White Paper

The Impact of 5G: Creating New Value across Industries and Society

In collaboration with PwC

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Foreword

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The Fourth Industrial Revolution offers an opportunity for diverse sectors to enhance their competitiveness and contribution to regional economies, while supporting the United Nations Sustainable Development Goals. This industrial revolution is powered by both established and emerging technologies, including the internet of things, artificial intelligence, advanced data analytics, robotic process automation, robotics, cloud computing, virtual and augmented reality, 3D printing and drones. One key enabler that allows these technologies to realize their full potential is connectivity.

Industrial revolutions have been characterized by the transformation of physical infrastructure networks. Electricity powered the Second and Third Industrial Revolutions, as networks achieved economies of scale by connecting large plants over high-voltage transmission grids to local distribution networks reaching many users. The Fourth Industrial Revolution's full potential will be fully realized through the wide-scale deployment of 5G communication networks.

5G will be critical because it will enable unprecedented levels of connectivity, upgrading 4G networks with five key functional drivers: superfast broadband, ultra-reliable low latency communication, massive machine-type communications, high reliability/availability and efficient energy usage. Together, these defining features will transform many sectors, such as manufacturing, transportation, public services and health.

To ensure the widespread deployment of 5G networks, key stakeholders must address important questions. Government regulators and city managers must decide whether and when to invest in 5G infrastructure; mobile and telecommunications operators must evaluate suitable business models; and citizens must find ways to realize the full benefits this technology can bring while ensuring the preservation of the community's rights.

The transition to 5G networks can only be achieved when all stakeholders – citizens, the private sector and government – collaborate to effectively address these questions. The insights and recommendations in this White Paper aim to pave the way towards accelerating a sustainable and inclusive transition to 5G networks globally, creating significant economic and social value.

Executive summary

The positive impact of the Fourth Industrial Revolution and its related emerging technologies will be fully realized through the wide-scale deployment of 5G communication networks in combination with other connectivity solutions. The key functional drivers of 5G will unlock a broad range of opportunities, including the optimization of service delivery, decision-making and end-user experience.

Significant economic and social value can be generated by enabling use cases activated by 5G. An IHS Markit study[1] estimates that $13.2 trillion in global economic value will be made possible by 2035, generating 22.3 million jobs in the 5G global value chain alone.

To better understand it, the 5G ecosystem was mapped out to identify its components, its stakeholders and interdependencies, and the actions needed to accelerate 5G deployment and fully realize the potential. A set of challenges was identified for each component (spectrum, infrastructure, devices, services, impact and security). To ensure that all the actions to accelerate 5G deployment are coordinated and the interdependencies are understood, strong collaboration between stakeholders is needed. One key area for collaboration that requires multistakeholder input is a strengthening of the business case for 5G through the quantification of the potential social value that can be created. Many of the current use cases are technically enabled by the functional drivers of 5G and activated through multistakeholder cooperation and collaboration.

An analysis of 40 use cases was conducted as part of the development of this White Paper, which identified key industrial advances and social impact areas in addition to the main functional drivers of 5G and the required maturity levels of these features. The results of this analysis, complemented by insights from stakeholder interviews and several cross-industry workshops, generated the following key findings:

Industrial advances

5G will contribute to industrial advances in three significant ways: by 1) enabling faster and effective inspections through predictive intelligence; 2) improving workplace and worker safety; and 3) enhancing operational effectiveness. 5G also has the potential to impact industry by managing the carbon footprint and bridging the digital divide, which together apply to 63% of the use cases identified.

Social impact

5G can deliver social value across 11 key areas that correspond to 11 of the United Nations' 17 Sustainable Development Goals (SDGs). This value derives mainly from contributing to good health and well-being, enhancing infrastructure, promoting sustainable industrialization and fostering innovation. Other key areas in which social value is created through 5G include contributing to responsible consumption, enabling sustainable cities and communities, and promoting decent work and economic growth.

Functional drivers

Five key functional drivers of 5G support certain technological applications. They are: 1) enhanced mobile broadband; 2) ultra-reliable low latency communication; 3) security; 4) massive machine-type communications; and 5) power efficiency. Most (93%) of the use cases analysed would be enhanced by ultra-reliable low latency communication and 78% by enhanced mobile broadband. Massive machine-type communications and security are also important, with each driver contributing to 45% of the use cases analysed. It is important to note that 5G could be the ideal technology for certain solutions, but others might be sufficiently served with WiFi, 4G or even earlier generations of networks.

5G maturity

5G deployment will occur in phases with certain functional drivers improving over time. However, not all the use cases identified require these functional drivers at full maturity. The key drivers in their current state and in the short term that have the highest potential to disrupt are low latency communication and enhanced mobile broadband.

Significant economic and social value can be gained from the widespread deployment of 5G networks. Technological applications, enabled by a set of key functional features, will both facilitate industrial advances, improving their bottom line, and enhance city and citizen experiences. To accelerate the adoption of 5G, new collaboration models among stakeholders are needed, along with clear methodologies to estimate the social value creation, which will enhance the business case of 5G.

For additional information on the use cases, their industrial advances and social value creation potential, as well as their enabling functional drivers, see the accompanying use case repository http://www3.weforum.org/docs/WEF_The_Impact_of_5G.pdf.

Introduction

Fast, intelligent internet connectivity enabled by 5G technology is expected to create approximately $3.6 trillion in economic output and 22.3 million jobs by 2035 in the global 5G value chain alone.[2] This will translate into global economic value across industries of $13.2 trillion, with manufacturing representing over a third of that output; information and communications, wholesale and retail, public services and construction will account for another third combined.[3] To make that happen, however, trillions will first have to be invested to introduce global 5G networks. 5G presents an opportunity for companies to be first movers, but greater cooperation is needed to accelerate deployment.

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Over the past decade, as 5G was first imagined, then developed, and then launched, those of us in the tech and telecommunications industries became increasingly excited by its potential. We knew from an early stage that 5G would make digitalization more accessible, allowing small businesses, public services and even individual households to reap the benefits of smart products and services. But what we didn’t know was exactly what those products and services would look like. Now we know. This paper, which we have actively contributed to, shows that 5G’s speed, reliability and scale are already unlocking huge social and economic gains. This is the future – and Nokia is delighted to play its part.

”

Rajeev Suri, President and Chief Executive Officer, Nokia

While several countries have initiated roadmaps for the 5G rollout, others are falling behind due to a diverse set of challenges that will require an unprecedented level of collaboration between business, the public sector and broader stakeholders in society. These have repercussions across several areas of the ecosystem, including in creating new business models, fostering innovation, defining investment models for digital infrastructure, preparing for cybersecurity scenarios and, more broadly, ensuring sustainability and positive societal impact.

To understand these systemic challenges, the World Economic Forum has initiated a 5G-Next Generation Networks Programme to help enterprises across industries transform while shaping an inclusive and sustainable transition to the next generation of networks. This programme is part of the Digital Economy and New Value Creation Platform, whose objective is to develop new economic and business models that are digitally driven, creating sustainable value for an inclusive economy.

The objective of this White Paper is to shed light on ways to realize the large estimated economic output potential by taking a bottom-up approach through a use-case-driven analysis. The analysis of 40 sample use cases in various industries establishes linkages between commercial and societal impact, and explores how the functional drivers of 5G could enhance the output of these use cases as 5G networks evolve. Additionally, this paper summarizes key challenges based on insights from several stakeholders, and presents a set of stakeholder actions to accelerate 5G deployment in order to realize its full potential.

Background of 5G

By definition, 5G refers to fifth-generation cellular network technology, which has been evolving since 1980. 5G is expected to significantly enhance the mobile network, enabling more connections and interactions. This connectivity enhancement across networks will unlock significant potential for various industries to improve their bottom line.

Functional drivers of 5G

The transition to 5G involves a new, end-to-end network architecture and presents several defining features that make it unique. The five key functional drivers[4] of 5G and possible use cases can be summarized as follows:

<table>
<tr><th>Functional driver</th><th>Description</th><th>Added value</th><th>Use cases</th></tr>
<tr><td>Enhanced mobile broadband (eMBB)</td><td>Faster connections, higher throughput and greater capacity (up to 10 Gbps)</td><td>Allows for an extension in cellular coverage into diverse structures (large venues) and the ability to handle a larger number of devices using high amounts of data</td><td>Fixed wireless access service, enhanced in-building broadband service, real-time augmented reality service, real-time virtual and mixed reality service, crowded or dense area service, enhanced digital signage, high-definition cloud gaming, public protection and disaster response services, massive content streaming services, remote surgery and examination</td></tr>
<tr><td>Ultra-reliable low latency communication (uRLLC)</td><td>Reduced time for data from device to be uploaded and reach its target (1 ms compared to 50 ms for 4G)</td><td>Enables time-sensitive connections wirelessly</td><td rowspan="2">Autonomous vehicles, drones and robotic applications, health monitoring systems/telehealth, smart grid and metering, intelligent transportation, factory automation, remote operation, self-driving cars, mission-critical services (security and safety), high-definition real-time gaming</td></tr>
<tr><td>Security</td><td>Robust security properties, leading to high reliability and availability</td><td>Creates an ultra-reliable connection to support applications where failure is not an option</td></tr>
<tr><td>Massive machine-type communications (mMTC)</td><td>Increased spectral efficiency plus small cell deployment</td><td>Allows for a large number of connections to support data-intensive applications</td><td rowspan="2">Asset tracking and predictive maintenance, smart cities/buildings/agriculture, internet of energy/utility management, industrial automation, smart logistics (advanced telematics), smart grid and metering, smart consumer wearables, environmental management, intelligent surveillance and video analytics, smart retail</td></tr>
<tr><td>Power efficiency</td><td>Efficient power requirements for massive multiple-input, multiple-output (MIMO), small cell implementation</td><td>Leads to lower costs and enables massive internet of things</td></tr>
</table>

Source: ITU, 2018.[5]

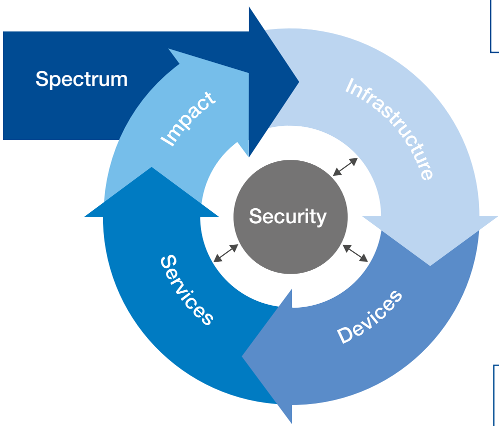
5G Ecosystem Cycle

The 5G Ecosystem Cycle[6] was identified to best use the new, end-to-end network architecture of 5G and its corresponding functional drivers. It enables the sustainable transformation of industry sectors and society. The cycle is based on interdependencies across all key areas of the ecosystem and the need for certain actions to occur in each of these areas to initiate and maintain momentum. The 5G Ecosystem Cycle aims to represent the need for stakeholder collaboration and alignment throughout the ecosystem, including coordinated decision-making that will have repercussions on the ecosystem's subsequent components. Figure 1 provides a visualization of the cycle and a description of its key components.

Figure 1: 5G Ecosystem Cycle

SPECTRUM is the oil of the 5G ecosystem, without which no 5G network infrastructure or devices can operate. The future networks will rely on a combination of mainstream and alternative technologies and will use both licensed and unlicensed spectrum across different spectrum bands together (low = long range, indoor penetration but low capacity density; high = short range, no indoor penetration, high capacity density).

INFRASTRUCTURE comprises the elements of the 5G network that provide coverage, bandwidth, latency and reliability for 5G devices such as base stations, mobile backhaul, edge clouds and core networks, as well as the end devices on which the 5G network will be used.



The actual and perceived end-to-end **SECURITY** of 5G infrastructure, devices and uses will be a key factor for end users, enterprises and public institutions when deciding to move their activities to 5G.

IMPACT can be achieved in two dimensions:

- Economic impact: employment (payroll), economic output, profits, investment
- Social impact: health, education, livelihood, air quality, greenhouse gas levels, land use and biodiversity, waste management, water consumption, water quality.

According to Gartner, the number of connected **DEVICES** (sensors, smartphones) in use will increase to 25 billion by 2021, from 14.2 billion in 2019, creating stronger sectorial dependencies on the networks. The devices must be able to support much greater performances and need to exist in a variety of form factors to support the new 5G-enabled use cases and business models.

5G represents an opportunity for connectivity providers to improve network leadership by being the first movers and competitively positioning themselves to deliver key **SERVICES** across diverse geographies. However, subscriber-based business models need to be transformed to enable digital services that support the roadmaps of enterprises across sectors. Involving non-traditional stakeholders across industries would be required to create partnership-based ecosystems and achieve the deployment of 5G networks more quickly.

5G ecosystem

Source: World Economic Forum and PwC project team.

Realizing the economic and social value of 5G calls for an effective approach to 5G deployment. To achieve this goal, specific existing challenges in the various components of the 5G ecosystem, and the stakeholder(s) responsible for each challenge, first needed to be identified. The stakeholders identified were grouped into four categories:

Regulators/Policy-makers	Enterprises/Organizations/ Associations	Service/Technology providers	Public-private partnership organizations
Government regulators/ regulatory agencies, such as the Federal Communications Commission (US), European Commission (EU), Ministry of Industry and Information Technology (China)	Enterprises, international associations, alliances with a geographical/thematic/sectorial focus, such as the International Telecommunication Union, GSMA, 3GPP, 5G Alliance for Connected Industries and Automation, 5G Automotive Association	Network operators, network equipment and operational technology providers, tower companies, software service providers, device/chip manufacturers	Organizations with a focus on public-private partnerships, such as the 5G Infrastructure Public Private Partnership, World Bank, International Monetary Fund, OECD, United Nations, United Nations Framework Convention on Climate Change

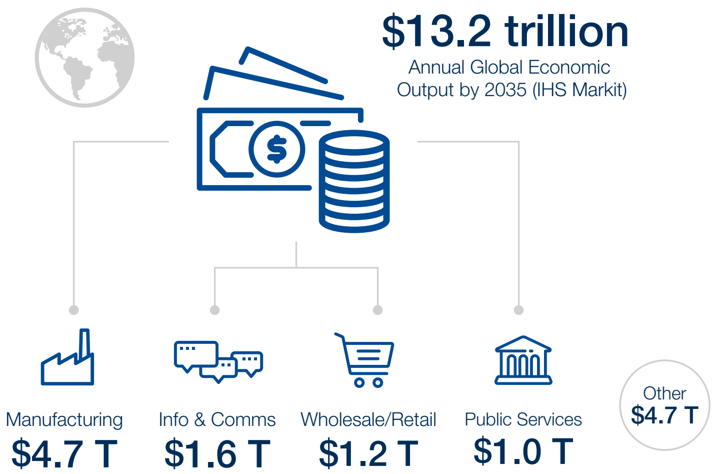
The following table summarizes the key challenges across these areas by stakeholder:

Component	Regulators/ Policy-makers	Enterprises/ Organizations/ Associations	Service/ Technology providers	Public-private partnership organizations	Challenges
Spectrum	●	●	●		Local permits and planning for spectrum usage Auctions and high fees for spectrum procurement Fragmentation during allocations of spectrum
Infrastructure	●	●	●	●	Fibre backhaul: capacity, availability, deployment cost and long-distance reach New funding models for fibre deployment/ownership Small cell deployments: local permits and planning
Devices		●	●		Availability of devices compatible with local spectrum and allocations, and in line with harmonized global standards Lack of clear roadmap for device manufacturers
Services	●	●	●	●	Guidelines and standards related to data exchange across borders Use cases arising from integration with new technologies (artificial intelligence, big data, internet of things) Lack of incentives for cross-industry collaborations Skills upgrade of service provider resources
Impact		●			Limited focus on societal and environmental benefits due to 5G Disintegration of benefits provided by 5G vs benefits by other IT technologies
Security	●		●	●	Security of personal data collection Device vulnerability Network data transmission vulnerabilities

Economic and social value

To incentivize them to collaborate on addressing the challenges of widespread 5G deployment, stakeholders must be aware of and aligned on the potential economic and social value of 5G . Intelligent connectivity, enabled by 5G, will be a catalyst for socio-economic growth in the Fourth Industrial Revolution with an estimated **$13.2 trillion of global economic value reached by 2035** (Figure 2).

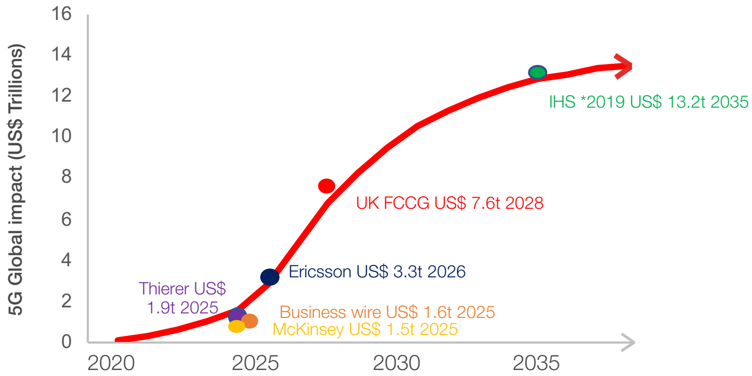
Figure 2: Economic and social value



Source: Based on IHS Markit, *The 5G Economy: How 5G will contribute to the global economy*, 2019.

Different industry sources have varying estimates regarding 5G's overall impact through its use in the future. Hence, it is essential to develop a mechanism to evaluate the quantified impact of each 5G use case on the economy, society and the environment.[7]

Figure 3: Cumulative global 5G impact, 2020-2035



Source: Chart extracted from *5G socio-economic impact in Switzerland* by tech4i2, February 2019, updated with the figure $13.2 trillion by 2035 from *The 5G Economy: How 5G will contribute to the global economy* by IHS Markit, November 2019.

Investments in 5G networks will reach $1 trillion worldwide by 2025 according to the GSMA, the body that represents the interests of mobile network operators globally. It also predicts that the global 5G network investment cycle will be longer than 4G, indicating that the coexistence of 4G and 5G will last into the 2030s.

When coupled with technology solutions, such as the internet of things, artificial intelligence or big data, 5G holds the potential to deliver large-scale societal value. A study conducted by Tech4i2 indicates that 5G will support 137,000 jobs in Switzerland alone and create economic output of 42.4 billion Swiss francs by 2030.[8] According to a European Commission Study conducted in 2016,[9] the potential economic output of 5G is estimated to be €141 billion with 2.3 million jobs created in the 28 Member States of the European Union.

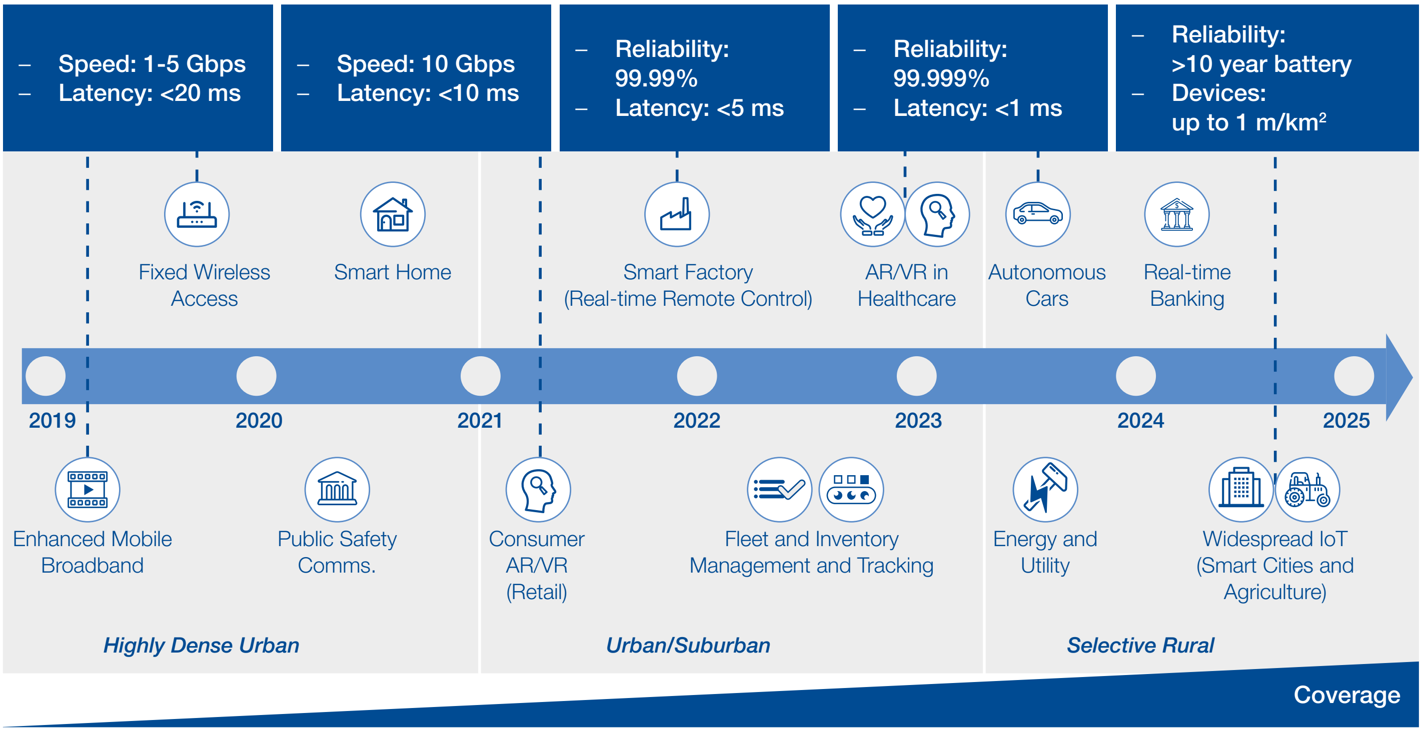
While significant research validates the macroeconomic potential of future networks, a wide range of socio-economic benefits that 5G enabled applications could provide and that will increase the demand for 5G networks are not being fully considered at the use-case level. This White Paper thus complements published findings on the potential impact of 5G by:

– Establishing commercial and societal linkages at the use-case level
– Analysing how macroeconomic value could be realized based on the way 5G could improve, enhance or uniquely enable new use cases
– Identifying the social impact areas to which 5G-enabled technologies can contribute.

5G sectors and use cases

The economic value that 5G can create can be identified through potential industrial advancement areas and subsequent major commercial opportunities across industry sectors:

Figure 4: Maturity of use cases enabled across industry sectors by evolving features of 5G



AR = augmented reality; VR = virtual reality; IoT = internet of things.
Source: PwC Strategy& and World Economic Forum, "5G for the Fourth Industrial Revolution", 2019.

In this section, specific use cases in which economic and social value are created are identified across different industry sectors, as are the specific defining features and the level of 5G maturity required.

5G use case analysis

Approach and methodology

The methodology to identify the specific economic and social value of 5G included collecting and analysing 5G use cases across various industries. Forty use cases covering diverse geographies and technology specialty areas were collected to extract key learnings pertaining to their potential impact and pathways to realize this potential. Transport and manufacturing were the most represented industry sectors with 15 and 11 use cases, respectively, representing 65% of the total. A series of multistakeholder workshops and interviews were also conducted to gather insights on the potential effects across a variety of industry sectors.

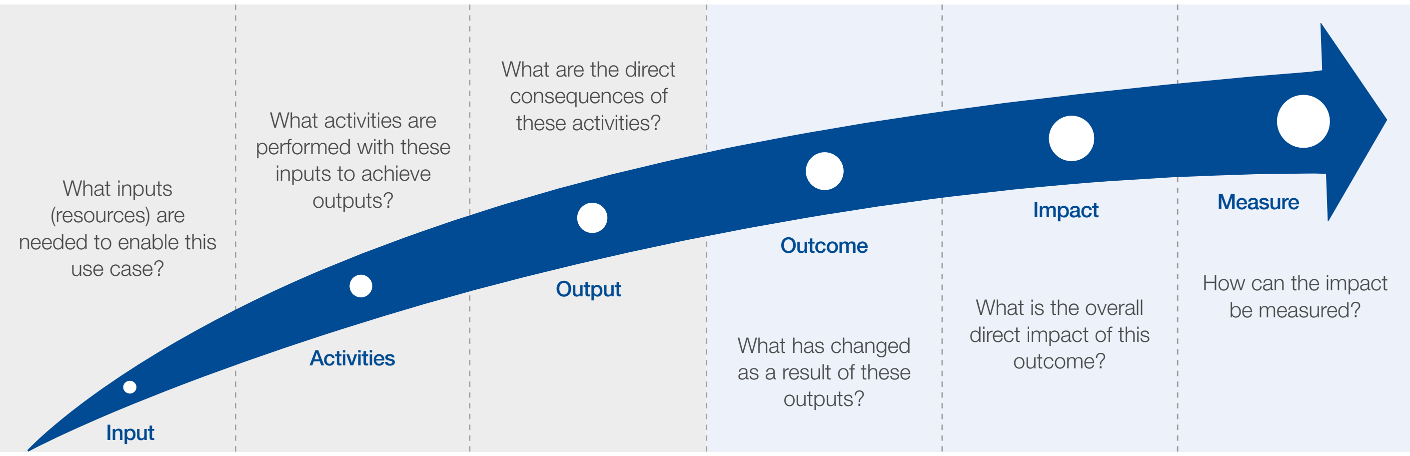
Primary industry sector (10)	Secondary industry sector (10)	Technology specialty area (11)
Manufacturing	Machinery and equipment	Internet of things
Transportation	Automotive	Mixed reality
Public services	Logistics	Autonomous driving
Health and social work	Railways	Drones
Agriculture	Education	Robotics
Energy	Info and communications	Advanced communication systems
Logistics	Semiconductors	Artificial intelligence
Media and entertainment	Urban infrastructure	Cloud
Mining and quarrying	Consumer goods	Digital twin
Professional services	Sports	Gamification
		Simulation/imaging

These use cases were then analysed across three key dimensions:

1. Industry advancement: How are they improving and advancing their specific industry-related key performance indicators: cost-cutting, enhanced safety, better decision-making, etc.
2. Social impact: What are the corresponding Sustainable Development Goals (SDGs) these use cases contribute to achieving? This information helps to assess the extent of and expected social impact areas.
3. Functional drivers: What 5G functional features enable this use case to exist? What is the timeline to realize its full potential? These defining features help to recognize the economic and social value and potential.

Based on the analyses, illustrative impact pathways were identified for each case (Figure 5).

Figure 5: Use case illustrative impact pathways



Source: World Economic Forum and PwC project team.

Finally, the level of maturity required for the 5G to realize its full potential was assessed for the current state, short term and long term. Selected functional drivers were used as a reference of the 5G networks' maturity level across all use cases for consistency, regardless of whether the analysed use case would benefit from those functional drivers.

Current state	Short term (1-3 years)	Long term (3+ years)
Speed: 1-5 Gbps | Latency: <20 ms	Reliability: 99.99% | Latency: <5 ms	Reliability: 99.999% | Latency: <1 ms

Industrial advances

The three most significant ways 5G will contribute to industrial advances are by: 1) enabling faster and effective inspections through predictive intelligence; 2) improving workplace and worker safety; and 3) enhancing operational effectiveness. Additionally, 5G has the potential to impact industry by managing the carbon footprint and bridging the digital divide, which together apply to 63% of the use cases identified.

1. **The manufacturing industry is expected to advance rapidly through faster and effective inspections due to predictive intelligence enabled by 5G.**

Almost two-thirds (63%) of the use cases include an aspect of predictive intelligence, particularly applied to the manufacturing industry, which will generate significant economic value.

Case study: Bright Machines

Bright Machines manages a cloud-based software for the design, simulation and deployment of the configuration and instructions used to set up, reconfigure and run any number of physical production lines for assembly, allowing enhanced operations. This software replaces traditional assembly processes. The key benefits realized through this software, applied in a North American factory, are:

- Defect rates reduced parts per million (PPM) by 88%.
- Unit production increased 33% per hour.
- Assembly-line staff could be reduced by 50%.

2. **Workplace and worker safety may be significantly enhanced due to technologies enabled by 5G.**

Half of the use cases identified lead to improved worker safety and reduced fatalities, through the use of such technologies as drones, the internet of things and mixed reality.

Case study: Delair
Delair Aerial Intelligence is a reality modelling platform for physical asset management, addressing business requirements in various industry sectors. It harnesses the computing power of the cloud to turn aerial and ground imagery data into key actionable insights for operational and corporate asset management. The value this solution generates includes:

- Maximized staff safety in sensitive (remote and dangerous) areas with real-time video surveillance and automatic hazard detection
- Savings for the clients due to reduced operating expenses to undertake surveys (eliminating the need to send workers to high altitudes or hire expensive airplanes for flyovers)
- Productivity enhancement and immediate returns on investment.

3. **Enhanced operational effectiveness is another key industrial advancement area that 5G can enable particularly related to logistics and machinery/equipment.**

Almost half (45%) of the use cases identified lead to enhanced operational effectiveness, such as reduced operating costs.

Case study: Nokia in cooperation with Omron
Traditionally, the Nokia factory in Oulu has managed machine and device telecommunications through Ethernet cables adding significant costs in rewiring work. Using Omron LD Autonomous Intelligent Vehicles, material flow is automated. It delivers material from storage to the production line, without any human interference. As product cycles become shorter due to fast-changing consumer demands, manufacturing sites are under increasing pressure to rearrange production lines at short notice. By taking advantage of 5G's high speed, large capacity, low latency and ability to connect multiple devices, autonomous mobile robots automatically convey components to the exact spot required based on communication with production line equipment.

Social impact
5G can deliver social value across 11 key areas in the context of the UN SDGs, mainly through contributing to good health and well-being, in addition to enhancing infrastructure, promoting sustainable industrialization and fostering innovation. Other key areas in which social value can be created through 5G include contributing to responsible consumption, enabling sustainable cities and communities, and promoting decent work and economic growth.

4. **5G has the ability to contribute significantly to societal well-being through reduced potential injuries and fatalities.**

Over half (55%) of use cases contribute to key performance indicators related to SDG 3: Good Health and Well-being, particularly in the transportation (eight use cases) and manufacturing (five use cases) industries.

Case study: Starsky Robotics
Starsky Robotics is developing self-driving trucks with remote driving capabilities. It uses teleoperation to remotely drive the truck between freight depots and the freeway where a highway-only automated driving system takes over. This has the following benefits:

- Solving the issue of driver shortages by allowing human drivers to work in office environments while making trucks autonomous on the highways
- Reducing the number of driver fatalities during long-haul journeys by using well-trained, well-rested teleoperators and exit-to-exit highway automation.

5. **5G is a key enabler to enhance infrastructure, promote sustainable industrialization and foster innovation.**

As many as 40% of use cases contribute to SDG 9: Industry, Innovation and Infrastructure. This SDG has a particularly strong correlation with the transportation and manufacturing industries. As such, given 5G's strong contribution to the advancement of those industry sectors, the key performance targets stipulated in SDG 9 can be achieved through various 5G applications.

Case study: Airobotics

Airobotics has developed an unmanned drone solution (total market value by 2025 will reach an estimated $13 billion). It is an end-to-end, fully automatic solution for collecting aerial data and gaining insights to inform decisions. The industrial grade platform is available on-site and on-demand, enabling industrial facilities to access premium aerial data in a faster, safer, more efficient way. The commercial impact this can achieve is:

– Identifying and analysing data for haul road optimization
– Surveying and mapping solutions: collecting and analysing data for better decision-making and enhanced risk management and planning
– Inspecting chemical plants, refineries and manufacturing sites, reducing budgets for disaster management.

Functional drivers

The five key functional drivers of 5G support certain technological applications. The key drivers identified from the use case analysis are ultra-reliable low latency communication and enhanced mobile broadband. Massive machine-type communications and security are also important, each contributing to 45% of the use cases analysed. It is important to note that 5G could be the ideal technology for certain solutions, but others might be sufficiently served with WiFi, 4G or even earlier generations.

6. **Ultra-reliable low latency communication is the key defining driver of 5G that will realize socio-economic value.**

Of the 40 use cases, 96% rely on the functional driver of ultra-reliable low latency communication. This feature reduces the time for data from a device to be uploaded and reach its target, enabling use cases that rely on fast response times.

Case study: Schneider Electric

Schneider Electric plans to leverage 5G to simplify factory IT operations, improve support to manufacturing and accelerate factory digitization. At its Le Vaudreuil factory, 5G demonstrations leverage low latency and high throughput, and secure indoor coverage to validate a range of use cases along various aspects. These include:

– Enhancing the operational efficiency of field maintenance technicians through content delivery and seamless assistance from remote experts
– Enabling Schneider customers to remotely tour the factory with a telepresence robot
– Enabling Automated Guided Vehicles (AGV) in the factory to send video streams and sensors and receive real-time instructions to perform tasks not programmed in AGVs.

7. **The second-most defining driver of 5G is enhanced mobile broadband, mainly related to artificial intelligence, mixed reality and drone-based applications.**

Almost four-fifths (78%) of the use cases rely on enhanced mobile broadband, which will help enable the cases that require a large amount of data to be processed. Ten use cases are related to artificial-intelligence-based applications, while drones and mixed reality account for four use cases each.

Case study: DataProphet

DataProphet provides technology solutions based in artificial intelligence that embed unique adaptations and advances of deep learning, enabling artificial intelligence to have a significant and practical impact on the factory floor. DataProphet's product PRESCRIBE accurately predicts the presence of defects by recognizing patterns that have previously been associated with one or more known defects, such as subsurface defects, latent defects (particularly important where warranty claims could be significant), uncaught quality violations and hidden scrap. Predicting engine block defects and identifying high-yield operating regions have resulted in:

– A 0% external scrap rate, ensuring cost savings and an overall increase in customer satisfaction
– Monthly cost savings of between $120,000 and $140,000 due to weld quality in automotive assembly lines.

5G maturity

5G deployment will occur in phases with certain functional drivers improving over time. However, not all use cases identified require these functional drivers at full maturity. The key features in the current state and in the short term that have the highest potential to disrupt are low latency and enhanced mobile broadband.

8. **Enhanced mobile broadband is a key functional driver mainly related to artificial intelligence, mixed reality and drone-based applications.**

In the short term (within 1-3 years), it will be possible to realize the economic value that 5G can bring to the use cases that depend on connected units for enhanced data analysis and ultimately, decision-making.

Case study: Volocopter

The company specializes in the design of electric multirotor helicopters in the form of ready-to-fly aircraft, designed for air taxi use. Its key features include remote control, GPS point tracking, possible sense and avoid integration, possible autonomous subfeature integration, additional battery capacity to extend range and flight time, air traffic management (including unmanned traffic management) to coordinate autonomous Volocopter fleets. The benefits enabled by 5G that could be realized are:

– Reduced number of accidents/crashes
– Reduction in fuel consumption
– Increase in logistical capacity, resulting in GDP contribution

9. **Driven by enhanced mobile broadband combined with low latency, faster image/video processing is a key added value from 5G that can be realized in the short term.**

One-fourth of the use cases yield faster image/video processing in the short term across many industry sectors.

Case study: Ericsson

In June 2018, Ericsson partnered with AT&T, FOX Sports, Fox Innovation Lab and Intel in a 5G trial at the 118th US Open at Shinnecock Hills Golf Club on Long Island, New York, to bring ultra-high-definition images of the event to FOX Sports viewers. Throughout the event, the 5G network demonstrated sustained uplink speeds of over 300 Mbps, meeting the 60-80 Mbps encoded video transmission requirements. The volumetric video market is expected to grow from $578.3 million in 2018 to $2,780.0 million by 2023, demonstrating the economic value 5G can create by enabling faster image/video processing.

10. **Low latency is key to enabling opportunities dependent on real-time machine learning, a feature that will fully mature in the long term**.

A latency of <1 ms will only be realized in the long term (in three or more years). Thus, many applications that can truly be empowered by this feature will have delayed deployment.

Case study: Pymetrics

Pymetrics provides recruitment solutions in the form of gamified assessments and video interviews that collect objective, behavioural data that is unbiased, unlike résumé data or self-report data. Through a customized and machine learning algorithm, it maximizes prediction efficiency. Unilever used Pymetrics to recruit 280,000 candidates, which yielded several benefits:

– 100% increase in hire yield
– 75% reduction in time to hire
– 25% decrease in recruiting costs.

5G potential for economic and social value across industry sectors

In addition to the socio-economic value identified in the use cases, specific industry sectors that will be significantly impacted by 5G were explored, focusing on several key areas:

Identification of high impact areas across selected vertical industries → Collection of most promising use cases by impact area → Mapping of use case requirements and 5G connectivity features → Quantification of socio-economic impact of use cases across sectors (bottom-up approach) → Mapping of connectivity/industry trends of impact areas and use cases (top-down approach) → Evaluation of cross-industry perspectives and collaboration opportunities

The UN SDGs have been used as a framework to classify societal impact across several areas.[10] The results of this analysis by industry are summarized in the following table:

Industry sector	Key industry trends	Sample use cases	SDG impacted	Transformation enabled
Manufacturing	– Hypercompetition with no sustainable competitive advantages – Increasing volatility from business cycles and product life cycles – Smart factory advances due to developments in the internet of things and automation – The need to securely connect systems on a common infrastructure – Increasing consumer demand for customized and personalized products – Demand for products that are more complex to build and deliver	– Smart factory floor – Human-to-robot collaboration – Predictive maintenance – Digital twins – Augmented reality – Virtual reality – Digital performance management	SDG 7 SDG 8 SDG 9 SDG 12 SDG 13	– Advanced predictive maintenance can lead to enhanced equipment availability and throughput. – Remote maintenance can lead to lower operational costs. – Digital performance management and digital standard operating procedures result in enhanced operational efficiency. – Factories of the future have smart, automated manufacturing.
Mobility	– Autonomous driving and a connected traveller with telematics – Car sharing and changing commuter habits – Electric mobility with the green agenda – Digital vehicle ecosystem – Infotainment on the move – Urbanization and intermodality – Environmental awareness and public spaces – Urban lifestyle and growing expectations on public transport	– Digital twin (predictive maintenance) – High-density platooning and automation (C-V2X) – Smart traffic control with prioritization – Remote vehicle health monitoring – Massive media car infotainment – Airborne taxis – Vehicle-to-vehicle	SDG 3 SDG 7 SDG 9 SDG 11	– Autonomous mobility as a reality leads to enhanced individual productivity (less time spent on driving). – Green and sustainable mobility reduces environmental impacts.
Healthcare	– Increasing consumer attention on well-being – Increasing cost to meet socio-demographic changes – Increasing demand on quality, patient safety and data storage – Changing consumer behaviour, freedom of choice and alternative service providers	– Remote patient monitoring – Internet of medical skills/remote surgery – Image transfer – AR/VR-enabled healthcare – Disease management – Wearables and ingestibles – Drone-enabled medical service delivery	SDG 3 SDG 4 SDG 5 SDG 8 SDG 9	– m-Health (mobile health) and the wider introduction of telemedicine result in increased accessibility to quality healthcare. – Preventive healthcare measures (wearables and ingestibles) lead to decreased long-term healthcare costs.

Financial services	– Disruption from fintech (technology used to support financial services) due to online payments, e-wallets, etc. – Challenging customer relations with online/mobile transactions and customized financial solutions – Structural changes: state involvement, protectionism and fiscal measures	– Mobile banking: centre of all banking transactions – Wearables for payment – Virtual personalized financial advisory – Internet of moving things – Digital deposits, payments and peer-to-peer lending – Mobile as a digital wallet – Remote teller	SDG 4 SDG 5 SDG 8 SDG 9 SDG 13	– Shorter settlement cycles in capital markets lead to enhanced economic activity. – Virtual personalized services and all-in-one mobile wallets enhance the customer experience.
Retail	– Omni-channel retail strategies – Personalized retail experience – Growing culture of immediacy – Increasing relevance of digital mobile wallets – Faster e-commerce shipping – Rising subscription e-commerce	– Consumer 3D calls/holograms – Consumer AR/MR – Automated checkout – Layout optimizations – Smart customer relationship management – In-store personalized promotions – Inventory shrinking prevention	SDG 2 SDG 3 SDG 8 SDG 12 SDG 13	– Try-before-you-buy using AR/VR results in an enhanced consumer experience. – Customized in-store advertisements lead to increased sales.
Energy	– Electrification and renewable energy generation – New decentralized business models – Structural shifts with increasingly retiring assets – Political and societal push for sustainable energy systems – Production and transmission assets often located in remote locations – Need for improved customer engagement	– Smart grid – Drone monitoring capabilities – Smart energy management – Hazard and maintenance sensing – Electric vehicles – Residential smart meters – Smart street lighting	SDG 7 SDG 8 SDG 9 SDG 13	– Smaller plants dependent on renewable energy and smart grids enhance reliability and availability. – Demand-side integration with suppliers unlocks commercial opportunities for suppliers. – The digitization of gas networks leads to faster decision-making, minimizing potential losses.
Entertainment/media	– Consumers of content acting as content co-creators – Increasingly interactive and immersive forms of entertainment – A new sensory dimension to entertainment – Expansion of digital content through new platforms and market players – Ecosystem complexity	– Immersive media applications (ultra-high-definition, AR, VR) – Live in-stadium experiences – Connected haptic suites – 3D holographic displays – Gaming (AR and cloud gaming) – Home entertainment subscription for car – In-venue media	SDG 3 SDG 4 SDG 5	– Content-fuelled interactions igniting emotional connections lead to increased customer expenditure. – The consumer as content co-creator results in increased consumer engagement. – Gamification is induced in other industries.

AR = augmented reality; VR = virtual reality; MR = mixed reality.

In addition to the direct economic impacts, indirect socio-economic value is also created in four environments:[11]

Benefits	Smart cities	Non-urban environments	Smart homes	Smart workplaces
Social benefits	– Greater access to information and interconnection between citizens – Ability to reduce traffic congestion, identify traffic black spots and reduce accidents	– Increased educational opportunities through massive online open courses – Better healthcare through faster, remote access to healthcare services – Greater access to information through improved connectivity	– Enhanced medical support/assisted living – Improved privacy/ security/safety – Superior access control	– Greater assistance to ageing and disabled populations – Overall improved quality of life
Environmental benefits	– Lower pollution and CO_2 reductions – Improved natural resource management	– Lower pollution and CO_2 reductions	– Reduced waste – Reduced energy consumption and CO_2 emissions – Better and more informed electronic waste	– Cleaner environments

To realize the social value that can potentially be created through 5G, all stakeholders must incorporate social value creation in the planning stage. The private sector's prioritization of social value creation when designing business models may not only maximize the benefits to society but may potentially strengthen the business case for 5G deployment by, for example, attracting sustainability-driven investments or better aligning with government agendas that prioritize GDP growth, job creation or climate change solutions. An area to explore further is the development of a methodology to more accurately quantify the social value that can be created by 5G, and an in-depth study would be useful to map stakeholder collaboration to maximize social value creation.

Overview of actions required by stakeholders

Stakeholders must align and cooperate to fully realize the socio-economic value that 5G can deliver through its defining key features and to unlock various use cases across multiple industry sectors. Using the 5G Ecosystem Cycle as a framework, key actions that stakeholders can take to contribute to the successful deployment of 5G are outlined below:

Number	Ecosystem component	Action	Regulators/ Policy-makers	Enterprises/ Organizations/ Associations	Network operators/ Service/Tech providers	Public-private partnership organizations
1	Spectrum	Design policy and standards for spectrum allocation, harmonization, pricing and sharing	●	●	●	
2		Align technical experts with government telecom regulators to create 5G deployment roadmaps		●		●
3		Curate a knowledge-sharing platform to highlight the successful pilots/ implementations carried out globally	●	●	●	●
4	Infrastructure	Define standards for the deployment of 5G technical features/use case families		●	●	
5		Align technical experts to design policies and guidelines to promote 5G infrastructure, such as public-private infrastructure sharing		●	●	●
6		Continue to monitor any health impacts of 5G networks		●	●	
7		Explore collaboration models to accelerate 5G deployment		●		●
8		Define the investment requirements of 5G networks			●	●
9	Device	Create a community for device manufacturers and industry players (demand and supply forecasting)		●	●	
10		Define guidelines for device-level security (device types) and upgrades		●	●	
11	Service	Engage cross-industry players to co-create a value generating ecosystem		●		●
12		Design guidelines for industry players to adopt the right business model	●	●	●	
13		Curate a knowledge repository, highlighting cross-industry/cross-operator/cross-country 5G use cases		●	●	●
14	Impact	Align ecosystem stakeholders to realize the value potential of 5G		●		●
15		Evaluate possible trade-offs and commitments that would align with public-sector goals	●			●
16		Assess the socio-economic impact of 5G-enabled use cases on industry sectors		●		●
17	Security	Design guidelines to ensure the right global architecture to deal with potential cybercrime scenarios	●	●	●	
18		Develop scenarios, threat predictions and mitigation actions	●	●	●	

Given the interdependencies of certain actions that involve several stakeholders, it is imperative that they continuously engage in dialogue to facilitate and expedite the execution of the relevant actions.

Conclusion

Several publications analysing the macroeconomic impact of 5G through different methodologies conclude that the economic value at stake is significant and the job creation potential is large.

This use-case-driven analysis reveals that the way 5G will primarily contribute to industrial advances is by enabling faster and effective inspections through predictive intelligence, improving workplace and worker safety, and enhancing operational effectiveness. On a social level, this White Paper calls attention to use-case-level linkages to social value creation in the context of the UN SDGs.

5G could transform certain industries, bearing in mind that, while some have more clearly defined use cases that could generate greater impact, 5G deployment will take place in phases. Therefore, certain use cases will only be enabled as the networks are expanded and the technology components mature, hence the importance of fostering innovation and collaboration to accelerate 5G deployment and its benefits. These phases will also mean that 5G will coexist with other networks and connectivity solutions. 5G could be the ideal technology for certain solutions, but others might be sufficiently served with WiFi, 4G or even earlier generations. Additionally, 5G has the potential to provide quality internet access to geographical areas that are currently underserved by the telecommunications network. This could unlock significant social impact through use cases related to tele-education and telemedicine.

To ensure that 5G deployment will accelerate and its components and interdependencies are understood, strong collaboration between stakeholders is needed. Many of the current use cases are technically supported by the functional drivers of 5G and activated through multistakeholder cooperation and collaboration. Regulators, industry associations, network operators, service/technology providers and public-private partnership organizations must engage in continuous dialogue to address the challenges facing widespread 5G adoption worldwide and to maximize the opportunities it will bring across sectors. Defining collaboration frameworks and models to initiate and sustain cooperation more effectively will be increasingly important moving forward.

Contributors

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World Economic Forum colleagues across the Platforms of Digital Economy and New Value Creation, Internet of Things, Robotics and Smart Cities, and Cybersecurity and Digital Trust also contributed to this paper.

We thank all the contributors for their role in the creation of this paper. More details about this community and the activities of the programme can be found on the World Economic Forum website.

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