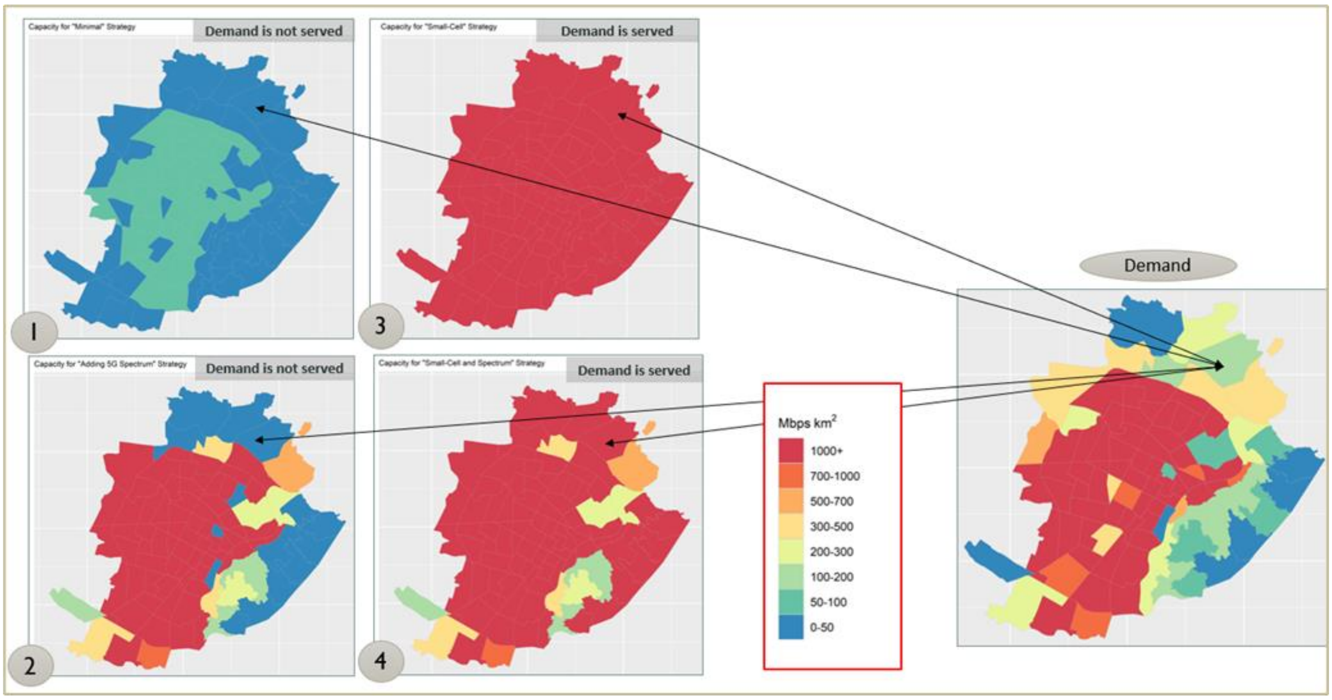

Figure 59. Capacity heatmaps in Turin for each intervention strategy, 2021.

Figure 59 shows the available capacity per zone for the strategies applied:

1. Figure 59-1, **minimal strategy**: Existing asset provide a relatively low capacity, as shown there are few blue and green areas.
2. Figure 59-2, **adding 5G spectrum strategy**: Some zones are blue, i.e. relatively low capacity available. This is due to missing macrocells sites in these zones. In this strategy we don't deploy new macrocell sites to satisfy demand.
3. Figure 59-3, **small cells strategy**: There is relatively larger capacity compared to the other strategies, i.e. red areas in all zones. In fact, deploying small cells adds a significant amount of capacity.
4. Figure 59-4, **adding 5G spectrum and some Small-Cells strategy**: Add a large amount of capacity in some zones, however some zones still have relatively low capacity available, i.e., yellow and green areas.

In conclusion, in terms of capacity, the small cell strategy provided the highest overall capacity. The 5G spectrum strategy add relatively less capacity.

Figure 60 shows the electricity consumption required to serve the mobile demand in Turin for the year 2021. In zones with a high density of sites (see Figure 55) and hence a large data demand, evidently the electricity consumption is the highest.

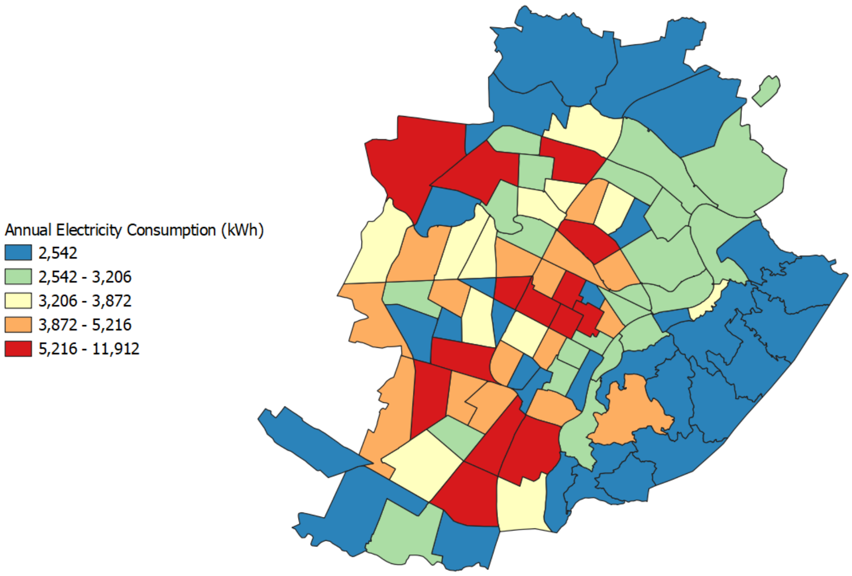

Figure 60. Electricity consumption distribution per zone in Turin, 2021.

Figure 61 translates electricity consumption into the carbon emission distribution per zone assuming that all zones and 5G sites are connected to the grid.

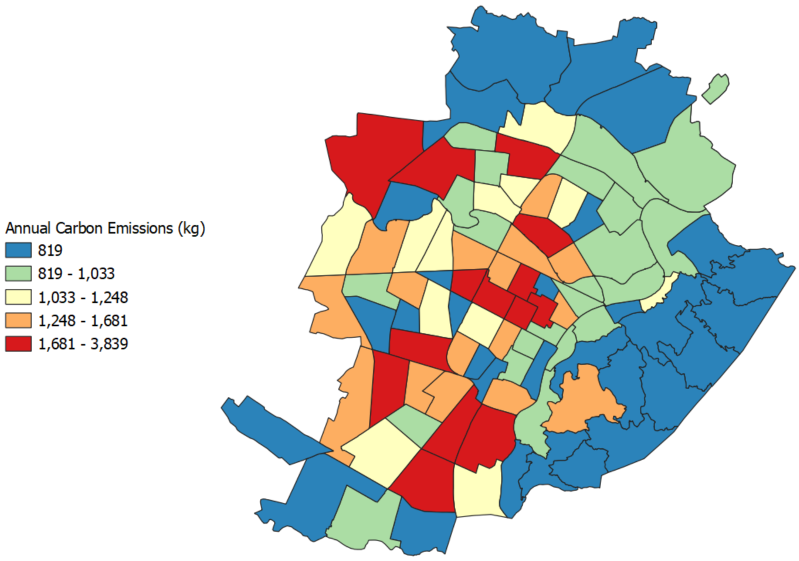

Figure 61. Carbon emission distribution per zone in Turin, 2021.

In **Annex A,** additional results on emissions due to 5G network in the city of Turin are shown.

5.6 Cost assessment for city wide UCs

This section describes the cost assessment for the citywide UC. We use techno-economic model to assess the TCO over 10 years to estimate the costs for the following UCs:

- XR immersive city tour experiences
- Excursion on an AR/VR-enhanced bus
- Remote healthcare
- High quality video distribution
- Remote video production

The methodology and the results are discussed in the following subsections.

5.6.1 Methodology

The example considered here in the Turin study area was set up in the context of considering an existing mobile network delivering eMBB services in and around the city. In 5G-TOURS, we consider several UCs that can be deployed in the cities. In the cost analysis, we estimate the incremental cost in terms of TCO to serve the demand generated from these additional UCs.

The cost estimation is carried out using the high-level modelling approach illustrated in Figure 62. The model considers the following inputs to calculate the number of sites and carrier upgrades required to meet the demand in each year for the next 10 years:

- Demand from existing and new UCs for the next 10 years
- Coverage requirements to support the UCs
- Current technology and its evolutions over the next 10 years
- Existing sites
- Current spectrum and new spectrum bands potentially available during the next 10 years.

It then calculates the incremental TCO for each UC defined below.

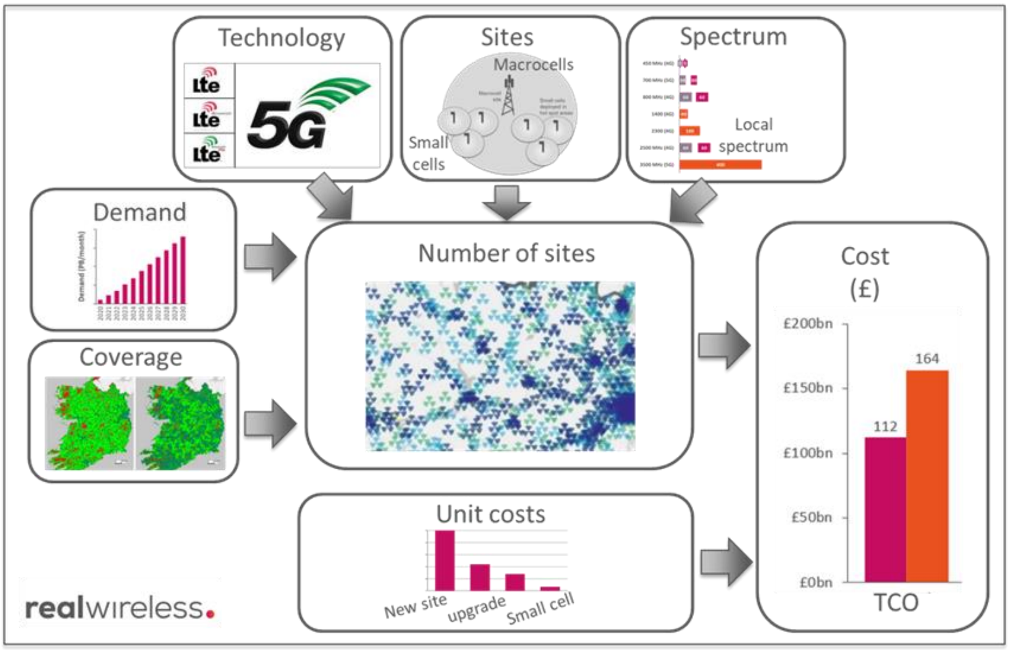

Figure 62. Cost calculation to serve the demand.

Once the cost (in terms of TCO) for each UC is estimated, the incremental cost is calculated by taking the difference between the cost of supporting each new UC and the base case as shown in Figure 63.

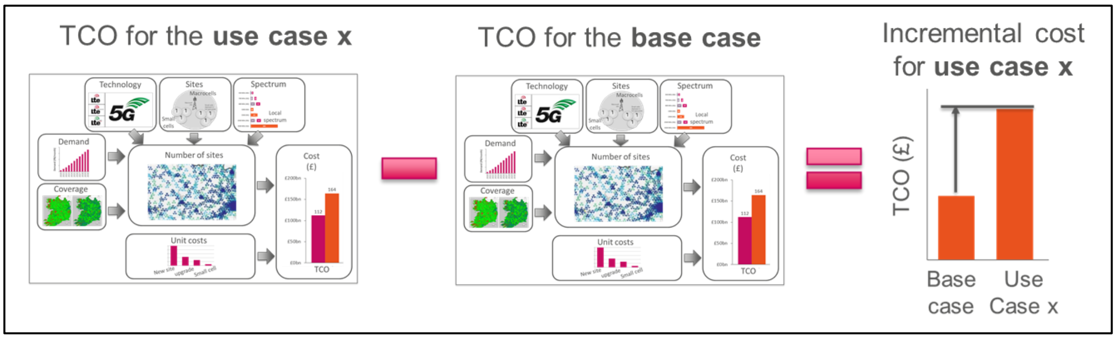

Figure 63. Estimation of the incremental cost to support new UCs.

5.6.2 The city base case

As explained above, in the cost assessment, we consider a scenario where additional network infrastructure is deployed to serve the additional demand generated from the selected UCs in Turin city. For each UC, we calculate the incremental TCO over 10 years by taking the difference between the TCO to serve:

1. eMBB traffic (base case)
2. Additional traffic generated from new UCs

For both cases, we consider typical capacity solutions MNOs use to increase the capacity in mobile networks.

For the base case: i.e. natural evolution of eMBB traffic, we consider three demand cases namely low, medium, and high demand. Typically, the capacity in mobile networks is driven by the demand during the busiest hour in the network known as the busy hour. The total demand generated by all users in Turin city during the busy hour is shown in Figure 64. We assume that three MNOs serve this total demand with each having a 33% market share.

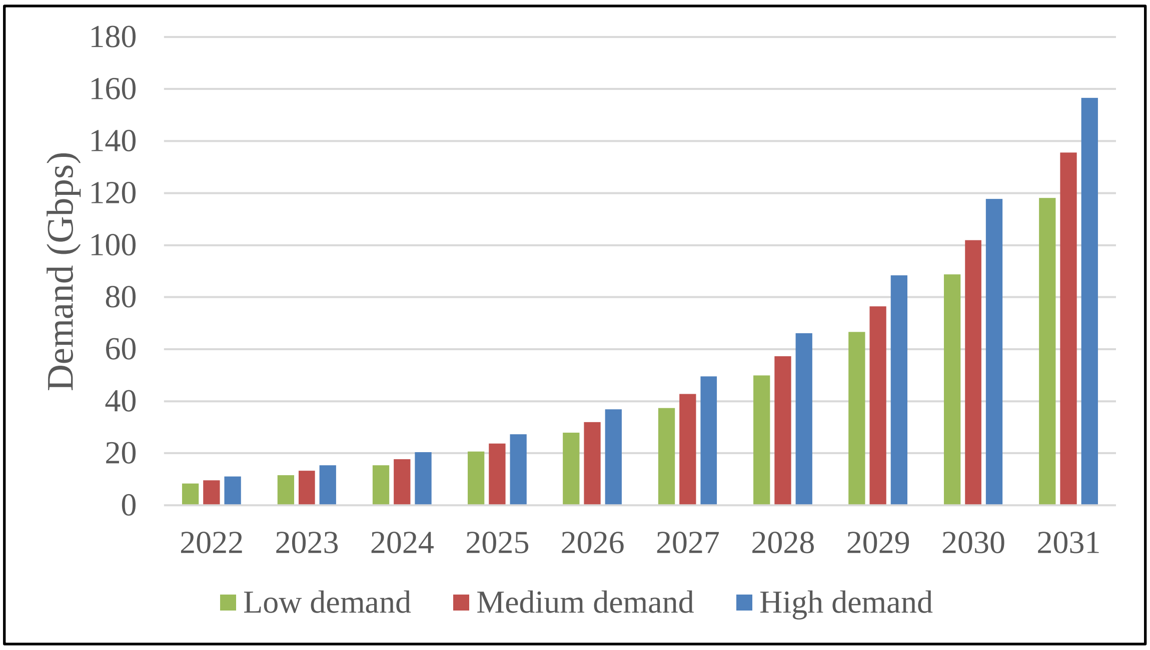

Figure 64. Total Average demand during the busy Hour in Turin.

To serve this demand the network capacity has be increased over the year.

Existing mobile networks deliver services across the city using a variety of different infrastructure types (cell sites). These include macrocells and small cells (SCs). Since this section of the study focuses on outdoor infrastructure, we calculate the outdoor infrastructure required to serve the demand.

The process for identifying the need for a macro cell site to be located has evolved over the years from a primarily coverage type requirement to a primarily capacity type requirement – there are exceptions to this in rural locations where the need for coverage for even the most basic of mobile services, voice, has never been fully met due primarily to the high costs and limited return on investment associated with building cell sites in rural locations.

There are many challenges associated with the acquisition and build of suitable cell sites at or near the locations required by the mobile networks to meet coverage and capacity requirements i.e. gaining consent from landlords and building owners and planning consent from local authorities, are particular challenges. We assume acquiring, designing and building new cell sites are possible around the desired locations.

Due to a variety of factors, most notably the cost of providing transmission and power to the site and the cost of building sites can vary greatly – this would normally lead to a range of site build costs of low, medium and high. For the purposes of the cost estimates in this report we have used medium site build costs only.

The assumed TIM infrastructure in place for 2021 is based upon the publicly available information, i.e. 221 macros in 2021.

Demand is assigned to each morphology separately but assumed to be even across urban, suburban and rural areas, i.e. demand is spread across each area uniformly. This means hot spots are not considered in this modelling.

The total spectrum utilized in the network depends on the availability of spectrum band, the terminal availability and penetration and the status of the deployment.

We considered two deployment options:

- MNO deployment using MNO spectrum: widely used option where MNOs expanding their networks to support the additional UCs emerging. We assumed the spectrum utilization as shown in Figure 65.
- Private operator deployment using localized spectrum: Private network operator deploying radio network assets and making use of localized spectrum. In this case, we assumed that 60 MHz of 3.6 GHz spectrum and 100 MHz of 26 GHz spectrum is available to the operator. The network consists of small cells deployed in the areas where the demand exists.

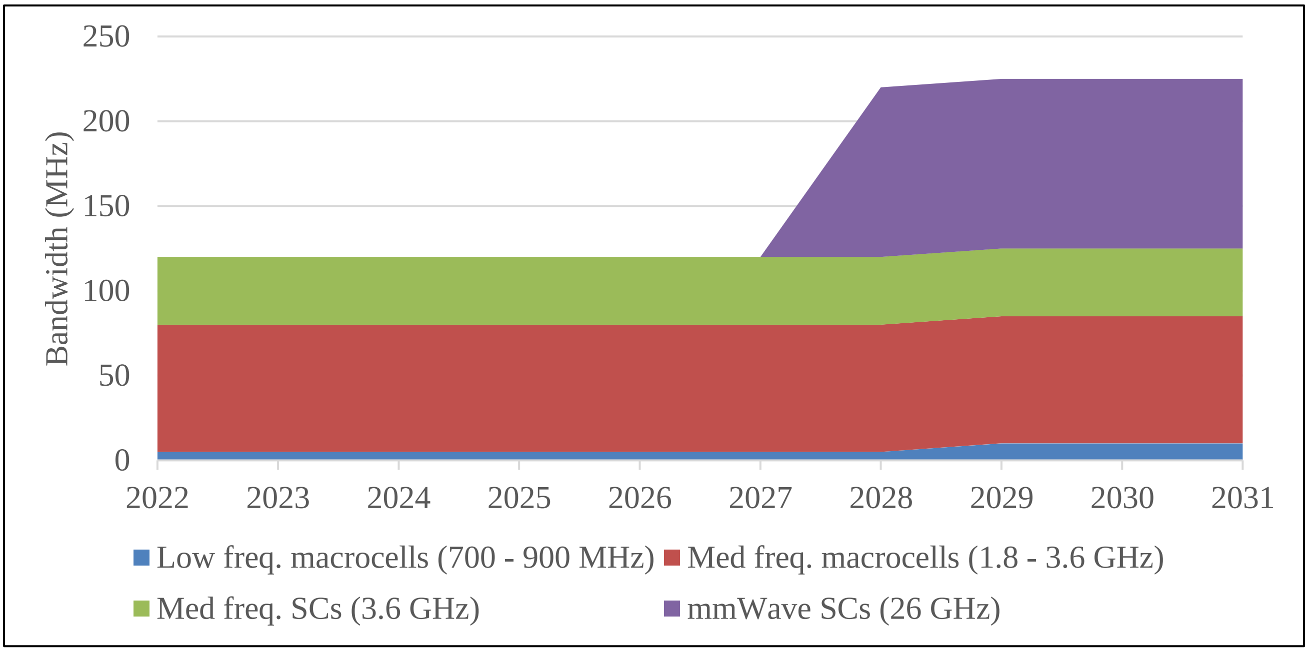

Figure 65. Total utilised spectrum.

The estimated number of sites to serve low, medium and high demand (i.e. the base case) are shown in Figure 66. The outcome shows that capacity increments available from deploying medium frequency carriers are sufficient until 2030. From 2031 onwards additional macrocells and small cells are required to meet the demand. It also shows that mmWave small cells are not required to serve the demand.

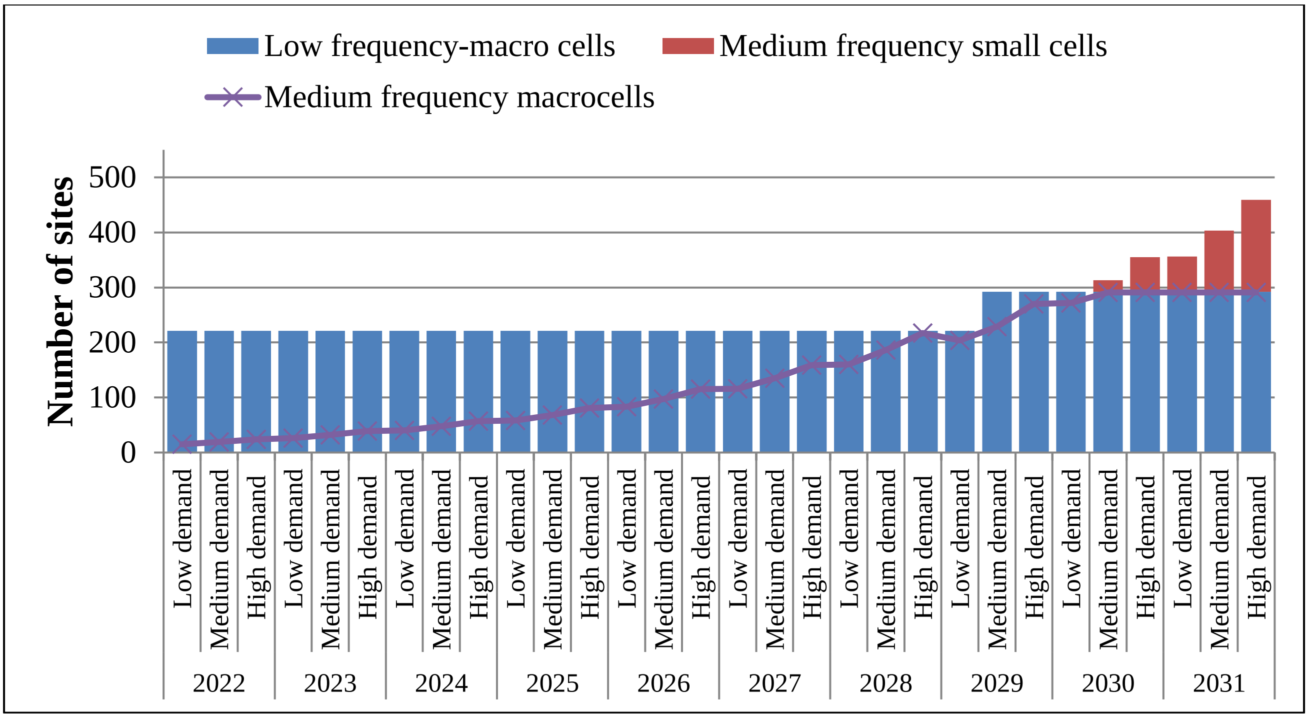

Figure 66. Total Average demand during the busy Hour in Turin.

Unit costs considered for the TCO calculation is shown in Table 6**.**

Table 6. Unit costs considered for TCO calculation

Cost item	Site type	CAPEX	OPEX
New build	Street furniture small cell	€ 47,000	€ 6,000
	3-sector macrocell	€ 113,000	€ 27,000
Carrier upgrade	Macrocell (low frequency band)	€ 13,000	€ 8,000
	Macrocell (med freq. band)	€ 42,000	€ 8,000
	Street furniture small cell	€ 12,000	€ 2,000

Figure 67 shows the TCO for MNO deployment using MNO spectrum for low, medium and high demand cases. For all demand cases, the cost is dominated by OPEX i.e. OPEX is approximately three times higher. This is because, for the considered demand evolution, network capacity can be met with low-cost options such as carrier upgrades until 2028. Once the additional new sites are deployed in 2029, the demand in the subsequent years can be met using low-cost options such as small cell and carrier upgrades. New site deployments are approximately 3 times more expensive compared to the deployment of small cells or carrier upgrades.

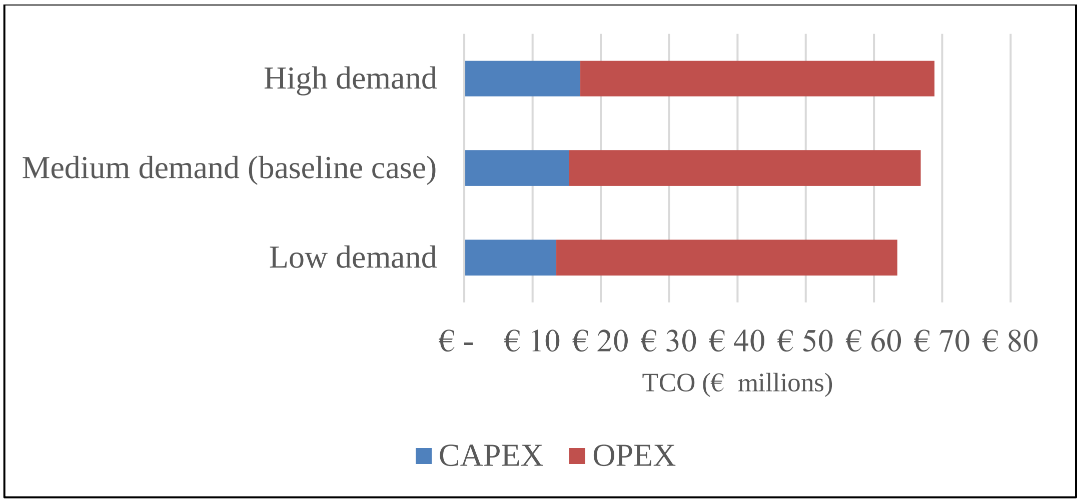

Figure 67. TCO for MNO + MNO spectrum deployment option.

The TCO of private operator deployment using localized spectrum is approximately 3.4 times cheaper compared to the TCO of MNO deployment using MNO spectrum. This is because the demand for the private operator option is met by deploying small cells in the areas where the demand is generated from the additional UCs rather than city wide coverage provided by the MNOs. Our objective is to calculate the incremental costs to serve these UCs for both cases. Therefore, we have not carried out a comparison of the absolute costs.

Private operator deployments using localized spectrum is expected to take place in the areas where the demand is generated from the additional UCs rather than city wide coverage provided by the MNOs. Our objective is to calculate the incremental costs to serve these UCs for both cases. Therefore, we have not carried out a comparison of the absolute costs.

5.6.3 Incremental cost assessment for the UCs

The cost assessment that will be carried out for the scenarios is shown in Table 7 below.

Table 7. Scenarios 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	Provide AR and VR 5G services for passengers inside a bus
Tourism	Provide several application services in and around tourism UCs
Broadcast	Broadcasting services on 5G network
Healthcare	Remote health services on 5G network

We assumed that the evolution of eMBB and the UCs listed in Table 7 are independent. Therefore, the total demand in the network would be the demand from each UC plus the demand from eMBB services.

The results and analysis for each of these UCs will be presented in the next deliverable, i.e. D8.4.

5.7 5G-TOURS network implementation aspects for Turin site

Work Package 4 – Touristic City – in Turin is utilizing the 5G technology to implement a number of UCs that aim to provide value services at the visited touristic attractions. The UCs 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 UC 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.

5.7.1 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 UCs 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 UCs 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 UCs (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.

5.7.1.1 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.

It was a crucial understanding (not only for Ericsson) 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 68. Indoor Radio Installation masked result.

Figure 69. R4422 radio detail.

5.7.1.2 GAM

GAM indoor coverage implementation started after the Palazzo Madama solution was completed. It took the advantages gained by the experience at Palazzo Madama even more considering the context in which the Network must be deployed. The building is provided 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 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 constraint 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 70. 5G Dot 4479 installation at GAM.

Figure 71. Ericsson Dot 4479.

5.7.2 Summary and opportunities for other deployment environments

Based on the experience gained so far in the deployment of the Museum UCs 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 UCs in Turin. It cannot be stressed enough the importance of this initial phase of a deployment 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 understand 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 to select from a network perspective, 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 (Ericsson Radio System, 2021).

Similar product portfolios are provided by other Telecommunications and Network providers.

The Robot UC in Turin should not be considered limited to this specific environment, on the contrary. The experienced achieved shows that a UC as advanced as the guiding Robot in a very complex environment like a museum is feasible and as such 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 the 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 models 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.

5.7.3 5G Sustainability

Sustainability and responsible business practices are fundamental to network providers’ strategy and culture and that of the wider supply chain. Ericsson, for example, 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 (see (Ericsson Sustainability, 2021)).

For that reason, in the introduction of 5G technology, sustainability has been a key requirement for the (Ericsson Radio System, 2021) 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 UCs with different requirements by securing that 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 offers unprecedented peak rates, latency and capacity and 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 ecosystem and provide 5G experience for all 5G devices from day one.

FDD low-band with our Ericsson spectrum sharing (Ericsson Spectrum Sharing, 2021) 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 nationwide 5G coverage from existing installations 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 (Ericsson Network Operations, 2021) to enhance the level of automation and openness of network leveraging on AI and ML to build data-driven, predictive and proactive zero-touch solutions.

6 Conclusions

This latest period has demonstrated considerable progress of the 5G-TOURS project. The technological innovations have been consolidated around the various evaluation case settings and the attention has turned toward the economic viability of those innovations and how they might be accessed by industry verticals to enable greater value realisation.

We have shown that 5G is 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, in many cases, wireless connectivity is not part of the verticals' core business and there are significant gaps in expertise and knowledge regarding the optimum method of delivery (whether technology or architecture related), or concerning the most appropriate business models.

One of the central themes that has been explored here are the challenges for actors in the vertical industries to navigate the increasing complexities of mobile technologies. We have seen there is a huge potential for 5G to underpin significant commercial, social and economic value from the wider efforts to digitise our world, however no single organisation or entity has the ability to act unilaterally, at the required scale, to realise these benefits. At the same time, the preliminary cost assessment has indicated the potential for considerable economies of scale if stakeholders can work together to implement the infrastructure needed to deliver value-enabling UC's and applications.

In the airport setting the cost savings of implementing smart parking together and video enabled follow-me vehicles together with a public eMBB 5G service could potentially save more than €1.1m of the cost to deploy each UC separately, representing savings of over 66%. It is easy to see how such savings might accumulate with further, *compatible* stakeholder's requirements in the mix. Value chains are evolving along various dimensions, turning into complex matrices of actors that are challenging to navigate. The key to unlocking the maximum benefit, therefore, must surely be through the collaboration of key stakeholders.

The supply side ecosystem has a major part to play in helping verticals along their journey by assisting them to navigate the complexities of 5G connectivity and the digital transformation it enables. At the same time stakeholders need to be transparent regarding their goals and requirements so that alignment can be sought across as many dimensions as possible, as quickly as possible. The 5G-TOURS business model framework has been developed to bring the supply side and the industry-specific demand side ecosystems together. We have taken the perspective of the demand side buyer and sought to demonstrate how the supply side ecosystem has evolved an abundant diversity of 5G innovations, architectures and business models, which can be exploited to leverage common ground and achieve strategic alignment between stakeholders on both sides.

What verticals really care about are business outcomes rather than the detailed features of the technology or the innovations and so the key to maximising investment in 5G infrastructure is to really understand the potential to create value. 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. This has been explored in some detail under task 2.3 and has been incorporated into the work described here. Allied to that is a need to understand the costs and the drivers of cost. Transparency amongst stakeholders on both demand and supply sides concerning benefits and costs is important in ensuring proportionality, fairness and equitable risk sharing.

In this period, we have laid the foundations for developing a suite of tools that can be used to explore the diversity of options open to buyers within the vertical and to help them understand the commercial and operational implications of those options.

Cost is a large component of the investment decision. Decision makers on the demand side will always weigh the opportunity cost of investing in 5G against other projects and technologies that might benefit their enterprise. Accordingly, the Real Wireless suite of tools has been developed to provide clarity on the costs and benefits from deploying 5G wireless infrastructure in various environments and across all of the architecture types covered in 5G-TOURS. 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 infrastructure.

We have also looked at how financial structuring is an important part of the investment decision, with some enterprises and stakeholders favouring solutions that are more biased towards OPEX than CAPEX and vice versa. In the case of private networks up to 66% of customers favour an OPEX based approach and this tendency may increasingly be reflected in the evolution of 5G business models as enterprises demand more flexibility and the ability to adapt their connectivity needs incrementally. Yet, since 5G has the potential to create enormous social and economic benefit, i.e. beyond its own market value, major vertical stakeholders[10] 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.

Work to refine the tools and expand the cost scenarios is in progress and will continue into the next reporting period where we aim to develop more detailed costings, validate our assumptions among the partners and examine willingness to pay by stakeholders within the verticals. This was intended to have been part of the various workshops and was therefore linked to the workshop schedule, however we may consider approaching stakeholders directly to endorse the claims of the project regarding business viability and suitability of the different business models.

[10] Landlords, anchor tenants and those driving 5G infrastructure investment.

Acknowledgment

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7 Bibliography

(2021). Retrieved from https://www.cellmapper.net/map.

3GPP. (2021). *Rel. 16.* 3GPP.

3GPP. (n.d.). *TR 23.757: Study on architectural enhancements for 5G multicast-broadcast services.* Retrieved from https://www.3gpp.org/ftp//Specs/archive/23_series/23.757/23757-120.zip

3GPP. (n.d.). *TR 26.802: 5G Multimedia Streaming (5GMS); Multicast architecture.* Retrieved from https://www.3gpp.org/ftp//Specs/archive/26_series/26.802/26802-030.zip

5G-Ensure. (2017). Deliverable D3.6 5G-PPP security enablers open specification.

5GPP. (2017). *White Paper Phase 1 Security Landscape.*

Allied Market Research. (2020). Retrieved from https://www.alliedmarketresearch.com/smart-parking-market.

B. Sas, K. S. (2014). Classifying Users based on their Mobility Behavior in LTE networks. *10th Int. Conf. on Wireless and Mob. Comms. (ICWMC).*

BNB, E. (2017). Retrieved from https://ecobnb.com/blog/2017/12/paths-italy-atlas.

Cisco. (2014). Quality of Service Design Overview. In *Cisco Press book End-to-End QoS Network Design: Quality of Service for Rich-Media & Cloud Networks, 2nd Edition* .

Cloud Watch Hub. (2017). Retrieved from http://www.cloudwatchhub.eu/exploitation/market-technology-readiness-level-mtrl-nutshell.

Cloud Watch Hub. (2017). Retrieved from https://www.cloudwatchhub.eu/exploitation/readiness-market-more-completing-software-development.

Cloud Watch Hub. (2020). Retrieved from https://www.cloudwatchhub.eu/exploitation/brief-refresher-technology-readiness-levels-trl.

D2.3. (2021). *D2.3.* 5G TOURS.

D2.3, 5. T. (2021). *D2.3.* 5G TOURS.

D2.3, 5.-T. (2021). *Technical requirements of the use cases, economic and deployment implications.*

D8.1, 5.-T. (2020). *First Report on Innovation Management, Dissemination, Standards and Exploitation Plans.*

D8.2. (2021). *Second report on innovation management, dissemination, standards and exploitation plans.* 5G TOURS.

DCMS. (2018). *Future Telecoms Infrastructure Review.* UK Government, Department for Culture Media and Sport and The Rt Hon Jeremy Wright QC MP. London: UK Government.

Ericsson. (2021). Retrieved from https://www.ericsson.com/492da5/assets/local/about-ericsson/sustainability-and-corporate-responsibility/documents/2021/ericsson-sustainability-and-corporate-responsibility-report-2020_eng.pdf.

Ericsson. (2021). *https://www.ericsson.com/492da5/assets/local/about-ericsson/sustainability-and-corporate-responsibility/documents/2021/ericsson-sustainability-and-corporate-responsibility-report-2020_eng.pdf*.

Ericsson Network Operations. (2021). Retrieved from https://www.ericsson.com/en/network-operations.

Ericsson Radio System. (2021). Retrieved from https://www.ericsson.com/en/portfolio/networks/ericsson-radio-system.

Ericsson Radio System. (2021). Retrieved from https://www.ericsson.com/en/portfolio/networks/ericsson-radio-system.

Ericsson Spectrum Sharing. (2021). Retrieved from https://www.ericsson.com/en/ran/spectrum-sharing.

Ericsson Sustainability. (2021). Retrieved from https://www.ericsson.com/492da5/assets/local/about-ericsson/sustainability-and-corporate-responsibility/documents/2021/ericsson-sustainability-and-corporate-responsibility-report-2020_eng.pdf.

GSMA. (2021). *The Mobile Economy 2021*.

Hsu, M. L.-J. (2013). Mining GPS data for mobility patterns: A survey. *Pervasive and Mobile Computing.*

IHS. (2019). *The 5G Economy.* IHS Markit.

IMT. (2015). *M2370 - IMT Traffic estimates for the years 2020 to 2030.*

Marjalaakso, M. (n.d.). Security Requirements and Constraints of VoIP. *Helsinki University of Technology*.

Market, M. a. (2020). *https://www.marketsandmarkets.com/Market-Reports/telehealth-market-201868927.html*.

Mckinsey. (2020). Retrieved from https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/telehealth-a-quarter-trillion-dollar-post-covid-19-reality.

METIS. (n.d.). *FP7-ICT-317669-METIS/D1.1* .

Mobile Europe. (2021). Retrieved from https://mobileeurope.co.uk/press-wire/15405-shared-and-unlicensed-spectrum-to-boom-this-decade.

NGMN. (n.d.). *5G White Paper.*

Ofcom. (2018). *Connected Nations.*

Ofcom. (2018). *Mobile call termination market review: 2018-21.*

Politicshome. (2021). Retrieved from https://www.politicshome.com/ugc-1/1/3/0/new_age_of_air_travel_infographic.pdf.

Qualcomm. (2016). *Making Immersive Virtual Reality Possible in Mobile.*

Qualcomm Technologies, I. (2017). *VR and AR pushing connectivity limits.*

Real Wireless. (2020). *Private cellular networks: opportunities, challenges and the future.* Retrieved from https://real-wireless.com/publications/private-cellular-networks/.

Research, A. M. (2020). *https://www.alliedmarketresearch.com/smart-parking-market*.

Rogers, E. M. (1962). *Diffusion of innovations.* New York: Free Press of Glencoe.

Rogers, E. M. (1962). *Diffusion of Innovations.* New York: Free Press of Glencoe.

S. Rangan, T. S. (2014). Millimeter-Wave Cellular Wireless Networks: Potentials and Challenges. *IEEE, 102*(3), 366-385.

Techradar. (2021). Retrieved from https://global.techradar.com/en-ae/news/telecom-operators-need-a-clear-proposition-to-drive-revenue-growth-in-b2b-space.

Union, E. (2019). Retrieved from https://european-union.europa.eu/principles-countries-history/key-facts-and-figures/economy_en.

WEF. (2020). *The Impact of 5G: Creating New Value across Industries and Society.* World Economic Forum.

World Economic Forum. (2016). Retrieved from https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/.

Annex A: Further results on 5G BSs emissions to provide smart city services

Figure 72 shows the Nitrogen Oxide emission distribution per zone. Zones with high electricity consumption emit larger amounts of Nitrogen Oxides than zones with a lower electricity consumption, given all zones are connected to the grid.

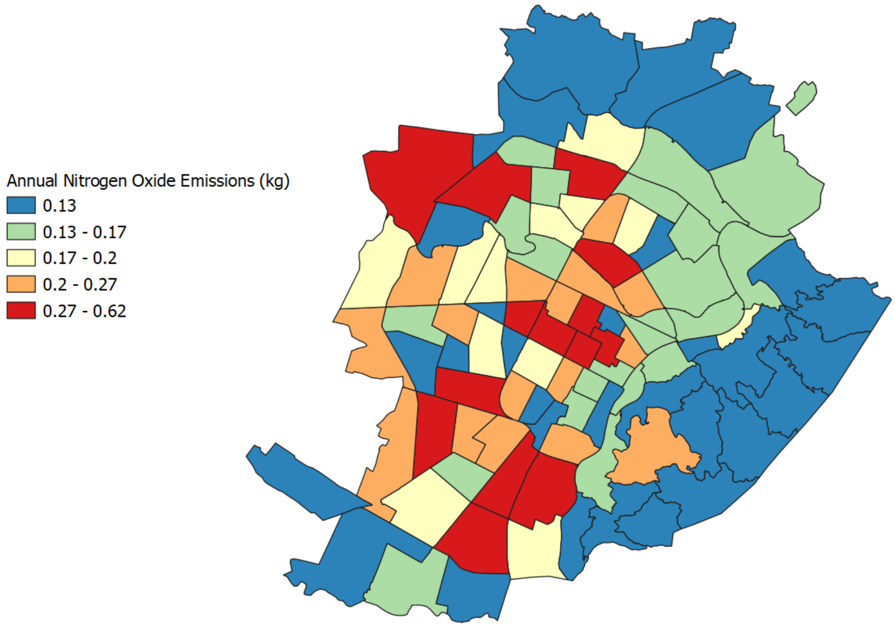

Figure 72. Nitrogen Oxide emission distribution per zone in Turin, 2021.

Figure 73 shows the Sulfur Dioxide emission distribution per zone. Zones with high electricity consumption emit larger amounts of Sulfur Dioxides than zones with a lower electricity consumption, given all zones are connected to the grid.

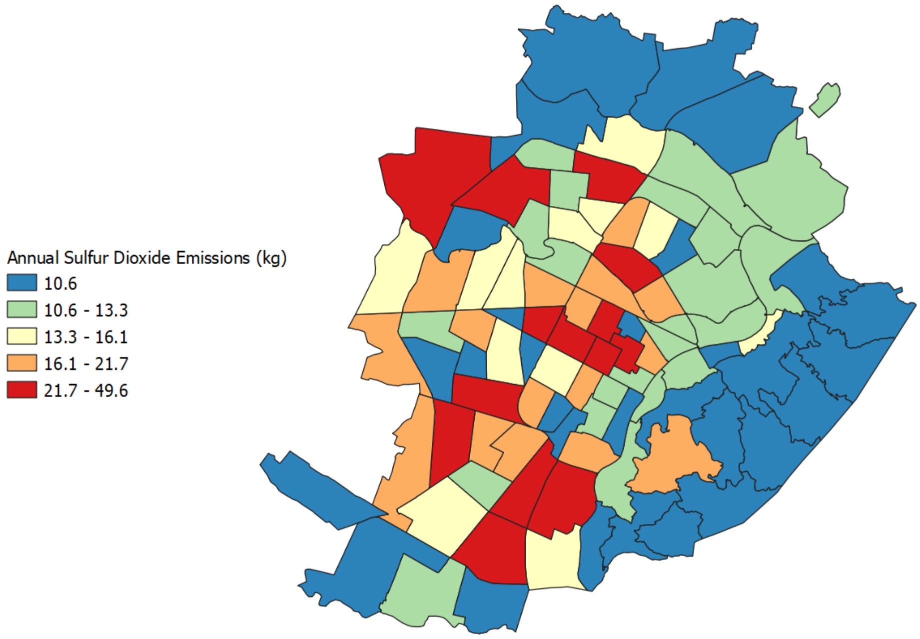

Figure 73. Sulfur Dioxide emission distribution per zone in Turin, 2021.

Figure 74 shows the particulate matter emission distribution per zone. Zones with high electricity consumption emit larger amounts of particulate matter than zones with a lower electricity consumption, given all zones are connected to the grid.

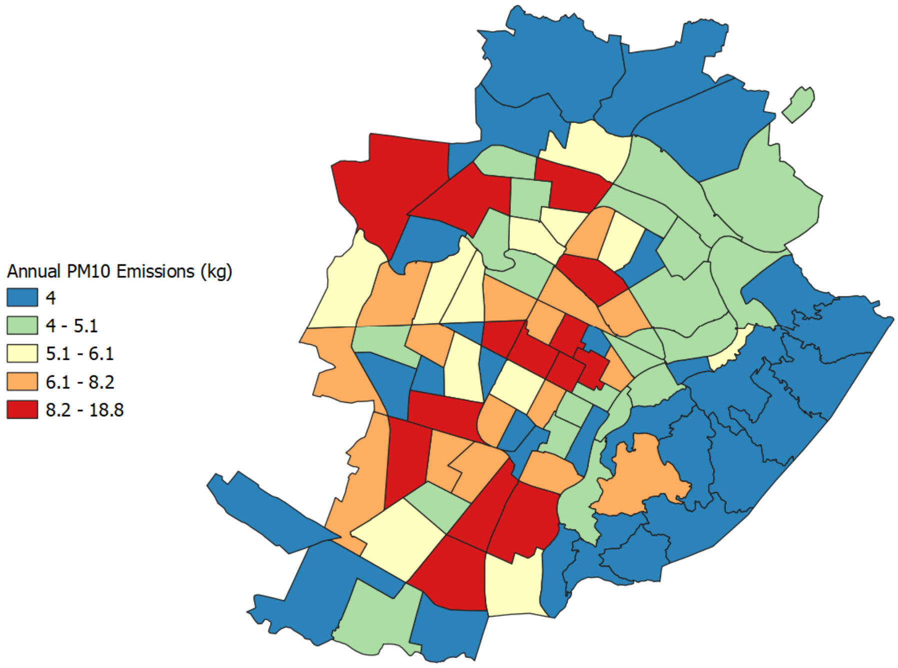

Figure 74. Particulate matter (PM10) emission distribution per zone in Turin, 2021.