5G socio-economic impact in Switzerland

February 2019

Contents

Executive Summary

In 2030 5G enabled output will be supporting 137,000 jobs and create CHF 42.4 billion in output. This will constitute approximately three per cent of Swiss output.

5G has the potential to produce CHF 44.15 bn of wider socio-economic benefits per annum to citizens and society in Switzerland in 2030.

These benefits will be eroded by 5G infrastructure deployment delays. A one-year deployment delay would reduce 5G enabled output by CHF 3.1 billion. A three-year delay would lead to cumulative losses of CHF 10 billion.

This Executive Summary presents the results of research, supported by the Swiss Telecommunications Association (ASUT), forecasting the socio-economic impacts of 5G in Switzerland. The Final Report investigates what 5G might actually mean for citizens, industries, operators and the Swiss economy. Research provides an insight to a potential reality utilising the capabilities provided by 5G.

5G will be different to previous generations of mobile technologies. 5G will provide revolutionary new technologies to deliver increased business productivity, enhanced lifestyles and create new business opportunities.

The research study developed a 5G Benefits Realisation Model to forecast the impact of 5G across all sectors of the Swiss economy. The model focused on increases in output arising from improvements enabled by 5G capabilities on productivity and efficiency.

On average, output from the Swiss economy grew by CHF 38 billion per annum between 2012 and 2016. The 5G Benefits Realisation Model forecasts that on average between 2020 and 2030 5G will contribute CHF 4.2 billion to output. 5G enabled output could therefore represent approximately 11 per cent of Swiss annual output growth if rates over the five year period studied (CHF 38 billion per annum) continue.

As well as these direct impacts across all industrial sectors 5G will also have an impact in different environments, such as homes, workplaces and cities. There are secondary benefits arising from the 5G enhanced products and services produced by industry. They include the

indirect benefits to individuals and society such as better quality public services, reduced pollution and enhanced sustainability. These secondary benefits will be additional to the 5G enabled output growth for industries forecast by the 5G Benefits Realisation Model.

Research for this study replicated and enhanced widely quoted European Commission research undertaken by Tech4i2[1] to forecast these secondary benefits in Switzerland, the methodology and results are described in the first chapter of the study report. The enhanced meta-analysis approach utilised more than 240 5G reports and studies to examine the qualitative and quantitative impact of 5G capabilities. References to these reports are provided in footnotes in the report.

The four sectors utilised to examine secondary benefits in the European Commission study and the Swiss research included healthcare, the automotive sector, transport and utilities. These are thought to be the sectors where 5G will have the greatest impact. Obviously similar or additional benefits will arise in other sectors. These four sectors provide a flavour of social, environmental and sustainability benefits of 5G. An overview of the monetary value of these indirect benefits (per annum in 2030) in the four sectors is provided in Table 1.

Table 1 5G impact in key sectors in 2030

Sector *(key components)*	**Consumer benefits**	**Additional benefits**	**Total (M CHF)**
Healthcare - Service quality improvements from data	3.9	16	19.9
Automotive - Telematics, traffic management, reduced congestion, infotainment	580	570	1,150
Transport[2] - Telematics, logistic efficiency	-	-	-
Utilities - Consumption reduction, Smart grids/meters	67	-	67
Total (M CHF)	**650.9**	**586**	**1,236.9**

The European Commission study emphasised that coverage of four sectors and a selection of first and second order benefits is not comprehensive. However, it does provide a useful overview of key benefits in the four sectors where most analysts believe 5G will have the greatest impact.

The second chapter of the report extrapolates results from the European Commission study to examine the additional areas and locations where 5G capabilities will also have an impact. Research investigated the impact of 5G in four environments. The four environments focus on two different scales of analysis - at the micro scale research investigated 5G benefits in households and workplaces. At the broader scale, the study investigated 5G impacts in smart cities and non-urban environments.

In each environment three key types of 5G impacts are identified - economic, social and environmental. 5G will also contribute to sustainability. 5G networks and equipment are designed to be more energy efficient, 5G capabilities will enhance transport efficiency and industrial efficiency improvements should reduce waste and improve recycling. Table 2 provides an overview of key 5G enabled benefits (per annum) in the four environments examined in 2030.

[1] In partnership with Trinity College Dublin and InterDigital. SMART 2014/0008.

[2] To avoid double counting transportation reductions in congestion and emission are included as smart city benefits.

Table 2 5G impact in different environments in 2030

Environments *(key components)*	Economic benefits	Social benefits	Environment benefits	Total (CHF m)
Smart Home – Energy efficiency, crime reduction, security	14.7	-	13.5	**28.2**
Smart Workplace[3] - Energy and waste reduction	-	-	125	**125**
Smart Cities - Traffic management, reduced congestion	72	103	0.79	**175.8**
Non-urban - Connectivity, service access	39	144	1.3	**184.3**
Total (CHF m)	**125.7**	**247**	**140.6**	**513.3**

The penultimate chapter of the report presents innovative research, developed for the study, which developed an International Benefits Realisation Model that forecasts 5G enable output across all sectors in national economies. Headline results from these forecasts were provided at the start of the Executive Summary in bullet points and forecasts of the impact of 5G capabilities on Swiss industrial output.

The temporal (time) dimension of the model examining 5G impacts from 2020 to 2045 is based on literature, the pace of adoption of previous generations of mobile technologies in Switzerland, and a survey of Swiss and European experts about 5G adoption and impact over time.

The impact dimensions of the model utilised well regarded and widely quoted studies about 5G impacts to forecasts the impact of 5G in 2030 in 16 industrial sectors in Switzerland; ten years after first deployment of 5G infrastructure is expected to take place. The International Benefits Realisation Model and methodology are described in detail in an annex of the study report.

Table 3 provides an overview of 5G enabled output across all sectors in Switzerland in 2030.

[3] To avoid double counting with economic forecasts (chapter three) workplace economic benefits are omitted.

Table 3 5G economic impact in Switzerland in 2030

Sector	5G enabled output 2030	5G enabled employment	5G enabled output %
Manufacturing	9,990	20,600	23.5%
Information and communication	4,970	14,350	11.7%
Public administration	4,230	7,750	10.0%
Retail and wholesale	4,040	15,050	9.5%
Finance and insurance	3,860	8,650	9.1%
Transportation and Storage	3,700	8,900	7.3%
Others (ten sectors)	12,300	61,760	29.0%
Total	**M CHF 42,400**	**137,100**	(100%)

The table highlights the CHF 42.4 billion per annum of 5G enabled benefits that are forecast to occur in Switzerland in 2030. The forecast provides details of an 'expected' potential reality that will occur in 2030 if Switzerland achieves the global average rate of infrastructure deployment and adoption of 5G capabilities by citizens, businesses and government.

The final chapter of the report presents further results from the International Benefits Realisation Model. It focuses on the timeline for benefits and the potential impact of 5G infrastructure deployment delays on benefits realisation.

Temporal analysis of the model highlights that 5G will produce economic benefits relatively quickly. Half of 5G enabled output benefits (CHF 31 bn) will be realised by 2028. As Figure 1 highlights benefits are forecast to reach CHF 62 billion in 2040, this represents just over 5 per cent of Swiss output. By then 5G will have been superseded by one or possibly two later generations of mobile technologies.

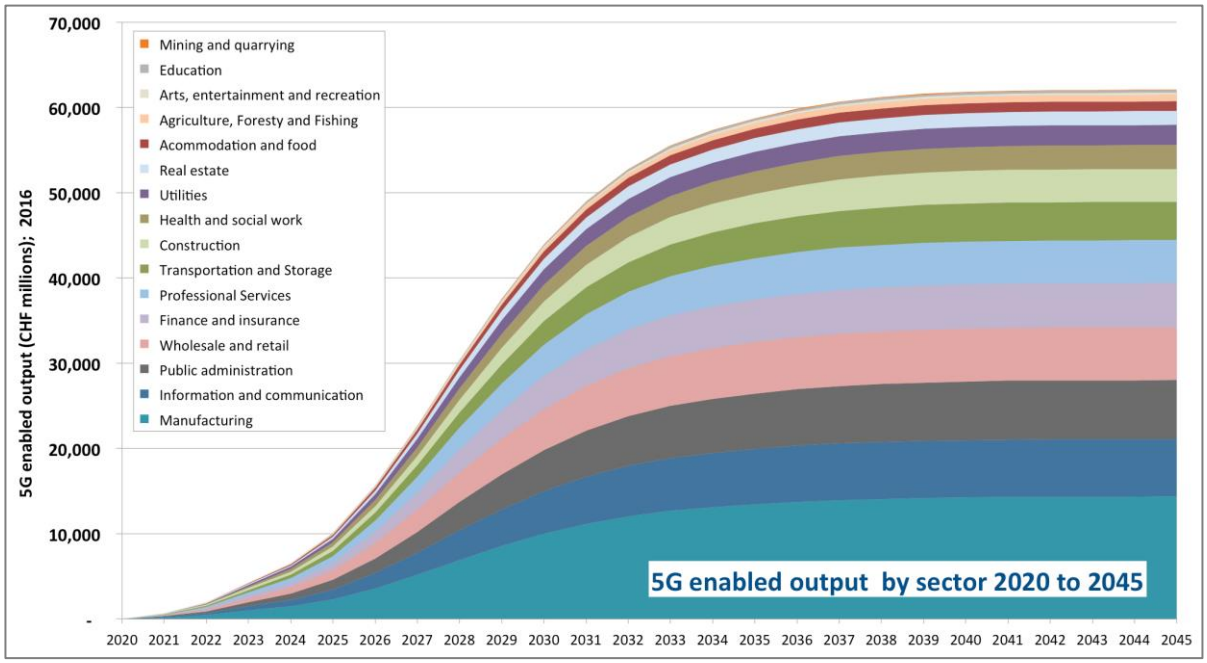

Figure 1 5G enabled output by sector 2020 to 2045

A critical issue in ensuring 5G benefits realisation is 5G infrastructure deployment and coverage. Despite a more challenging and mountainous topography, Switzerland achieved 99 per cent coverage of 3G and 4G technologies faster than other European countries.

To examine the impact of delays in 5G infrastructure deployment the study used previous subscription data (for 3G and 4G provided confidentially by a Swiss mobile operator) to forecast the decrease in subscribers if 5G deployment was delayed by six months, 12 months, two years and three years[4]. Delays caused by infrastructure deployment and other reasons were compared with the baseline 5G impact forecast.

Analysis showed that for the first two years, when the benefits from 5G are limited, the impact of delays is relatively small. But between years three and six the impact of deployment delays increases considerably.

[4] 5G will obviously be used by far more than just mobile phone handsets. The annex describes the methodology used to calculate the impact of deployment delays.

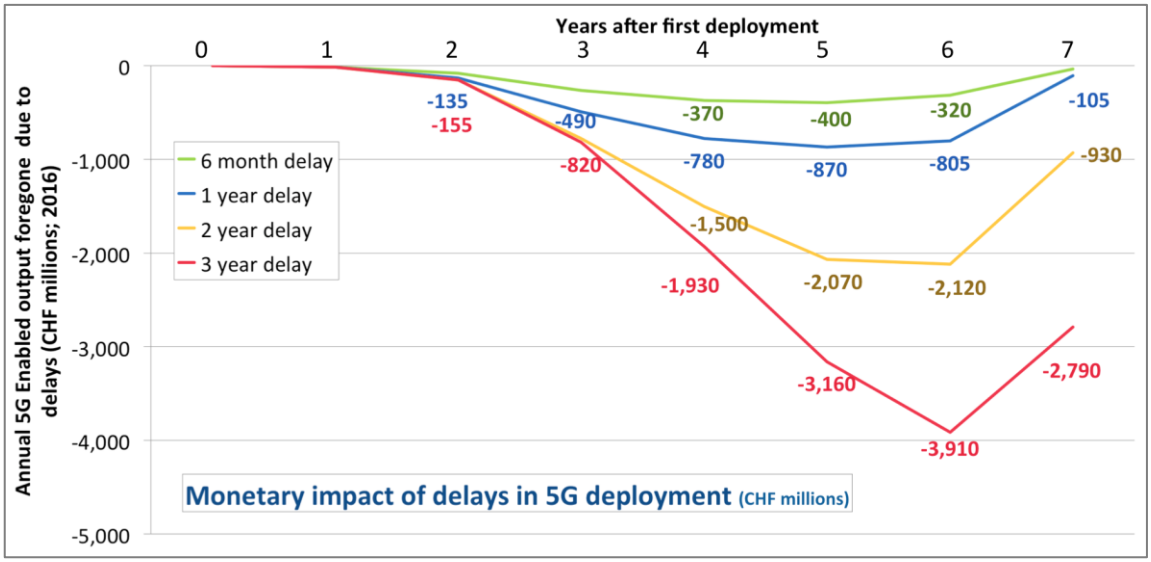

Figure 2 Economic impact of delays in 5G deployment

As the blue line in the graphic shows, a one year delay would lead to losses in 5G enabled output of CHF 870 million (in comparison with the baseline situation five years after first mass market deployment) in 2025. The graphic highlights that losses are made each year and therefore become cumulative over time. After six years of a one-year deployment delay there are cumulative total losses of CHF 3.1 billion. Deployment delays of three years increases losses nearly five fold to reach CHF 3.9 billion in 2026 (cumulative losses over the six years examined would be CHF 10 billion).

It must be highlighted that these figures only relate to losses in output. It is probable losing first mover advantage in new markets will compound these problems; difficulties are also likely to arise in regaining market share in established markets.

Chapter 1
Introduction

This report presents the results of research, supported by ASUT[5], forecasting the socio-economic impact of 5G in Switzerland. The study investigates what 5G might actually mean for citizens, industries, operators and other stakeholders. Research provides an insight to a potential reality utilising capabilities provided by 5G. This study will enable stakeholders to better understand the benefits, barriers, disruption and new business opportunities offered by 5G.

5G will be different to the previous generations of mobile technologies (2G, 3G and 4G)[6]. When introduced in 2020 5G will provide revolutionary new technologies to deliver increased business productivity, enhanced lifestyles and create new business opportunities[7]. Standards and operational parameters for 5G will not be finalised until the World Radiocommunication Conferences (WRC-19) to be held in Egypt between October 28th and 22nd November 2019; but there is already considerable publicity about the potential impacts of 5G[8]. In the light of hype concerning 5G, there is a need to provide an independent

[5] Association Suisse des Telecommunications; The Swiss Telecommunications Association.

[6] European Commission. 2017. Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe. https://publications.europa.eu/en/publication-detail/-/publication/ee832bba-ed02-11e6-ad7c-01aa75ed71a1/language-en

[7] Future Communications Challenge Group. 2017. UK strategy and plan for 5G and digitisation: Driving economic growth and productivity. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/582640/FCCG_Interim_Report.pdf

[8] Neue Zürcher Zeitung. 2017. Wenn Handys tausendmal schneller warden. 16th August. Neue Zürcher Zeitung. 2017. Der grosse Mobilfunkpoker hat begonnen. 13th December 2017.

evidence-based understanding of the impact of 5G in Switzerland. This study has adopted a clear meta-analysis methodology[9] utilising results from more than 200 5G research studies.

Chapters two and three replicate widely utilised European Commission research undertaken by Tech4i2[10] to forecast the impact of 5G in Switzerland in 2030 in four key sectors (healthcare, the automotive sector, transport and utilities) and in four environments where 5G capabilities will be utilised - Smart Homes, Smart Workplaces, Smart Cities and non-Urban environments.

The fourth and fifth chapters have a different focus. The chapters present results derived from an International Benefits Realisation Model, developed for this study, to forecast the impact of 5G capabilities in improving performance and output across all industrial sectors in Switzerland. The model also investigates the impact of infrastructure deployment delays.

[9] Described in the methodological annex – Chapter 6.

[10] Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe. SMART 2014/0008. In partnership with Trinity College Dublin and InterDigital.

Chapter 2
5G sector insights

*5G sensors and health telematics will improve wellbeing for the elderly and ill and provide benefits of CHF 458 million in the **healthcare** sector.*

*5G capabilities in the **automotive** sector will provide CHF 1.68 billion of business and consumer benefits per annum.*

*5G support of smart meters and smart grids in the **utilities** sector will produce benefits of CHF 145 million a year in Switzerland in 2030.*

2.1. Introduction

When introduced in 2020 5G will provide revolutionary new technologies to deliver increased business productivity, enhanced lifestyles and create new business opportunities[11]. In the light of hype concerning 5G, there is a need to provide an independent evidence-based understanding of the impact of 5G in Switzerland.

This chapter (and the next chapter examining the impact of 5G in different Swiss environments) replicates the methodologies[12] used in a study undertaken by Tech4i2 for the

[11] Future Communications Challenge Group. 2017. UK strategy and plan for 5G and digitisation: Driving economic growth and productivity. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/582640/FCCG_Interim_Report.pdf

[12] Full details of the methodologies and assumptions used in forecasts can be found in the European Commission study. Footnotes provide further details of how results were applied to Switzerland for more complex calculations. European Commission. 2017. Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe. https://publications.europa.eu/en/publication-detail/-/publication/ee832bba-ed02-11e6-ad7c-01aa75ed71a1

European Commission[13] to forecast the impact of 5G in 2030. The study looked beyond benefits and impacts already achieved with 3G and 4G mobile technologies and instead focused on the added benefits of 5G. In many cases these were new capabilities, on some occasions 5G permits existing mobile benefits to be achieved more efficiently or more extensively. A full description of added 5G benefits is provided in the European Commission report and, where appropriate, in footnotes in this report.

This chapter focuses on four verticals or sectors[14] - healthcare, automotive, transport and utilities - in Switzerland where 5G is expected to have the greatest impact. The four sectors were chosen in the European Commission because they were the areas where the largest number of use cases had been developed to examine the operations and impact of 5G.

For each sector strategic and operational benefits for businesses are examined first, before investigating benefits for citizens, society and other organisations.

European Commission analysis of the four sectors examined the direct or 'first order' benefits (strategic and operational impacts) of 5G capabilities to producers of goods and services and the 'second order' benefits of using 5G enabled goods and services. Second order benefits are relevant to consumers, administrators and third parties, these are also examined in this chapter. These benefits are comprised of the more indirect impacts to individuals and society such as better quality public services, congestion reduction, reduced pollution and enhanced security.

Second order benefits are examined in greater detail in four 'environments' in chapter three. The European Commission study emphasises that the list of sectors (and environments in chapter three,) and first and second order 5G benefits reviewed, are not comprehensive. Obviously many other sectors exist. However, those examined do provide a useful representative overview of key benefits.

2.2. Healthcare Sector

Ageing populations[15], health inequalities and the social determinants of health[16] present significant challenges to healthcare systems. Utilisation of 5G capabilities will facilitate new systems of care delivery with a greater emphasis on preventing illness and proactively building wellbeing and quality of life[17]. Healthcare costs have steadily increased in recent years[18]. Cost-effectiveness, preventative measures and pharmaceutical pricing are important elements providing opportunities to reduce health costs. One cost saving method would be asset tracking in hospitals and management of pharmaceuticals. Tracking

[13] Ibid. European Commission. 2017.

[14] A vertical is a market in which vendors offer particular goods and services. A sector is a distinct subset of an economy whose components share similar characteristics. The term 'vertical' was widely used in the development of 'use cases' selected by researchers to more closely examine the operations and impacts of 5G. The term 'sector' is more widely utilised to describe in economic studies to describe an industry. In this study the terms are used interchangeably to avoid the unfortunate juxtaposition of words.
Read more: http://www.investorwords.com/4430/sector.html#ixzz5eGhTlG00

[15] Economics Help. 2016. https://www.economicshelp.org/blog/8950/society/impact-ageing-population-economy/

[16] World Health Organization. 2018. About the social determinants of health: Key concepts. http://www.who.int/social_determinants/sdh_definition/en/

[17] Center for Technology Innovation at Brookings. 2016. https://www.brookings.edu/wp-content/uploads/2016/07/How-5G-tech-enables-health-iot-west.pdf

[18] The DG for Economic and Financial Affairs projected in 2012 that public spending on health care would increase by one to two per cent of GDP on average across EU countries between 2010 and 2060,

medications that are coming to the end of expiry and having automated ordering systems in place to re-stock key items would have efficiency benefits and be cost saving[19].

5G capabilities are expected to provide a powerful platform to enhance connectivity and improve data management and sharing (consensual and regulated) between patients, healthcare providers and other stakeholders. Human health and social work is the eighth largest industrial sector in Switzerland (CHF 80 billion output in 2016[20]). The healthcare sector is expected to be one of the few sectors to experience the early benefits of 5G[21].

Strategic benefits: Strategic benefits for healthcare providers will primarily arise from the growth of enhanced health telematics[22] information. Big Data will enable new ways of analysing treatments and health and enhance the value of information in making better-informed strategic decisions and promoting preventative healthcare. These benefits will be realised through more extensive continuous capture of health and bio-data from large population sets. Health devices[23] (supported by 5G capabilities and coverage) will be central to changes in strategic and operational activities in the sector.

Preventative healthcare strategies focus on encouraging patients to make lifestyle choices that help them remain healthy, such as proper diet and exercise, and take an active role in their own care if they become sick. Health devices (including wearable devices[24]) will include software-enabled instruments that sense, monitor or measure particular medical conditions. They will be used for wellness, diagnostic or therapeutic purposes[25]. Healthcare professional will also be able to monitor their patient's health data remotely allowing real-time collection and analysis through wearable medical devices[26]. These devices will use enhanced network access and coverage provided by 5G and Massive Internet of Things (IoT) capabilities to provide preventative strategic benefits of ***CHF 90 million per annum*** in healthcare costs[27].

Operational benefits: Big Health Data and enhanced health telematics will provide better information to enhance operational activities in healthcare institutions. 5G capabilities, particularly Mission Critical Services for chronically ill patients, will be directly embedded in medical devices that can operate outside healthcare facilities; but still report real-time data to clinicians. 5G data capabilities will provide operational benefits of ***CHF 348 million per annum[28]***. The use of telemedicine and e-Health will allow healthcare systems to meet a

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[19] BEREC. 2018. Study on Implications of 5G Deployment on Future Business Models. https://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/8008-study-on-implications-of-5g-deployment-o_0.pdf

[20] Eurostat. 2016. Eurostat (nama_10_a64) GVA Current Price, Millions of Euro. 2016 is the last year for which information is available for Switzerland from the Eurostat statistics; Eurostat was last updated on 18th January 2019.

[21] TechRepublic. 2018. https://www.techrepublic.com/article/5g-market-predictions-for-2019/

[22] IoT Technology Solutions. 2017. http://www.iottechnology.com/markets/telematics/

[23] Deloitte. 2015. https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/life-sciences-health-care/deloitte-uk-connected-health.pdf

[24] Wearable devices can be worn by users, they can include biometric sensors, tracking information and motion sensors related to health and fitness.

[25] IBM 2016. Cognitive systems have the potential to dramatically change healthcare in Canada. https://www.ibm.com/blogs/insights-on-business/healthcare/cognitive-healthcare-in-canada/

[26] The Impacts of Mobile Broadband and 5G. 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/714112/The_impacts_of_mobile_broadband_and_5G.pdf

[27] The European Commission report examined the 2.6 per cent savings in healthcare due to preventative initiatives and healthy living. 5G capabilities were estimated to contribute five per cent of these savings, equating to €1.1 billion. Swiss healthcare expenditure is substituted pro-rate for EU healthcare expenditure in calculations to get strategic benefits of CHF 90 million per annum.

[28] The European Commission study forecasted a ten per cent saving in healthcare due to IoT. 5G was estimated to contribute five per cent of these savings. These percentages were calculated using Swiss healthcare expenditure to get operational benefits of CHF 348 million per annum.

rising population "by employing technologies such as remote consultation and surgery"[29]. It is likely that in the long term, costs will be reduced in the healthcare due to more efficient use of 5G.

Consumer benefits: 5G capabilities will support an increase in wearable devices and the exchange of data from numerous health data storage and exchange databases will provide the opportunity to gather and analyse increasing quantities of health telematics data[30] [31]. This will allow patients to connect wearable devices to cloud-based services that store, analyse and report their condition. 60 per cent of individuals believe wearable devices will lead to a healthier lifestyle[32]. 5G capabilities will provide consumer benefits of ***CHF 3.9 million per annum*** in reduced life insurance premiums[33]. Benefits of 5G in the healthcare sector include patient centred applications used outside of the traditional hospital environment. Examples of these patient applications are precision medicine and applications to monitor health, alert and administer medicines remotely[34]. As remote diagnosis will allow a doctor to analyse the symptoms from a distance, this would be particularly beneficial for patients who are unable to travel to visit a doctor and for those living in rural areas without medical resources nearby[35].

Administrator/third party benefits: The pharmaceutical industry is a third party that has considerable interest in healthcare. Drug trials are an expensive and unavoidable cost for pharmaceutical companies. Trial drugs undergo four phases of R&D before final approval. Phase III[36], where the drugs are evaluated on human volunteers, is the biggest cost (40 per cent of R&D) of any trial. Additional access to healthcare data (consensual/anonymised and regulated) facilitated by 5G is expected to reduce drug development costs by ***CHF 16 million per annum*** in the pharmaceutical research and development sector[37].

Additional applications and new business opportunities for 5G-facilitated healthcare include smart medication, bioelectronics medicine, personal health systems, telesurgery, telecare and telemedicine, connected ambulance, assistive robots, VR/AR for medicine and battlefield medicine[38].

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[29] Latif, S. et al (2017). How will 5G wireless (and concomitant technologies) revolutionise healthcare? Future Internet. 9,4. pp.93

[30] Patients Like Me https://www.patientslikeme.com/

[31] Patients Know Best http://www.patientsknowbest.com/

[32] Ericsson. 2018. From healthcare to homecare: The critical role of 5G in healthcare transformation. https://www.ericsson.com/en/trends-and-insights/consumerlab/consumer-insights/reports/transforming-healthcare-homecare

[33] Benefits in the European Commission report were applied (pro-rata) in-line with population size in Switzerland.

[34] Ericsson, 5G Healthcare. https://www.ericsson.com/en/networks/trending/insights-and-reports/5g-healthcare

[35] Ericsson. 2018. Transforming healthcare with 5G. https://www.ericsson.com/en/cases/2016/5gtuscany/transforming-healthcare-with-5g

[36] Centrewatch. 2018. Overview of clinical trials. https://www.centerwatch.com/clinical-trials/overview.aspx/

[37] The European Commission report took the percentage of pharmaceutical research and development expenditure that was spent on Phase III trials. McKinsey estimated IoT solutions could reduce these costs by 15 per cent. The European Commission study estimated five per cent of this to be enabled by 5G capabilities. The proportion of Phase III spending was calculated for Switzerland and applied to this equation.

[38] Vodafone. 2017. Creating a gigabit society: The role of 5G. https://www.vodafone.com/content/dam/vodafone-images/public-policy/reports/pdf/gigabit-society-5g-14032017.pdf

2.3. Automotive Sector

Automotive is the most cited sector amongst sectors and use cases in previous 5G studies[39]. Enhanced mobile coverage through 5G will be important for infotainment and communications between vehicles. 5G Mission Critical Service capabilities will be important in supporting communications between moving vehicles. Automotive is a potentially huge market for 5G-enabled advances[40]. Data, particularly from telematics devices[41] is increasingly seen as 'the new fuel of transport' driving the development of new innovative automotive and transport services[42]. 5G will provide opportunities for next generation services within the automotive industry and the supply chain, allowing further improvement in vehicle design, production and performance. 5G will have a latency of 1 millisecond, allowing much faster communication than the current 10 to 30 millisecond latency with 4G LTE[43]. It is expected that 5G will arrive on roads in 2021, however this is dependent on a number of factors such as collaboration amongst stakeholders and infrastructure deployment[44].

Strategic benefits: 5G supported strategic benefits primarily arise from better use and access to enhanced telematics information[45]. Utilisation of 5G data management systems through IoT vehicle sensors will enable manufacturers and those servicing vehicles to analyse the performance of vehicle components (a passenger vehicle is typically comprised of 6,000 mechanical, electro-mechanical and electronic parts), particularly those causing breakdowns and equipment failure[46]. 5G supported data collection and analysis capabilities will provide strategic benefits of approximately CHF 87 per vehicle. This equates to benefits of ***CHF 530 million per annum*** in Switzerland.

Consumer benefits: Enhanced convenience and benefits to consumers from 5G capabilities will include services such as remote vehicle monitoring[47], remote air-conditioning/heating activation and 'find my car' (when a vehicle is misplaced or forgotten). Parking in public will be made more simple and easier. With real-time information available, the vehicle will be alerted of empty on-street parking spaces, through a low cost 5G sensor on a street lamp potentially[48]. This reduces congestion in parking areas and will also save time for the individual.

Navigation services, and in particular traffic information, rank amongst the highest customer requirements in many consumer surveys. Traffic information in particular is increasingly viewed as a must-have service. This information is currently delivered over analogue networks (such as RDS TMC). These channels only support low-bandwidth services, reducing the quantity and quality of the traffic information that can be delivered.

Another benefit will be improved safety. Developments in the automotive industry from 5G applications will help to improve vehicle-to-everything communications, allowing for features

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[39] There is no mass market production of vehicles in Switzerland (there are a few smaller producers such as Rinspeed). In this study we therefore omit benefits arising from production and operations and instead focus on 5G benefits to vehicle retailers/wholesalers and service/repair operations.

[40] Ericsson. 2014. 5G What is it for?

[41] SMMT. 2017. https://www.smmt.co.uk/2017/06/telematics-unlocking-potential-connected-vehicle/

[42] EC. 2017. Europe on the move. COM(2017) 283 Final

[43] EECatalog. 2018. The impact of 5G on Autonomous vehicles. http://eecatalog.com/automotive/2018/10/09/the-impact-of-5g-on-autonomous-vehicles/

[44] Automotive World. 2018. https://www.automotiveworld.com/research/special-report-5g-and-the-autonomous-vehicle/

[45] Original equipment manufacturers. After-market solutions for passenger cars or fleets are not considered.

[46] Datafloq. Self-driving Cars Will Create 2 Petabytes Of Data, What Are The Big Data Opportunities For The Car Industry? https://datafloq.com/read/self-driving-cars-create-2-petabytes-data-annually/172

[47] Ericsson. 2017. https://www.ericsson.com/en/mobility-report/remote-monitoring-and-control-of-vehicles

[48] Phan, A. and Qureshi, S. 2017. 5G impact on smart cities. https://www.researchgate.net/publication/315804922_5G_impact_On_Smart_Cities

including collision avoidance, emergency braking, intelligent traffic systems and driver assistance[49]. Elderly or disabled individuals are one group that will benefit from autonomous vehicles. This gives them increased accessibility and mobility which they would previous not have had being unable to operate road vehicles[50].

Embedded 5G data capabilities will provide consumer benefits of approximately CHF 96 per vehicle. This equates to benefits of ***CHF 580 million per annum.***

Administrator/third party benefits: Administrators and third parties can benefit from access to data from sensors in connected cars and fixed and mobile sensors placed in roads to monitor traffic densities and to determine average traffic speeds. This real-time information can be used to enhance traffic management and, in the longer-term, improve safety on roads[51]. Automotive News suggests that a connected car is expected to provide benefits to administrators of CHF 365 per vehicle annually via enhanced access to telematics data[52]. This study estimates that 5G data capabilities will provide benefits of about CHF 94 per vehicle. This equates to benefits of ***CHF 570 million per annum.*** The evolution of 5G for autonomous cars will create benefits for the agricultural and mining sectors including surveillance of remote natural resources, autonomous transport of metals, and self-driving tractors[53].

2.4. Transportation Sector

Transportation is the most widely cited sector amongst use cases forecasting the impact of 5G[54]. Major innovations are being developed in logistics and autonomous vehicles[55]. Transport is the seventh largest industrial sector in Switzerland (CHF 80 billion output in 2016[56]).

Enhanced 5G networks and coverage will provide the ability to monitor the movements of vehicles and cargo real-time. 5G capabilities should help to enhance Intelligent Transport Systems (ITS[57]) that gather, organise, analyse, use and share information about vehicles on transport infrastructure, usually through a dense infrastructure of roadside units to communicate to 'on-board units' in vehicles[58]. 5G could eliminate the need for this relatively expensive roadside technology.

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[49] Study on Implications of 5G Deployment on Future Business Models. 2018. https://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/8008-study-on-implications-of-5g-deployment-o_0.pdf

[50] The Impacts of Mobile Broadband and 5G. 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/714112/The_impacts_of_mobile_broadband_and_5G.pdf

[51] House of Parliament, Parliamentary Office of Science and technology. Big and Open Data in Transport. PostNote, Number 472. July 2014. www.parliament.uk/briefing-papers/POST-PN-472.pdf

[52] Sedgwick, D. Automotive News. 2013. 'Big data' from a car is worth $1,400 a year, Cisco exec says. http://www.autonews.com/apps/pbcs.dll/article?AID=/20130805/OEM06/130809928#

[53] The Innovator. 2018. https://innovator.news/how-5g-will-impact-countries-cities-and-companies-e00539e5462

[54] Ibid. European Commission. 2017. To prevent double counting of benefits the EC study recorded transportation benefits for consumers and administrators in the smart city overview. The same approach has been adopted in this study.

[55] European Commission. 2017. https://ec.europa.eu/transport/sites/transport/files/com20170283-europe-on-the-move.pdf

[56] Eurostat. 2016. Eurostat (nama_10_a64) GVA Current Price, Millions of Euro

[57] The EC has supported ITS deployment activities since the 1990s with the Euro-Regional Projects funded from the Trans-European Transport Network (TEN-T) budget made significant advances in harmonised data exchange (DATEX) between European road authorities and in the use of language independent traffic message. The 'ITS Directive' (Directive 2010/40/EU of 7 July 2010) provides a legal framework for the deployment of ITS services across Europe.

[58] Din, S. et al .2018. 5G-enabled hierarchical architecture for software-defines intelligent transportation system. *Computer Networks.* 150, pp. 81-89

Some of the benefits widely quoted in technology studies are already being achieved. For example 5G supported advanced driver assistance[59] and, in the long-term, complete autonomous driving which is forecast to reduce the number of fatal accidents, ease traffic congestion and facilitate less congested cities[60]. Some benefits from 5G adoption include decrease traffic and commute times, an increase in the number of autonomous vehicles, and taxi drivers working for companies such as Uber would be able to save money on fuel and deliver more journeys[61]. 5G-assisted transport will also present additional opportunities for businesses and the environment[62].

Strategic benefits: Benefits will primarily arise from better access to enhanced real-time telematics information. 5G embedded connectivity in consumer and commercial vehicles is expected to provide a powerful communication channel, transferring large volumes of data on vehicle's ever changing locations, performance and driver behaviour. 5G data will provide strategic benefits when insightful data about vehicle components and equipment failures is transferred to automotive manufacturers. Embedded 5G data capabilities are forecast to provide strategic benefits of about CHF 175 per commercial vehicle. This equates to benefits of ***CHF 67 million per annum*** in Switzerland.

Operational benefits: According to Eurostat surveys 24 per cent of the good vehicles in EU Member States are running empty. Enhanced access to real-time information about commercial vehicles' locations and their loads should offer opportunities for transport businesses, or newcomers providing new business models, to increase the efficiency of operations by ensuring lorries run closer to full capacity and lorries have less idle time waiting to be loaded. Embedded 5G data capabilities will provide operational savings of ***CHF 51 million per annum***[63]***.***

Benefits arising from the use of 5G capabilities are likely to arise from the development of ***new business models*** in the sector[64]. New models are likely to include the sale of telematics information and data. This could offer new sources of income for transport providers, commercial vehicle manufacturers and businesses that might be established as transport data brokers. New business models have also been suggested within the insurance industry. Vehicle insurance premiums are traditional calculated through risk algorithms for specific groups of drivers[65]. 5G capabilities will enhance the ability to offer pay-as-you-drive[66] or pay-how-you-drive insurance[67]. 5G-enabled telematics could detect fraudulent claims made by customers and, through systems such as eCall, notify insurers of accidents[68].

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[59] Huawei. 2018. http://www.huawei.com/uk/about-huawei/publications/communicate/84/5g-shifts-connected-vehicles-up-a-gear

[60] Carritech telecommunications. 2017. http://www.carritech.com/news/5g-use-cases-vehicles-transportation/

[61] Independents Fiber Network. 2018. https://www.ifnetwork.biz/resources/blog/5g-transportation-smart-cities

[62] 5G PPP https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

[63] The European Commission study asserted that inefficiencies in freight and the use of commercial vehicles cost Europe €160bn. These results were applied (pro-rata) in-line with the number of commercial vehicles in Switzerland.

[64] Impact Research Hub. 2017. https://www.autonomousvehicletech.com/ext/resources/AVT/2017/September/20170928-Impact-Research-5G-Report-pdf.pdf

[65] National Association of Insurance Commissioners. 2015. Usage based insurance and telematics http://www.naic.org/cipr_topics/topic_usage_based_insurance.htm

[66] Confused.com. 2017. https://www.confused.com/car-insurance/guides/pay-as-you-go-car-insurance

[67] Ernst and Young. 2016. http://www.ey.com/Publication/vwLUAssets/ey-introducing-pay-how-you-drive-insurance/$FILE/ey-introducing-pay-how-you-drive-insurance.pdf

[68] SBD. 2012. 2025 Every car connected: Forecasting the growth and opportunity

Consumer benefits: Transportation and vehicles fitted with 5G connectivity will make roads safer and allow public transport such as buses and trains to run more efficiently[69]. Consumers benefits will include better high-speed Internet access on private and public transport[70]. Professionals will be able work more easily while they are travelling; creating a more productive workforce.

2.5. Utilities Sector

Government, commercial and environmental factors have already pushed utilities to develop smart grids[71], bringing intelligence to the systems that generate, distribute, manage and secure energy and water. The socio-economic benefits of smart grids[72] will increase as they utilise the extended coverage of 5G networks and 5G Mission Critical ultra-low latency capabilities to support vast numbers of sensors and deliver ubiquitous coverage with high security and low latency. Smart grids, using 5G, enable unconnected energy-consuming devices to be more accurately monitored, which will improve forecasting the demand for energy. They will be integrated into the grid through low-cost connections and will lead to better demand-side management. This will improve provision load balancing, help to reduce electricity peaks, and reduce energy prices. Real-time analysis is another impact from adopting smart grids. This should help to fasten repairs and reduce downtimes of any poles that may be affected by an outage[73].

Utility associated benefits will also arise from increased deployment of 'next generation' smart meters. Most of the smart meters installed today use mobile phone-type signals to send meter readings to suppliers, and other wireless technologies to send information to in-home/premises displays[74]. The next generation of smart meters will be supported by 5G capabilities, offering a range of 'more intelligent' functions, including real-time data exchange with suppliers, adaptive pricing and better energy management.

Strategic benefits: Strategic benefits will primarily arise from better access to enhanced information. Smart meters provide information and data on energy use, highlighting preference and seasonality patterns. Strategic benefits of installing smart meters with embedded 5G capabilities will arise from increased access to data and real-time information provision. This will support efficient energy generation, enabling savings in generation capacity, particularly during periods of high demand. When supply loads are shifted from peak to off-peak periods, electricity providers observe savings in short-term marginal costs due to lower generation costs. 5G data capabilities in smart meters will provide strategic benefits in the utilities industry of ***CHF 17 million*** in 2030[75].

Operational benefits: The main operational benefits for utilities are also likely to arise from data generated by smart meters. Smart meters with embedded 5G capabilities allow utility providers to avoid frequent site visits for meter readings and safety inspections. Energy and water utilities will be able to connect to millions of networked devices, making autonomous

[69] Ericsson, Smart vehicles and transport. https://www.ericsson.com/en/5g/use-cases/smart-vehicles-and-transport

[70] Ericsson. 2018. https://files.vogel.de/vogelonline/vogelonline/files/9763.pdf

[71] 5GPPP. 2016. https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

[72] European Commission. 2017. Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe. https://publications.europa.eu/en/publication-detail/-/publication/ee832bba-ed02-11e6-ad7c-01aa75ed71a1/language-en

[73] Phan, A. and Qureshi, S. 2017. 5G impact on smart cities. https://www.researchgate.net/publication/315804922_5G_impact_On_Smart_Cities

[74] https://www.gov.uk/guidance/smart-meters-how-they-work

[75] The European Commission study asserted that 5G would provide strategic benefits of €2.75 per smart meter. This number was applied to research into the rollout of smart meters in Switzerland by 2030.

decisions and taking real-time[76]. Being able to connect and monitor remote sites such a wind farms is seen as an important benefit to this sector[77].

More accurate and up-to-date billing systems, enhanced by smart meters with 5G capabilities, should also eliminate the requirements for utility companies to 'estimate' bills, leading to reductions in billing enquiries. 5G data capabilities will provide operational benefits in the utilities industry of ***CHF 61 million*** in 2030[78]. It has been estimated that operational benefits will be €2.7 billion in 2025 and €3.1 billion in 2030 in the European utilities industry[79].

Consumer benefits: Increased use of smart meters is expected to enable customers to better understand their energy consumption by devices and activities (via 5G IoT capabilities)[80], allowing access to historical information and anonymised information about neighbours habits and best practices in energy use and consumption. This information is important in reducing energy consumption[81]. Savings in energy consumption will obviously be dependent on household energy consumption habits but 5G capabilities in smart meters will provide consumers with benefits of ***CHF 67 million*** in 2030[82].

2.6. Conclusions

The chapter replicated the methodology used in a European Commission study to examine the benefits of 5G in four key sectors in Switzerland - healthcare, automotive, transport and utilities.

In total the 5G impacts described above are forecast to create CHF 2.4 billion of benefits in 2030. This is comprised of CHF 704 million strategic benefits, CHF 460 million in operational benefits, CHF 650 million of consumer benefits and CHF 586 million of administrator or third party benefits. These benefits are presented alongside others investigate in this study in the Executive Summary.

This chapter has focused on the four key sectors where 5G is expected to have the greatest impact. It has also focussed on the main areas where benefits are expected, many other benefits and opportunities for development will arise. Obviously the magnitude of 5G benefits would be far greater if all industrial sectors in Switzerland were analysed at a similar level of detail.

Chapter 4 goes some way to examining the impact of 5G more broadly across the Swiss economy. It utilises a 5G Benefits Realisation Model, developed for this study, to provide forecasts for the impact of 5G across all sectors in Switzerland.

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[76] Ericsson, Critical services and infrastructure control. https://www.ericsson.com/en/5g/use-cases/critical-services-and-infrastructure-control

[77] Ericsson. 2018. https://files.vogel.de/vogelonline/vogelonline/files/9763.pdf

[78] The European Commission study asserted that 5G would provide operational benefits of €9.81 per smart meter. This number was applied to research into the rollout of smart meters in Switzerland by 2030.

[79] The Innovator. 2018. https://innovator.news/how-5g-will-impact-countries-cities-and-companies-e00539e5462

[80] TATA Consultancy. 2016. https://www.tcs.com/content/dam/tcs/pdf/Industries/energy_resources_and_utilities/Smart%20Grid%20&%20the%20internet%20of%20Things.pdf

[81] Portilla K. 2013. Will smart meters really help homeowners save energy? The Guardian. 23 June. http://www.theguardian.com/environment/blog/2013/jun/28/smart-meters-homeowners-save-energy

[82] The European Commission study asserted that 5G would provide consumer benefits of €10.70 per smart meter. This number was applied to research into the rollout of smart meters in Switzerland by 2030.

Chapter 3

5G impact in different environments

*5G enabled connectivity and sensors will provide CHF 28 million of benefits from energy reduction and increased security in Swiss **smart homes**.*

*5G will help to better join-up systems and enhance data sharing in **smart cities**. Benefits from advances such as better traffic flow and reduced emissions will be CHF 176 million.*

*5G provides opportunities to increase connectivity in **non-urban areas**. 5G capabiliites will help to provide CHF 184 million of benefits in 2030.*

3.1. Introduction

The preceding chapter examined strategic and operational benefits arising from 5G capabilities in four key sectors. This focus omitted consideration of the many additional areas and locations where 5G capabilities will also have an impact.

This chapter replicates research undertaken by Tech4i2 for the European Commission to investigate the impact of 5G in four environments[83]. The four environments focus on two different scales of analysis - at the micro scale research investigates 5G benefits in households and workplaces. At the broader scale, the study investigates 5G impacts in smart cities and non-urban environments. These two scales of analysis enabled research to

[83] Full details of the methodologies and assumptions used in forecasts can be found in the European Commission study. European Commission. 2017. Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe. https://publications.europa.eu/ en/publication-detail/-/publication/ee832bba-ed02-11e6-ad7c-01aa75ed71a1/language-en

better identify specific 5G benefits[84]. In each environment two key types of 5G impacts are identified - economic benefits and environmental benefits.

3.2. Smart Homes

Home automation has increased due to improved affordability of technologies, increasing simplicity and remote control through smartphone connectivity. Smart home automation can cover lighting, temperature control, all manner of electronic devices and security. There would also be the possibility to have garden sensors connected to short-term weather forecasts to stimulate automated watering[85]. Smart homes can provide economic benefits, environmental improvements and health/well-being enhancement. The concept of the 'Internet of Things' (IoT) is closely tied to the popularisation of home automation[86]. 5G capabilities will enhance functionality[87]. More extensive mobile coverage with improved network reliability and quality will extend connectivity and 5G's Massive IoT capability will more easily link more smart home devices.

In 2014, Samsung created its Smart Home platform allowing users to connect and control their home through their Samsung device[88]. In 2018 Vodafone became a strategic telecoms partner to Samsung to develop smart home products and services, these will be available in many European countries; including Switzerland[89].

A survey conducted in Switzerland found that 53 per cent of 1,507 respondents are interested in smart homes[90]. Respondents stated that their key interests in smart homes were the potential in cost savings and increases in security.

In Switzerland, revenue in the Smart Home market in 2019 is estimated to be CHF 380 million. Household penetration of 18.5 per cent is expected to increase to 31 per cent by 2023[91].

Economic benefits: 5G capabilities will support data exchange with the growing number of sensors and devices in smart homes in the future[92]. Smart meters and other heating, ventilation and air conditioning devices will increase energy efficiency. A growing area of activity in smart homes is home security in relation to crime, fires and flooding. 5G will play a role in supporting the development of more effective home security and decreasing crime. Growth in sensors is expected to make homes more secure. Enhancements in sound detection, panoramic video and in some cases drones will improve security and act as a deterrent to burglars[93].

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[84] Obviously the two larger scale environments are predominantly composed of homes and workplaces. Care has been taken in presenting the impacts of 5G to avoid duplication and double counting of benefits.

[85] Bureau of Communications and Arts Research. 2018. https://www.communications.gov.au/file/35551/download?token=0MlSFttv

[86] Humotronix http://www.humotronix.com/home-automation.html

[87] IoT @ Intel. 2017. https://blogs.intel.com/iot/2017/03/01/laying-the-foundation-today-for-tomorrows-5g-smart-and-connected-home/

[88] Cheonshik, K. Special issue: Advanced technology for smart home automation and entertainment. *Personal and ubiquitous computing.* 22 (1), pp. 1-2

[89] Vodafone. 2018. https://www.vodafone.com/content/index/media/vodafone-group-releases/2018/Vodafone-and-samsung-strategic-partership.html#

[90] Fintechnews Switzerland. 2017. http://fintechnews.ch/iot/smart-home-intelligent-living-next-hot-trend-comes-switzerland/11214/

[91] Statista. 2019. https://www.statista.com/outlook/279/155/smart-home/switzerland

[92] http://www.huawei.com/minisite/5g/img/5G_Security_Whitepaper_en.pdf

[93] http://www.technologyintegrator.net/article/the-top-four-trends-impacting-the-connected-home-security-market-through-2020/

5G data capabilities are forecast to reduce the cost of domestic burglary by ***CHF 14.7 million per annum***[94].

Environmental benefits: More extensive wireless coverage and 5G's Massive IoT capabilities will enable greater use of smart meters. These can create significant monetary savings for homeowners as heating, ventilation and air conditioning are used more efficiently. For example the Nest Learning Thermostat[95] is claimed to deliver savings of up to 20 per cent compared to standard behaviour. This is achieved with methods such as automatically turning down the heating when the house is unoccupied. Likewise the lights in a smart home can be turned on and off automatically based on occupancy sensors.

Smart homes can also utilise energy management by keeping track of energy usage for each and every appliance in the house. This allows the operation of heavy power consuming appliances to be scheduled to take maximum advantage of off peak electric rates[96].

5G data capabilities will provide environmental benefits in smart homes of ***CHF 13.5 million*** in 2030[97].

5G enabled smart homes will be able to assist with the personal health and wellbeing of residents. Technology will enable the physiological monitoring of occupants (and notification of emergency services in the case of abnormalities), functional uses (automatic lighting, fall reduction, hazard detection), safety monitoring and assistance, social interaction monitoring and assistance (virtual participation in groups) and cognitive (medication reminder).

With faster 5G connectivity and VR (virtual reality) technologies users will be able to access immersive, life-changing home experiences[98]. This will include exploring sporting events, concerts and festivals in addition to keeping in touch with relatives on the other side of the world.

3.3. Smart Workplaces

In Switzerland, ABB Ltd is one of the prominent players in the smart workplace market[99]. Sunrise and Swisscom are also launching the Smart Workplace; an IT workstation from the cloud enhanced with AI[100]. This innovations herald the beginning of the development of smart workplaces integrated more smartly and immediately into cities and rural environments.

Globally, 70 per cent of people work remotely at least once a week[101]. With an increasingly mobile workforce, comes higher demand for a smart workplace and the ability to be able to connect to work where ever the worker is located. New digital technologies have brought a change in the pattern of work where knowledge-intensive work activities are not all taking

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[94] The European Commission report examined the cost of domestic burglary in Member States. 5G capabilities were forecast to increase home security and decrease the cost of burglary by ten per cent. These results were applied (pro-rata) in-line with the number of households in Switzerland.

[95] Nest Labs. Energy savings from the Nest Learning Thermostat: Energy Bill Analysis Results. February 2015.

[96] Eng. Inji Ibrahim Attia Prof. Dr. Hamdy Ashour. Energy Saving Through Smart Home. The Online Journal on Power and Energy Engineering (OJPEE). Vol. (2) – No. (3).

[97] The European Commission study assumed 5G enabled smart meters would provide environmental benefits of CHF 2.49 per household in Member States. These results were applied (pro-rata) in-line with the number of households in Switzerland.

[98] Nokia. 2018. https://networks.nokia.com/innovation/5g-use-cases/home/infographic

[99] ABNEWSWIRE. 2018. http://www.abnewswire.com/pressreleases/smart-workplace-market-2018-leading-growth-drivers-emerging-audience-segments-sales-profits-analysis_189835.html

[100] Swisscom. 2018. https://www.swisscom.ch/en/about/medien/infos-und-fakten/20181114-fc-smart-workplace.html; Sunrise 2018. https://e3.marco.ch/publish/sunrise/821_3672/20181115_MM_Mobile_Workspace_E.pdf

[101] JLL. 2018. https://www.jllrealviews.com/trends/workplace/5g-internet-will-enable-ultra-smart-workplaces/

place in a normal office building[102]. Smart Workplace reports predicts that by 2030 the workplace will be a dynamic, living entity that transcends the physical boundaries of the office and offers fluid interaction among on-site and off-site knowledge workers[103]. Important characteristics of the smart workplace will include ubiquitous high-speed connectivity with ultra low latency – these are characteristics that will be provided by 5G. The ubiquitous nature of the smart workplace will go beyond machine-to-machine and IoT communications.

The connectivity of devices, systems, and services in the smart workplace will be enhanced by a variety of protocols, domains and applications, including those that will be adopted for 5G. 5G will also make multi-person video calling on the move a reality, delivering a fully wireless, cloud-based office, with all unified communications apps more reliably and consistently available[104]. Enhanced mobile broadband will drive adoption and value creation in the 5G economy[105]. More specifically, this will result from extending cellular coverage into structures such as offices and industrial parks and an augmented capacity to manage a significantly greater number of devices using high volumes of data.

Economic benefits: Manufacturing assembly operations are comprised of combinations of people and programmable robots/machines, supported via semi-automated sensing, actuation, fixing and tooling elements. The location of manufacturing operations and others in the supply chain is always physically distributed, yet interconnected through communications and digital ecosystems. The transport of raw materials and other components to the workplace and the goods and services produced by the workplace are distributed by logistic operations which, through utilising 5G capabilities, will be more easily co-ordinated with those of general (road, rail, sea and air) transport systems throughout countries and globally.

5G data exchange capabilities will undoubtedly be the catalyst for further major advances in the globally competitive life cycle of engineering and manufacturing. 5G data exchange capabilities will enhance productivity by one per cent per annum creating productivity gains of ***CHF 1 billion per annum***[106] in Switzerland.

Environmental benefits: A study by McKinsey advocates the use of lean-value-add identification methodologies to map waste creation and energy consumption at every step of their operating processes[107]. These methods can identify where waste is created, how waste can be reduced and value recovery methods to reuse materials previously discarded as waste. 5G capabilities will reduce waste production by one per cent per annum creating waste disposal savings of ***CHF 125 million per annum***[108].

In addition to these benefits, 5G will be usable by businesses as a fixed-line network replacement. This means business owners and managers will be able to connect between

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[102] Vallicelli, M. 2018. Smart cities and digital workplace culture in the global European context: Amsterdam, London and Paris. *City, Culture and Society.* 12, pp. 25-34

[103] Johnson Controls. 2015. The smart workplace 2040. http://www.i-fm.net/documents/file/JCI_SW2040report_small.pdf. and Johnson Controls. 2009. The smart workplace 2030.

[104] Orange. 2016. https://www.orange-business.com/en/magazine/next-generation-mobile-what-can-5g-do-for-the-enterprise

[105] IHS. https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf

[106] To avoid double counting the European Commission study calculated a one per cent improvement in productivity in the non-automotive manufacturing sector, the automotive sector was investigated separately. This forecast was applied (pro-rata) in-line with Swiss GVA. Chapter 5 identifies a number of studies that suggest 5G impact of up to six per cent. This figure is therefore very conservative.

[107] http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/manufacturing-resource-productivity

[108] The European Commission study utilised data about costs of waste disposal and quantities of waste generated in Member States. These results were applied (pro-rata) in-line with the number of businesses in Switzerland.

enterprise branch offices much more quickly and easily[109]. 5G capabilities in wearable devices and sensors will also increase safety at work. There are also forecasted to be additional 5G benefits in office security and energy management[110]. Using remote 5G enabled digital security cameras with advanced image-processing capabilities and Artificial Intelligence will enable operators and managers to monitor activity throughout a plant or offices eliminating the need to have guards and patrols monitoring CCTV screens.

Smart workplaces and offices will support employees to maximise their productivity and performance, benefiting from automation and other 5G applications. These smart offices should be able to connect to smart phones, which will help employees to resolve professional and personal communications[111].

3.4. Smart Cities

The final two environments studied cover a wider scale of analysis. It is in these more extensive locations - urban and rural environments - that 5G capabilities, particularly network coverage and quality, could have a major impact.

Cities contain large numbers of people and businesses that are already relatively well digitally connected by fixed and wireless technologies. This section therefore focuses on key benefits arising from 5G capabilities related to enhanced communications and information access for policymakers, between vehicles and other static and moving devices in cities. Swiss cities, including St Gallen and Winterthur, have joined together in partnership with SBB, Swisscom and Swiss Post to form the Smart City Hub Switzerland Association. This aims to promote the smart city concept throughout Switzerland with robust innovative projects[112].

Smart cities use digital technologies and data to optimise the efficiency and effectiveness of city processes, activities and services. This optimisation is achieved by joining up diverse elements and actors into a more interactive intelligent system. 5G will play a considerable role in providing connectivity and supporting smart city development. Utilising the data connectivity capabilities of 5G (through Massive IoT and Mission Critical Services) will be central in exchanging data and facilitating the smart city.[113]

Economic benefits: One of the unique capabilities provided by 5G is support for the exchange of data in very large scale IoT networks. This 5G capability will enable better traffic management from roadside sensors and real-time data from vehicles. Enhanced information about traffic flows and journeys should enable smart city traffic controllers to better manage traffic real-time and reduce congestion. Enhanced information about congestion should enable drivers and/or autonomous vehicles to avoid congested routes and complete journeys more rapidly.

[109] Orange. https://www.orange-business.com/en/magazine/next-generation-mobile-what-can-5g-do-for-the-enterprise

[110] McKinsey. https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/The%20Internet%20of%20Things%20The%20value%20of%20digitizing%20the%20physical%20world/Unlocking_the_potential_of_the_Internet_of_Things_Executive_summary.ashx

[111] Muñoz, S. et al (2018) An Emotion Aware Task Automation Architecture Based on Semantic Technologies for Smart Offices. *Active Sensor for Microwave Tissue Imaging with Bias-Switched Arrays.* 18 (5)

[112] Smart Cities World. 2018. https://www.smartcitiesworld.net/news/news/smart-city-hub-for-switzerland-3311

[113] Nokia. https://onestore.nokia.com/asset/191721/Nokia_Smart_City_White_P

5G data capabilities will provide congestion reduction benefits of ***CHF 72 million*** in 2030[114]. They will also provide €8.1 billion in congestion, accident and pollution reduction benefits to smart cities in Europe by 2025[115].

Social benefits: 5G capabilities will be used to optimise the efficiency and effectiveness of city processes, activities and services. 5G supporting the joining up of diverse elements and actors into a more interactive intelligent system will enhance this optimisation[116]. Smart cities will increase public safety with high quality CCTV video being able to detect threats and crime[117].

One of the most important benefits arising from the utilisation of 5G capabilities, recognised; but rarely quantified in smart cities studies, are the benefits arising from better traffic management. 5G data exchange capabilities and data analytics provide the ability to reduce traffic congestion, identify traffic black spots and reduce accidents[118].

5G data capabilities will reduce the cost of road accidents by ***CHF 103 million*** in 2030[119].

Environmental benefits: Several benefits arising from improvements in transport planning and reductions in congestion have been presented from economic and social viewpoints. Clearly environmental benefits will also arise from the utilisation of 5G and reductions in congestion and thus emissions. Faster journeys should reduce the consumption of fuel (hydro-carbon and electricity). This in turn should lead to reduced emissions from vehicles and this should lower pollution and CO_2 reductions. 5G will facilitate communication between infrastructure and different amenities making cities not only smarter but cleaner and safer too[120].

5G data capabilities will provide environmental benefits due to a reduction in traffic congestion in smart cities of ***CHF 790,000*** per annum[121]***.***

5G will address some of the key future requirements of smart cities with higher bandwidth, delivery and performance guarantees, adaptability, energy efficiency and real time capabilities[122]. 5G and Smart City benefits will enable the reduction of commuting times[123], improve public safety and create improved smart grid efficiencies[124].

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[114] The European Commission report utilised an AT Kearney report that dynamic access to IoT data will reduce congestion by ten per cent. It was assumed that half of the real time access to data would be provided by 5G and thus half of the ten per cent reduction in the cost of congestion (estimated to be CHF 172 billion in EU Member States in 2030. These results were applied (pro-rata) in-line with the number of vehicles in Switzerland.

[115] The Innovator. 2018. https://innovator.news/how-5g-will-impact-countries-cities-and-companies-e00539e5462

[116] EC. 2014. ibid

[117] The Impacts of Mobile Broadband and 5G. 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/714112/The_impacts_of_mobile_broadband_and_5G.pdf

[118] Smart Minds. 2015. Road Accidents Will Happen and Now We Know When and Where. http://people4smartercities.com/series/road-accidents-will-happen-and-now-we-know-when-and-where

[119] The European Commission report utilised data about the cost of accidents and fatalities. These costs were applied to the number of fatal and non-fatal accidents in EU Member States. The general trend in reducing accidents observed over many years was extrapolated to 2030 and the costs of accidents was calculated per accident. These results were applied (pro-rata) in-line with accident data in Switzerland.

[120] PCR. 2018. https://www.pcr-online.biz/features/the-generation-game-the-impact-5g-will-have-on-retail-storage-smart-cities-and-more

[121] The European Commission report utilised data about reductions in CO_2 emissions resulting from reduced congestion. These results were applied (pro-rata) in-line with vehicle and congestion data in Switzerland.

[122] IEEE. 2017. https://www.ieee.org/publications_standards/publications/periodicals/ieee-smart-cities-trend-paper-2017.pdf

[123] Business Insider. 2017. http://uk.businessinsider.com/how-5g-will-revolutionize-the-internet-of-things-2017-6

[124] Accenture. 2017. https://www.ctia.org/docs/default-source/default-document-library/how-5g-can-help-municipalities-become-vibrant-smart-cities-accenture.pdf

3.5. Non-urban Environments

The rural environment has historically lagged behind its urban counterparts in terms of access to, and exploitation of, fixed and mobile broadband access and the digital technologies that are enabled by broadband access. 5G, through its inherent enabling of multi-tenanting for mixed uses and users could play a considerable role and present obvious benefits[125] by providing an economically sustainable ICT-enabling infrastructure for the rural environment. Difficulties in Switzerland may arise with the adoption of 5G due to the radiation protection regime, which is reported as being ten times more exacting than regulations abroad[126]. This has the potential to delay the implementation of 5G, especially in rural areas and the benefits that 5G will bring. Connectivity enhancements in rural areas, with the help of 5G, would equalise economic development opportunities and the places employers want to be located[127].

5G in rural areas might be applied differently to the way it is deployed in urban areas. 5G will support new ways of farming and living with the use of drones[128]. Mobile networks enabling drones for smart farming is likely to increases in annual profits for farmers using precision farming. DigitalSwitzerland have the aim for Switzerland to be one of the worldwide leaders in smart farming[129]. Farmers will be able to grow more crops more efficiently, monitor livestock more closely and gain higher profits through 5G capabilities. Equipment, livestock and other devices could be equipped with sensors to collect data that will be sent directly to farmers, those maintaining equipment and farm vets. From here, farmers will have a full view of their crops and livestock at all times[130]. In rural areas, there may have to be a compromise between achieving greater coverage of 5G and faster speed internet access. 5G may not give rural homes very high-speed Internet access (though connectivity should be faster than at present). It has been suggested that greater coverage, but at a lower speed, will probably be the most beneficial way forward in rural areas[131].

Economic benefits: One of the key capabilities of 5G enhanced coverage and service quality is the expectation to deliver up to 50Mbps and more. This capability, if realised, has the potential to transform non-urban areas that have consistently lagged behind urban areas in terms of broadband access quality. In more extreme rural locations, where fixed broadband access is thought to be too expensive to provide 'economically', 5G (and its successor technologies) will offer a permanent substitute for higher bandwidth fixed fibre connections.

5G will result in fixed broadband deployment cost savings equivalent to ***CHF 39 million*** in 2030[132].

Social benefits: Broadband connectivity, at an adequate speed, provides numerous advantages in terms of well-being, education and training, health and welfare, economics

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[125] https://eandt.theiet.org/content/articles/2017/03/5g-the-benefits-and-difficulties-of-creating-a-new-wireless-standard/

[126] Mobile Europe. 2018. Sunrise aiming to bring 5G to the people in remote areas https://www.mobileeurope.co.uk/press-wire/sunrise-aiming-to-bring-5g-to-the-people-in-remote-areas

[127] Teale, C. 2019. https://www.smartcitiesdive.com/news/5g-digital-divide-urban-rural-communities/545211/

[128] Kate Pressland. 2018. *Innovative Farmers.*

[129] DigitalSwitzerland. 2019. http://www.smartfarming.ethz.ch/about.html

[130] Segan, S. 2018. https://uk.pcmag.com/netflix/118863/what-will-5g-do-for-rural-areas

[131] Oughton, E. and Frias, Z. 2018. The cost, coverage and rollout implications of 5G infrastructure in Britain. *Telecommunications Policy.* 42 (8), pp. 636-652

[132] The European Commission report examined differences between fixed broadband coverage and mobile broadband coverage provided by network operators for households in EU Member States. This provided estimates of the number of households that could receive sufficient connectivity with 5G to not warrant a fixed broadband connection. Connectivity costs per household were extrapolated and the costs savings of utilising 5G capabilities instead of a fixed broadband connection were calculated. These results were applied (pro-rata) in-line with the number of households in Switzerland.

and employment and community cohesion[133]. Distance learning has historically been a service that has enabled people living remotely from schools and universities to participate in educational courses. In recent years, a new form of distance education has emerged - Massive online open courses (MOOCs). MOOCs have been embraced by prestigious universities such as Stanford, MIT, EPFL and the Sorbonne[134], to offer access to an unlimited number of students to certain courses. Research has shown that offline UK households were estimated to be forgoing an average consumer saving of CHF 820 per year[135].

5G capabilities will result in benefits for households that are currently poorly connected of ***CHF 144 million*** per annum[136].

Environmental benefits: The European Commission study calculated CO_2 emissions arising from congestion in non-urban areas. It was noted that 5G capabilities should have the same impact on traffic reduction in non-urban areas as they do in cities. Estimates were then made of the economic benefits of reducing CO_2 emissions in non-urban areas.

5G data capabilities will provide environmental benefits due to a reduction in traffic congestion in non-urban environments of ***CHF 1.5 million*** per annum [137].

3.6. Conclusions

The chapter replicated the methodology used in a European Commission study to examine the benefits of 5G in four environments in Switzerland – Smart Homes, Smart Workplaces, Smart Cities and non-urban locations. In total the 5G impacts described above are forecast to create CHF 513 million of benefits in 2030. This is comprised of a total of CHF 126 million economic benefits, CHF 247 million in social benefits and CHF 141 million of environmental benefits[138].

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[133] Tech4i2 et. al. 2016. Review of the scope of Universal Service. https://publications.europa.eu/en/publication-detail/-/publication/59a30817-9a95-11e6-9bca-01aa75ed71a1/language-en

[134] http://www.paris-sorbonne.fr/MOOC

[135] UK Race Online 2012. Manifesto for a networked nation. 2010 https://joinup.ec.europa.eu/document/uk-race-online-2012-manifesto-networked-nation

[136] The European Commission report utilised data about offline UK households to extrapolate potential savings across poorly or non-connected EU Member State households . These results were applied (pro-rata) in-line with households in Switzerland.

[137] The European Commission report examined utilised research to estimate reductions in congestion in rural areas and subsequent reductions in CO_2 emissions. These results were applied (pro-rata) in-line with vehicle and congestion data in Switzerland.

[138] Due to rounding totals do not correspond.

Chapter 4

5G economic impact in Switzerland

*5G has the potential to produce **CHF 42.4 billion of output in 2030**. Three per cent of Swiss output (at 2016 prices).*

***Manufacturing** will provide the largest contribution to 5G enabled output - CHF 9.9 billion in 2030 (23 per cent of total 5G benefits).*

*5G enabled output will support **137,100 jobs in 2030***

4.1. Introduction

This chapter forecasts the impact of 5G in 2030 in 16 industrial sectors in Switzerland; ten years after first deployment of 5G infrastructure which is expected to take place. The next chapter looks more closely at the timeline to 2030 and beyond for benefits realisation.

Research has utilised more than 240 5G reports[139] and studies to examine the qualitative and quantitative impact of 5G capabilities in industrial sectors in Switzerland. Our study team utilised results from many of these studies to produce a robust benefits realisation model to estimate 5G impacts in Switzerland and other countries in February 2018. Interestingly, in April 2018 Australian government published a study of 5G impacts in Australia, using a complementary methodology.

[139] Many, though not all, have been referenced in this report.

Annex 1 provides an overview of the benefits realisation model that forecasts benefits between 2020 and 2045 and the impact of delays in deployment. The model provides insights to a potential reality that will enable stakeholders to better understand the benefits of 5G.

This chapter presents a forecast of the 'expected' potential reality that will occur in 2030 if Switzerland achieves the global average rate of 5G deployment and adoption of 5G capabilities by citizens, businesses and government. Since Switzerland has achieved faster rates of 3G and 4G infrastructure deployment than nearly all European countries this is not an unreasonable assumption[140].

After a review of headline 5G impact forecasts the remainder of this chapter provides an overview of 5G impacts in six sectors (manufacturing, ICT, public administration, retail, finance and transportation and storage) that are expected to achieve the largest increase in 5G enabled output in 2030 in Switzerland. This review complements the four core sectors (automotive, healthcare, transport and utilities) examined when replicating the European Commission 5G impact study methodology for Switzerland in chapter 2.

Collectively the six sectors examined in this chapter will provide CHF 30.2 billion (69 per cent) of 5G-enabled output, creating more than 75,000 jobs, in 2030.

4.2. 5G Impact in Switzerland in 2030

Figure 3 presents overview of the value of 5G enabled outputs in Switzerland forecast to 2030 using the economic benefits realisation model.

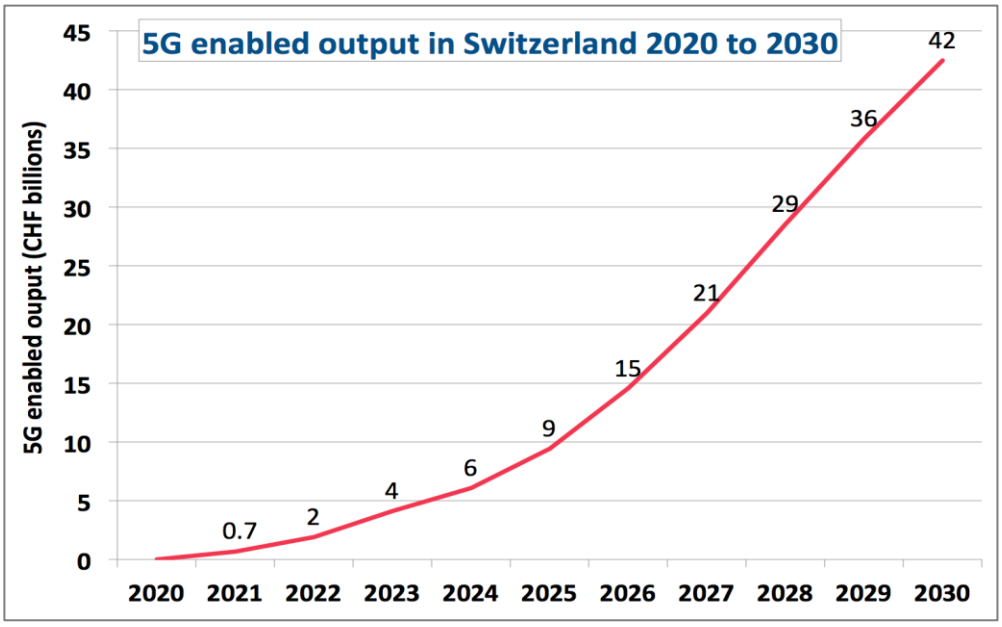

Figure 3 5G enabled output 2020 to 2030

[140] ITU statistics reveal that despite a more challenging topography 99 per cent 3G coverage was achieved in 2013, approximately a year faster than other European countries, and 99 per cent 4G coverage was achieved in 2014, only one country in Europe achieved this benchmark earlier (Sweden in 2013). International Telecommunications Union. 2017. Data sets - ITU WFID i271G and ITU WFID i271GA

Analysis found that after limited impact in the early years of deployment 5G-enabled output grows considerably between 2024 and 2030[141]. Relatively high rates of early adoption of 5G mobile handsets and devices lead to 50 per cent of 5G enabled output benefits being realised by 2028 and 69 per cent of benefits in 2030. The timeline for achieving 5G benefits is therefore relatively fast. Sensitivity analysis, presented in the next chapter, investigates the impact of delays in infrastructure deployment on 5G benefits realisation in Switzerland.

5G enabled output figures are used to calculate 5G enabled jobs by dividing the predicted output by output per employee for each sector[142], see Table 4 In total it is forecast 5G enabled output (CHF 42.4 billion in 2030) will support 137,100 jobs.

Table 4 5G enabled sectoral output and employment in Switzerland in 2030

Sector	2030 Impact (CHF 2016 millions)	5G enabled employment in 2030[143]	Percentage of 5G enabled output in 2030
Manufacturing	9,990	20,600	23.5%
Information and communication	4,970	14,350	11.7%
Public administration	4,230	7,750	10.0%
Retail and wholesale	4,040	15,050	9.5%
Finance and insurance	3,860	8,650	9.1%
Professional Services	3,700	18,750	8.7%
Transportation and Storage	3,070	8,900	7.3%
Construction	2,630	11,500	6.2%
Health and social work	1,710	12,050	4.0%
Utilities	1,550	1,550	3.6%
Real estate	1,120	1,200	2.7%
Accommodation and food	740	7,900	1.7%
Agriculture, Forestry and Fishing	430	4,700	1.0%
Arts, entertainment and recreation	190	1,700	0.4%
Education	150	2,300	0.4%
Mining and quarrying	50	110	0.1%
Total	**42,400**	**137,100**	(100%)

4.3. Manufacturing

Manufacturing is Switzerland's largest industry with total output of CHF 341 billion in 2016. Several studies have predicted that the largest impacts from 5G enabled production will arise

[141] This type of s-shaped adoption (and thus complementary benefits) curve is typical of early stage adoption for nearly all technologies.

[142] Using 2016 datasets from Eurostat - bd_9ac_l_Form_r2 and lfsa_egdn2. 2016 is the last year for which information is available for Switzerland from the Eurostat statistics; These statistics were last updated on 18th January 2019.

[143] Eurostat data highlights that sectors have considerably different outputs/ per employee. For example Utilities and Healthcare have similar magnitudes of 5G enabled output (CHF 1,550m and 1,710m respectively). But they have significantly different output per employee productivity (Utilities CHF 1,011,000 per employee and Healthcare 142,500 per employee). Due to rounding totals may not correspond.

in manufacturing[144]. Ericsson forecast that 19 per cent of 5G enabled industry digitalization revenues in 2026 will be created in the manufacturing sector[145]. Qualcomm sponsored research predicts that 27 per cent of 5G enabled output will be generated from the manufacturing sector in 2035[146]. The benefits realisation model developed for this study forecasts CHF 9.99 billion of 5G enabled output per annum will be achieved by 2030. This is 22.9 per cent of the 5G benefits achieved across all sectors in Switzerland.

As the world becomes ever more digitally and globally connected, manufacturing is forecast to experience an ICT-driven transformation[147]. 5G will be a major technology in growing industrial digitalisation by providing flexibility, efficiency, productivity, safety and security within the manufacturing sector[148].

Manufacturing assembly operations are comprised of combinations of people and programmable robots/machines, supported via semi-automated sensing, actuation, fixing and tooling elements. Necessarily, the location of manufacturing operations must be physically distributed (throughout a manufacturing site or over many sites). 5G will provide major advances by enabling operations to be interconnected physically and logically[149] in smart workplaces. Smart factories will be able to take advantage of technologies including automation, AI, and IoT[150]. This will be achieved through flexible computer controlled conveyors (typically distributed over many kilometres) and production platforms. Items for production and finished goods will be moved through flexibly co-ordinated logistics systems that will be linked to extensive transport systems (road, rail, sea and air)[151].

During recent years, the dominant elements in product realisation paradigms within manufacturing have been 'mass production' (scale) and 'mass customisation' (scope)[152]. 5G will enhance the economies of scale (where large quantities of products are made efficiently using optimised systems of people and machine resources) and economies of scope (where variants within products and/or between products are accommodated by using common flexibly/computer controlled semi-automated resource systems that are also designed to operate efficiently in response to predicted variations in production demand)[153]. Gartner forecast that by 2020 more than 50 per cent of new business processes in manufacturing would contain IoT connected devices[154].

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[144] Studies predicting high rates for adoption in manufacturing include IHS. 2017. The 5G economy: How 5G technology will contribute to the global economy. https://www.qualcomm.com/invention/5g/economy Verizon. 2017. State of the Market: Internet of Things 2017. p4. predict adoption rates for IoT network connections twice as great in manufacturing than any other sector. http://www.verizon.com/about/sites/default/files/Verizon-2017-State-of-the-Market-IoT-Report.pdf

[145] Ericsson. 2017. The 5G business potential. http://www.5gamericas.org/files/7114/9971/4226/Ericsson_The_5G_Business_Potential.pdf

[146] IHS. 2017. The 5G economy: How 5G technology will contribute to the global economy. https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf

[147] GSA 2017. 5G Network Slicing for Vertical Industries. http://www.huawei.com/minisite/5g/img/5g-network-slicing-for-vertical-industries-en.pdf

[148] Nokia. 2017. 5G Connected Industries: Transforming industry with 5G. https://onestore.nokia.com/asset/201731/Nokia_5G_Connected_Industries_eBook_EN.pdf

[149] 5GPPP. 2016. 5G empowering vertical industries. https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

[150] Ericsson. 2018. https://www.ericsson.com/en/networks/trending/insights-and-reports/5g-for-manufacturing

[151] Vodafone. 2017. Creating a Gigabit Society- The role of 5G. https://www.vodafone.com/content/dam/vodafone-images/public-policy/reports/pdf/gigabit-society-5g-14032017.pdf

[152] Ericsson. 2018. The Industry Impact of 5G. http://www.astrid-online.it/static/upload/eric/ericsson_report-bnew-18000486-rev-a-uen.pdf

[153] Tech4i2 et al. 2016. Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe. European Commission.

[154] Gartner. 2016. More than half of major new business processes and systems will incorporate some element of the Internet of Things. https://www.gartner.com/en/newsroom/press-releases/2016-01-14-gartner-says-by-

Fraunhofer IPT, Ericsson and GF Machining Solutions have joined together to create wireless sensor connections for real time data analysis[155] utilising 5G capabilities. The approach maximises communication between machines and sensors to reduce errors and ensure control of production processes with shorter reaction times. Nokia has been manufacturing 5G equipment for manufacturing in India[156]. They suggest India will be one of the first countries to experience 5G manufacturing and Smart Manufacturing.

Presently, there are manufacturing companies who are using augmented and virtual reality but are unable to fully invest in these technologies due to the large bandwidth needed to run them. Employees are required to be connected to the network to use the technologies. However, with the rise in 5G, employees will be able to work with the technologies from anywhere on the factory floor[157].

4.4. Information and Communication Technologies

Information and Communication Technologies is Switzerland's tenth largest industry[158]. Since the sector produces the technological equipment that will support the digitisation of industries in the future it is not surprising that several studies forecast the information and communications sector as one of those to benefit most from 5G capabilities[159].

Enhanced mobile broadband provided by 5G will support the delivery of HD video for media and gaming and immersive communication for video calling and augmented/virtual reality[160]. Ultra-low latency capabilities provided by 5G will provide a more immersive experience for augmented reality and virtual reality device users. Immersive technologies are forecast to undergo considerable growth[161]. Forecasts suggest the global augmented reality market is growing at a CAGR of 79 per cent and this growth will continue into the next decade[162][163]. The market for virtual reality technology was valued globally at CHF 1.14 billion in 2015. The global virtual reality market is forecasted to grow to reach CHF 33 billion by 2022 (CAGR of 57 per cent).

Research from Ericsson states that in 2026 5G-enabled industry digitalisation revenues for ICT players will reach $1.3 trillion. 19 per cent of this comes from energy and utilities and 18

2020-more-than-half-of-major-new-business-processes-and-systems-will-incorporate-some-element-of-the-internet-of-things

[155] Fraunhofer IPT. 2018. https://www.ipt.fraunhofer.de/en/Press/Pressreleases/20180911_fraunhofer-ipt-ericsson-and-gf-to-present-5g-manufacturing-solution-first-time-us.html

[156] The Economic Times. 2018. https://economictimes.indiatimes.com/industry/telecom/telecom-news/nokia-begins-manufacturing-of-5g-equipment-in-india/articleshow/66360136.cms

[157] New Equipment Digest. 2018. https://www.newequipment.com/industry-trends/5-ways-5g-will-power-smart-factory-future

[158] Information and Communications: Output CHF 58 billion in 2016.

[159] 5TONIC. 2017. Programa del Foro de Movilidad 2017. Open 5G Lab. http://www.rediris.es/gt/gt2017/programa/movilidad/ IMDEA Networks 5G set to revolutionize communications and to transform industry http://www.networks.imdea.org/whats-new/news/2017/5g-set-revolutionize-communications-and-transform-industry

[160] GSMA. 2017. https://www.gsmaintelligence.com/research/?file=0efdd9e7b6eb1c4ad9aa5d4c0c971e62&download

[161] TechTrends. 2017. Market Report: Augmented and virtual reality market growth. http://techtrends.tech/tech-trends/report-augmented-virtual-reality-market-continues-grow. 2degrees. 2017. Virtual reality is a growing technology. https://www.2degreesnetwork.com/groups/2degrees-community/resources/virtual-reality-vr-market-growing-technology. Zion Market Research. 2017. Virtual Reality Market Size Projected Reach $26.89 Billion by 2022. https://www.zionmarketresearch.com/sample/virtual-reality-market

[162] Research and Markets. 2016. Augmented Reality and Virtual Reality Market by Device - Global Forecast to 2022. http://www.researchandmarkets.com/reports/3736899/augmented-reality-and-virtual-reality-market-by

[163] Markets and Markets. 2015. Augmented Reality Market by Component, Display Type, Application and Geography – Global Forecast to 2020. http://www.marketsandmarkets.com/Market-Reports/augmented-reality-market-82758548.html

per cent from manufacturing[164]. According to Huawei, 5G would be able to generate almost $270 billion for the regional ICT sector in the next 10 years[165]. Research forecasts CHF 4.98 billion of 5G-enabled output, supporting 14,350 jobs, in 2030. This is 11.3 per cent of 5G benefits in Switzerland, the second largest contribution to 5G enabled benefits across all sectors.

4.5. Public Administration

Public Administration is Switzerland's fourth largest sector[166]. Chapter 3 provided an overview of Smart City 5G benefits that will be led by public administrations. This section briefly reviews new services and benefits for public administrations. The additional speed and capacity of 5G networks could lead to the development of fresh content formats for public service media. This could include cross-media, multi-lingual and interactive content. There will also be opportunities for new kinds of interactive content utilising virtual reality and augmented reality[167].

More extensive coverage and the ability to link sensors provided by 5G networks will provide greater opportunities for efficiency savings by public administrations. Waste management[168] is one advantage can that come from 5G. Bigbelly is a good example of how a public service - waste collection and recycling services - can be transformed by the application of Internet of Things technology. Sensors are attached to rubbish and recycling bins. This data is analysed alongside information about other waste/recycling collection lorries and routes to provide the optimum collection cycle and route to collect rubbish/recycling, ensure bins are never over-flowing and improve service quality[169].

5G can also support public safety applications. Robots could be sent to work in dangerous situations, such as bomb disposal and fire fighting[170]. To function efficiently highly reliable network connections are required, with exceedingly low error rates for data transmission and end-to-end latency of less than one millisecond to support haptic (tactile sensation) feedback when controlling robots[171]. Superfast Internet, analytics and advanced software programmes could support smarter and fast-response emergency services. Predictive analytics from 5G adoption also has the capacity to be able to forecast and mitigate the impact of natural disasters[172].

A public good that can benefit from 5G is street lighting[173]. Smart lighting (or smart LED lighting) can both reduce light pollution and keep a neighbourhood safe. Smart lights could

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[164] Ericsson. 2018. The Industry Impact of 5G. https://files.vogel.de/vogelonline/vogelonline/files/9763.pdf

[165] Trade Arabia Business News Information. 2018. http://www.tradearabia.com/news/REAL_346398.html

[166] Public Administration: Output in 2016 CHF 106 billion.

[167] 5G.co.uk. 2018. What will 5G mean for public service media? https://5g.co.uk/guides/5g-public-service-media/

[168] Department for Culture Media and Sport. 2017. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/597421/07.03.17_5G_strategy_-_for_publication.pdf

[169] Futurum, 2016. How IoT will impact the public sector; https://futurumresearch.com/iot-will-impact-public-sector. Trash can image http://iiot-world.com/smart-cities/smart-cities-using-internet-of-things-practical-applications. LoRa, LPWAN and other proprietary and open Long Range Wireless IoT communications methods exist alongside 5G. For examples see LoRa Network Protocol and Long Range Wireless IoT https://www.postscapes.com/long-range-wireless-iot-protocol-lora/

[170] Nokia, 2016. 5G for Mission Critical Communication; http://www.hit.bme.hu/~jakab/edu/litr/5G/Nokia_5G_for_Mission_Critical_Communication_White_Paper.pdf

[171] BLER (Block Error Rates) up to 10-9. Haptics applies 'touch' (tactile sensations) and control to interaction with computer and robot applications. It is considered an important additional dimension to a VR to provide a fully immersive environment.

[172] Bureau of Communications and Arts Research. 2018. https://www.communications.gov.au/file/35551/download?token=0MlSFttv

[173] Ofcom. 2018. https://www.ofcom.org.uk/phones-telecoms-and-internet/advice-for-consumers/advice/what-is-5g

save power by lowering public lighting when there are no pedestrians or vehicles present[174]. This will also reduce energy costs for the local council or government that fund lighting.

Research forecasts CHF 4.23 billion of 5G-enabled output, supporting 7,750 jobs, in the sector in 2030. This is ten per cent of 5G benefits in Switzerland, the third largest 5G facilitated output across all sectors.

4.6. Retail and wholesale

Retail and wholesale is Switzerland's second largest industry[175]. IHS research[176] suggests that the utilisation of 5G capabilities will lead to the third highest proportion (5.6 per cent) of 5G-enabled output in this sector. 5G provides the opportunity to radically enhance online and High Street shopping experience, particularly through 5G supported augmented reality (AR) and virtual reality (VR) applications[177]. For example IKEA has created an AR catalogue app[178] to help customers visualise how their selected furniture would fit and look in their own homes, enabling users to explore designs and colours that suit their home before purchase. Benefits do not just arise for customers, but also shop assistants and others employed in the retail sector. Shop assistants will be able to browse larger stock lists and at a much faster speed[179].

5G in the retail sector will change customer expectations and it is likely that there will be some radical changes. Firstly, over the past few years many customers like to be able to shop from home due to eCommerce expansion and this is going to grow with the application of 5G. There is also a trend towards omni-channel retail. Retailers will therefore need to offer complete flexibility in sales channels, this can be supported by 5G. In the next few years, customers will be expecting a unique, personalised shopping experience, with customised products and offers. A fourth change in the retail sector is the location of stock storing. As costs rise for retail space, in-store stock will be forced to move to central warehouses[180].

Many personalised shopping experiences can be created through the use of 5G. For example, interactive dressing rooms. These enable the customer to alert the shop assistant when they require a different size by the push of a button. Interactive "magic mirrors" is another idea that would be possible with applying 5G. These mirrors will recognise the product the customer is trying on and could display personal ads such as accessories or shoes that will match the outfit[181].

There are many applications of VR that can be adopted into the retail industry and sales. Customers will have VR incorporated into their shopping experience. When a company releases a new product, the workforce could learn about the item by interacting with it in a VR setting instead of only reading the features and benefits. Employees will be able to see them in action[182].

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[174] Phan, A. and Qureshi, S. 2017. 5G impact on smart cities. https://www.researchgate.net/publication/315804922_5G_impact_On_Smart_Cities

[175] Retail and Wholesale: Output in 2016 CHF 182 billion.

[176] Ibid. IHS. 2017. The 5G economy: How 5G technology will contribute to the global economy. https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf

[177] Huawei. 2016. 5G Opening up New Business Opportunities. http://www.huawei.com/minisite/5g/img/5G_Opening_up_New_Business_Opportunities_en.pdf

[178] Enterprise Innovation. 2017. Will 5G truly transform our lives? ; https://www.enterpriseinnovation.net/article/will-5g-truly-transform-our-lives-1244626393

[179] PCR. 2018. https://www.pcr-online.biz/features/the-generation-game-the-impact-5g-will-have-on-retail-storage-smart-cities-and-more

[180] Techwire Asia. 2018. https://techwireasia.com/2018/03/5g-5-minutes-retailers/

[181] AT&T Business. 2018. https://www.business.att.com/learn/updates/how-5g-will-boost-the-retail-industry.html

[182] Teo, S. 2017. https://sipmm.edu.sg/impact-of-the-emerging-5g-network-technology-on-logistics-and-supply-chain-management/

Research forecasts CHF 4 billion of 5G enabled output, supporting 15,050 jobs, in 2030. This is the second largest number of jobs created by 5G enabled output (after manufacturing 20,600 jobs). Output of CHF 4 billion is 9.5 per cent of 5G benefits in Switzerland, which is the fourth largest across all sectors.

4.7. Finance and Insurance

Finance and Insurance is Switzerland's third largest sector. 5G capabilities provide opportunities to enhance customer experience and realise back-end infrastructure efficiencies[183]. The financial services industry has previously been early adopters of digital technology such as online and mobile banking.

5G networks and technological innovations in the financial sector will provide customers with increased availability of products, with greater speed and integration (less friction) when using financial services. Greater access to real-time and historic data about customers' habits and preferences will enhance product design and service quality[184]. 5G will also enable the ability to handle a larger volume of data, better analytics and faster speed that could help with fraud detection and customer segmentation[185].

5G could be utilised alongside artificial intelligence, cognitive computing and machine learning to develop personal banking assistants that scan all data in the cloud about someone's life and financial behaviour to produce a daily spending limit. This kind of 'robo-advisor' service is already happening in a blunter way in areas like portfolio management and investment advice, but a properly personalised and private banking experience should be possible with 5G[186]. 5G's support for Massive Internet of Things will support the development of payments systems through wearable devices, such as smart watches, activity trackers, healthcare devices, jewellery[187] and even advanced textiles[188]. In 2017 collaboration between Bank of America and FitPay enabled Bank of America credit and debit cardholders to make contactless payments directly from wearable devices at NFC-enabled point of sale locations[189]. NFC capabilities were added to the 6th generation of Apple iPhones launched in September 2014[190]. According to Gartner, it is estimated that 225 million wearable devices will be shipped globally in 2019, up 26 per cent from 2018[191].

Data is central to the business models of most retail and investment banks[192]. 5G will provide enhanced access to higher volumes of data with ultra low-latency. 5G has a very low latency, therefore banking transactions and payments will be made instantly from

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[183] White and Case. 2017. Fintech. Key issues for operating fintech businesses. https://www.whitecase.com/publications/article/fintech-key-issues-operating-fintech-businesses

[184] CEMLA. 2017. FinTech: key issues and challenges for central banks. http://www.cemla.org/comunicados/2017-08-fin-tech.html

[185] Bureau of Communications and Arts Research. 2018. https://www.communications.gov.au/file/35551/download?token=0MlSFttv

[186] 5G.co.uk. 2018. Why FinTech needs 5G. https://5g.co.uk/guides/why-fintech-needs-5g/

[187] FitPay. 2017. Biometric identity ring allows anyone to live keyless, cardless, andf of passwords. http://www.fit-pay.com/nxt-id-subsidiary-fit-pay-to-power-payments-on-token/

[188] CNET. 2016. Wearable tech: Many, many small steps. https://www.cnet.com/news/wearable-tech-at-ces-2014-many-many-small-steps/

[189] Millman. 2017. Bank of America, FitPay partner to speed up wearable payments. https://internetofbusiness.com/bank-america-fitpay-wearable-payments/

[190] iPhones 7, 8 and X also have NFC for payments but additionally, with iOS 11 and an NFC App, they can read NFC tags. The latest iPhone XS, XS Max and XR have NFC for payments and can read NFC tags with or without an additional App. At present, no iPhone can write to an NFC tag.

[191] PYMNTS. 2018. https://www.pymnts.com/mobile/2018/how-5g-will-shake-up-banking-and-fintech/

[192] Allen and Overy. 2018. The challenge faced by the Fintech market and how to capture innovation while preserving the stability of the banking network. http://www.allenovery.com/publications/en-gb/Fintech/Pages/Issues.aspx

devices[193]. Speedy buying and selling is essential for trading and fractions of a second can make huge differences, especially in the stock market. Observers[194] have suggested that 5G's ultra low latency (1ms) will prove irresistible to brokerage firms and they are expected to be amongst the first to utilise 5G.

Insurance companies will be able to benefit from the implementation of 5G. For example, sensors in connected cars could feed back to insurance companies[195] so they can develop a better understanding of the customer and the data would be more accurately stored.

Research forecasts CHF 3.86 billion of 5G enabled output, supporting 8,650 jobs, in 2030. Output of CHF 3.86 billion is 9.1 per cent of 5G benefits in Switzerland, the fifth largest across all sectors.

4.8. Transportation and storage

Transportation and storage is Switzerland's seventh largest sector[196]. As chapter 2 highlighted transport and storage is a sector ideally placed to benefit from the ability of 5G networks to monitor the movements of vehicles and cargo real-time. This should provide considerable opportunities for efficiency improvements in logistics. Transport has some of the highest profile future applications for 5G and observers have identified 5G as a critical driver of innovation, productivity and competitiveness in the sector[197].

Connecting private vehicles, public and private transport with 5G will completely revolutionise transportation[198]. Fully automated driving will require new telecommunication and satellite infrastructure and services for positioning and communication between vehicles[199]. 5G's enhanced broadband network coverage offers considerable opportunities to support the high volume of data transfer that will be required to enhance transportation, reducing traffic congestion and associated emissions[200].

Utilising 5G Massive Internet of Things capabilities will have a substantial impact on logistics operations. 5G will make it possible to monitor parcels, assets and people in real time throughout the entire logistics value chain, including warehousing operations, freight transportation, and last-mile delivery[201]. Tracking parcels or containers will be greatly improved by installing 5G-connected sensors to vehicles and packaging. The stakeholders in the supply chain can see the items location, temperature, g-forces etc, at any given time[202].

Better communication along roads using intelligent transport systems will close the gap between the real world and smart world. 5G could enable a system to be designed that will

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[193] Carter, J. (2018) https://5g.co.uk/guides/why-fintech-needs-5g/

[194] Ibid. 5G.co.uk. 2018.

[195] Ericsson. 2018. The Industry Impact of 5G. https://files.vogel.de/vogelonline/vogelonline/files/9763.pdf

[196] Transportation and Storage: Output in 2016 CHF 80 billion.

[197] Impact Research Hub. 2017. Policy Insights: How will 5G revolutionise the European automotive industry? https://www.autonomousvehicletech.com/ext/resources/AVT/2017/September/20170928-Impact-Research-5G-Report-pdf.pdf

[198] Carritech telecommunications. 2017. 5G uses cases: Vehicles and transportation. http://www.carritech.com/news/5g-use-cases-vehicles-transportation/

[199] European Commission. 2017. Europe on the move. https://ec.europa.eu/transport/sites/transport/files/com20170283-europe-on-the-move.pdf

[200] Accenture. 2017. How 5G can help municipalities become vibrant smart cities. https://www.ctia.org/docs/default-source/default-document-library/how-5g-can-help-municipalities-become-vibrant-smart-cities-accenture.pdf

[201] DHL and CISCO. 2015. Internet of Things in logistics. https://www.dpdhl.com/content/dam/dpdhl/presse/pdf/2015/DHLTrendReport_Internet_of_things.pdf

[202] Togard, A. 2017. https://www.2wglobal.com/news-and-insights/articles/features/the-impact-of-5g/

be able to construct routes for the transportation without facing challenges[203]. This will enable customers to benefit from more “next day” or “same day” deliveries. The use of robotics and automation from 5G applications will create lower costs, improved delivery, and better warehouse management[204].

Other 5G applications include real-time cross-docking hubs, which will strengthen loads and reduce dead-end millage, and exchange platforms[205]. Another benefit from 5G in this sector is thought of to be improved business process efficiency[206]. Research forecasts CHF 3 billion of 5G-enabled output, supporting 8,900 jobs, in 2030.

[203] Din, S. et al (2018). 5G-enabled hierarchical architecture for software-defines intelligent transportation system. *Computer Networks.* 150, pp. 81-89

[204] Study on Implications of 5G Deployment on Future Business Models. 2018. https://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/8008-study-on-implications-of-5g-deployment-o_0.pdf

[205] Bunegar, S. 2017. https://www.joc.com/international-logistics/logistics-technology/5g-services-likely-transform-freight-industry_20170925.html

[206] Wazir, B. (2018) https://www.raconteur.net/technology/5g-iot-logistics

Chapter 5
5G benefits realisation

5G will produce economic benefits relatively quickly. Half of 5G enabled output benefits (CHF 31 bn) will be realised by 2028.

Manufacturing will provide the largest contribution to 5G enabled output between 2020 and 2045 - CHF 14.3 billion per annum (23 per cent of total 5G enabled output).

5G deployment delays will have a significant effect on benefits realisation. A one year delay over the first seven years of deployment will lead to a cumulative loss of CHF 3.1 billion in 5G enabled output. Job losses from output foregone would reach 2,820 in 2025.

5.1. Introduction

It presents results from a benefits realisation model developed for this study that delivers insights to the impact of 5G across all sectors of the Swiss economy. The model, described in the annex, assumes that 5G infrastructure deployment and the adoption of 5G enabled devices proceed at the rate observed for previous generations of mobile technologies. The model also examines the economic and employment impacts of delays in 5G-infrastructure deployment.

5.2. Innovation and digital momentum

Switzerland has been the most innovative European country during the last decade[207]. Switzerland attracts the highest number of international scientists[208] and is at the forefront of technology development in Europe, see Figure 4.

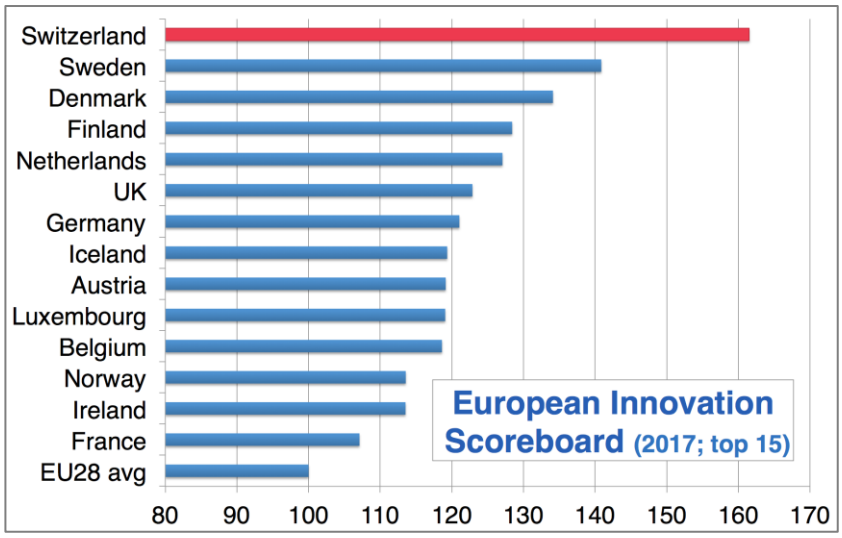

Figure 4 Switzerland's position in the European Innovation Scoreboard

But a major global study, published in 2017, suggests that the situation in Switzerland is stalling. Switzerland is ranked third (of 60 countries) in the Mastercard sponsored 2017 Global Digital Evolution Index[209] that examines how well countries are making the transition towards a digital future. The study highlights that Switzerland is one of the digitally most advanced nations in the world (ranked 3rd) but its digital momentum (ranked 42nd, measuring the rate of technological development) is stalling. The study emphasises that Switzerland needs to further support digital technology and eliminate impediments to innovation. The results of this research are therefore significant in examining the benefits of 5G and investigating the impact if 5G deployment is delayed.

5.3. 5G Impact in Switzerland – 2020 to 2045

The 5G benefits realisation model that underpins this study used Swiss and European expert forecasts to examine the likely rate of benefits realisation for three key capabilities provided by 5G[210], see Figure 5. These are:

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[207] European Commission. 2017. European Innovation Scoreboard 2017. p 7. Switzerland has been placed first every year since benchmarking studies commenced in 2010 http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en

[208] OECD. 2017. Science Technology and industry scoreboard 2017. p 73. http://www.oecd-ilibrary.org/docserver/download/9217081e.pdf?expires=1519638380&id=id&accname=guest&checksum=948328025AA28339FB801CBFCDBF0BA0

[209] Tufts University. 2017. Digital Planet 2017: How competitiveness and trust in digital economies vary across the world. https://sites.tufts.edu/digitalplanet/files/2017/05/Digital_Planet_2017_FINAL.pdf. At the time of writing (January 2019) an index for 2018 has not been released.

[210] Tech4i2 et al. 2016. Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe. European Commission p21

Enhanced Mobile Broadband - This simple but challenging 5G capability goal aims to provide a universal minimum data rate to enable high level quality of service coverage everywhere (including homes, office buildings, shopping malls and large venues) with increased capacity provided to considerably more 5G enabled devices;

Massive Internet of Things - 5G is designing its entire system to support very large scale machine-to-machine and Internet of Things networks operating at low-power in licensed and unlicensed spectrum;

Mission Critical Services - Mission Critical capabilities are seen as essential to support new market opportunities that will be supported by 5G's highly reliable connections, ultra-low latency connectivity, with strong security and availability.

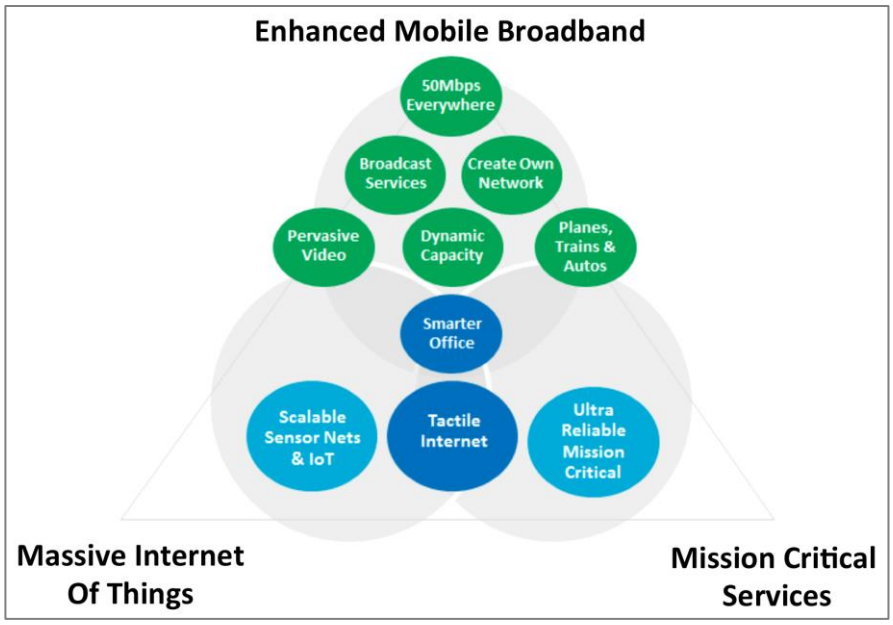

Figure 5 The three core capabilities provided by 5G

Figure 6 shows the contribution of the three key 5G capabilities in providing benefits. This insight is important because 5G infrastructure delays, reviewed in the final part of this chapter, will have different impacts on the three key 5G capabilities.

Enhanced Mobile Broadband Communications will achieve the largest proportion of benefits. These benefits are reliant on access to 5G communications networks; delays in deployment will have a major impact on these capabilities. Enhanced Mobile Broadband is forecast to provide CHF 23.7 billion of 5G enabled output per annum in 2045; this is 38 per cent of overall benefits (of CHF 61.7 billion in 2045). Forecasts suggest that early benefits from Enhanced Mobile Broadband will provide 43 per cent of all benefits (5G enabled output of CHF 12.3 billion) in 2028.

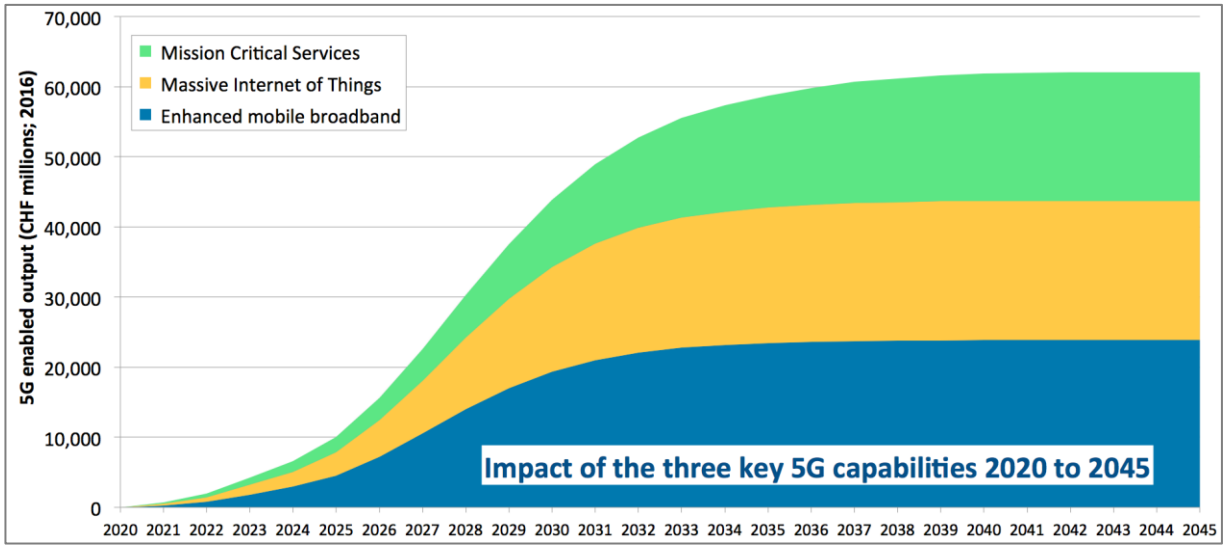

Figure 6 Impact of the three core 5G capabilities 2020 to 2045

Mission Critical Services are the slowest to reach maturity[211]. In 2028 they are expected to provide 20 per cent of total 5G-enabled output (CHF 6.9 billion). By 2045, when Mission Critical Services reach their maximum potential, they will contribute 30 per cent of total 5G-enabled output (CHF 18.3 billion). Massive Internet of Things will contribute 32 per cent of benefits in 2045 (CHF 19.8 billion). However, Massive Internet of Things benefits could be provided by licence-exempt wireless technologies[212], such as WiFi and LoRaWan[213], that will not require 5G infrastructure deployed by mobile operators. This is an important consideration that has been incorporated into calculations of the impact of delays in deployment.

5.4. 5G Sectoral Impact – 2020 to 2045

The 5G Impact in Switzerland (chapter 4) examined 5G impact in 2030 and highlighted that the largest contribution to 5G-enabled output (by value) is provided by the manufacturing sector. Manufacturing will provide CHF 14.3 billion of 5G enabled output in 2045, this

[211] Although first deployments are expected to commence in 2020 surveys suggest that very few operators see a business case to utilise ultra-low latency capabilities in the near future. ReThink Research (rethinkresearch.biz) has found that only about 15 per cent of operators can see a case for 5G ultra-low latency capabilities by 2025. This is one of the reasons why observers predict limited impacts for Mission Critical Services (supported by ultra-low latency) in the near future. However, whilst the general level of uptake of this 5G capability might be limited, it is possible that business opportunities might arise for providers delivering network capabilities that are optimised to provide ultra-low latency or other capabilities for a specific vertical.

[212] One of the imponderables concerning 5G development is the evolution of non-3GPP wireless technologies to support similar capabilities, especially the IEEE – 802.11/WiFi roadmap. Convergence of WiFi and 5G roadmaps would probably spur adoption in some industries; but liaison has been limited. Related to this is the speed of evolution of robust unlicensed spectrum options for 5G. 5G-unlicensed spectrum allocations are due to be agreed in late 2019. This could greatly affect the economics for some industrial sectors because it could enable businesses that are not mobile operators to run specially optimised or even private vertical market networks. Since these networks can operate independently of 5G infrastructure deployed by mobile operators the benefits realisation model assumes that only half of Massive Internet of Things benefits will arise from 5G infrastructure and this proportion will be unaffected by delays in 5G infrastructure deployment.

[213] LoRaWAN™ is a Low Power Wide Area Network (LPWAN) specification intended for wireless battery operated Things. LoRaWAN specification provides seamless interoperability among smart Things without the need for 5G infrastructure deployed by mobile operators. The low power, low bit rate and intended use distinguish this type of network from others.

represents 23 per cent of all benefits and is twice as much as the next largest sector – Information and Communications (CHF 6.7 billion) that will provide 11 per cent of total 5G enabled output in 2045.

Manufacturing sector benefits will be relatively slow to be realised in comparison with other sectors (see Figure 7); only reaching 50 per cent of 5G enabled output (CHF 7.15 billion) in 2029 and 100 per cent of benefits in 2043. Due to faster technology adoption four industries consistently achieved the fastest level of 5G benefits - Information and communication, Wholesale and retail, Finance and insurance and Professional Services. All four achieve 50 per cent of expected total benefits (between 2020 and 2045) early in 2028.

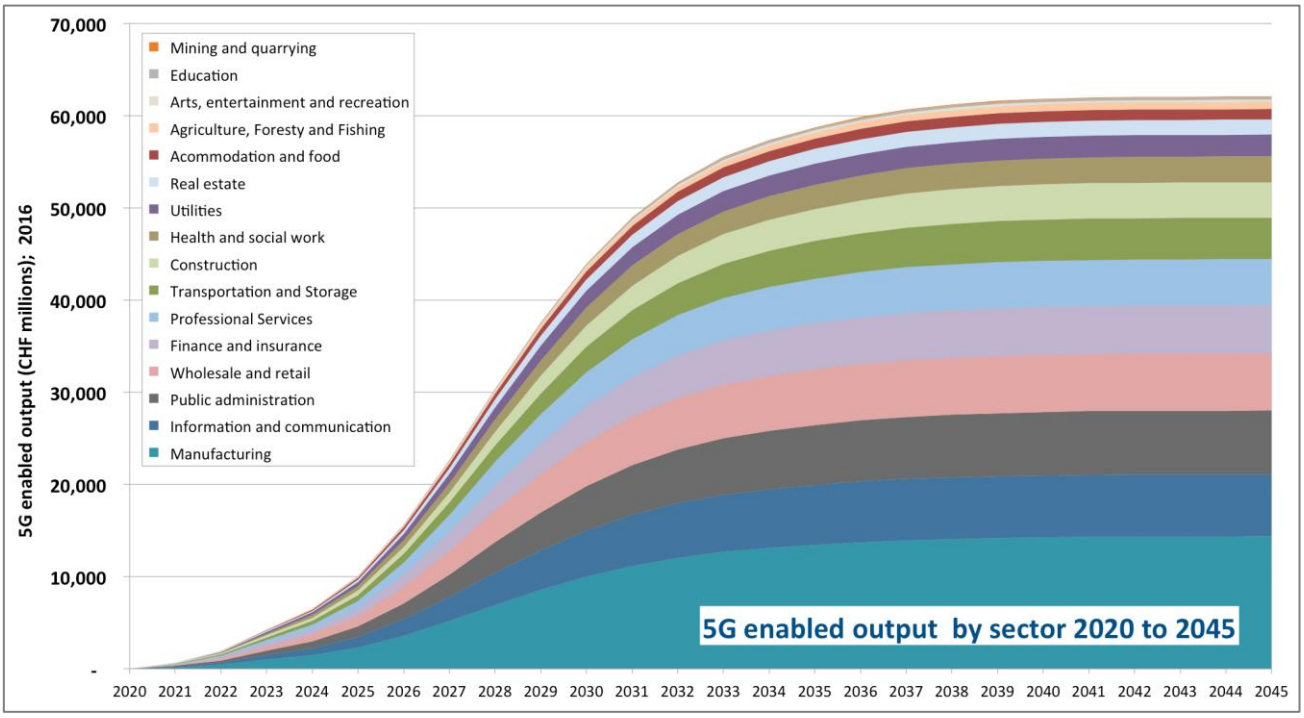

Figure 7 5G enabled output by sector 2020 to 2045

Across all 16 sectors it is estimated that 25 per cent of 5G-enabled output (CHF 15.5 billion) will be achieved in 2026. Half the 5G-enabled output benefits (CHF 30.8 billion) will be reached in late 2028 and 75 per cent of 5G-enabled output (CHF 46.5 billion) will be achieved in 2031. The majority of benefits are therefore realised relatively quickly after the first deployment of 5G infrastructure in 2020. Figure 8 provides forecasts of 5G enable output in CHF (billions) between 2020 and 2045.

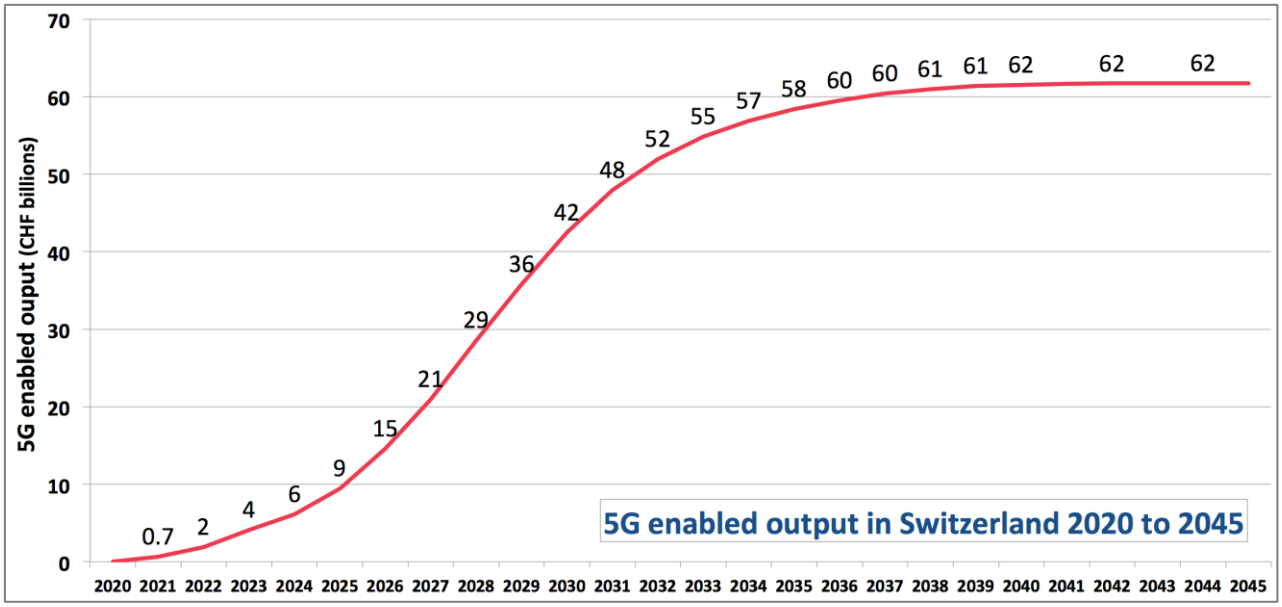

Figure 8 5G enabled output 2020 to 2045

5.5. The impact of delays in 5G Infrastructure deployment

A critical issue in ensuring 5G benefits realisation is 5G infrastructure deployment and coverage. Despite a more challenging and mountainous topography, 99 per cent 3G coverage was achieved in Switzerland in 2013, approximately a year faster than other European countries. 99 per cent 4G coverage was achieved in 2014 - only one country in Europe achieved this level of coverage earlier (Sweden in 2013)[214]. Analysis of 3G and 4G coverage and subscription data in Switzerland showed consistent but slightly improving times for network deployment[215].

To examine the impact of delays in 5G infrastructure deployment research used previous subscription data (for 3G and 4G) to forecast the decrease in subscribers if 5G deployment was delayed by six months, 12 months, two years and three years. However, it must be noted that 5G technology will be used by far more than just mobile phone handsets. 5G will be used by Internet of Things devices, autonomous vehicles and utilised for communication by mission critical operations. The annex describes the methodology used to calculate the impact of deployment delays.

Infrastructure deployment delays over different time periods were compared with the baseline 5G impact forecast (that assumed deployment at previous rates for 3G and 4G in Switzerland)[216]. Figure 9 shows that for the first two years, when the benefits from 5G are limited, the impact of delays is relatively small. But between years three and six the impact of deployment delays increases considerably. The model forecasts that delays will have the greatest impact between 2025 and 2026, five or six years after infrastructure deployments are expected to commence.

[214] International Telecommunications Union. 2017. Data sets - ITU WFID i271G and ITU WFID i271GA

[215] Confidential data provided by Swisscom. These relatively quick deployment times facilitated through the simple exchange of GSM1800 system with LTE1800 are matched by relatively fast times to achieve the maximum level of mobile network subscriptions for 3G and 4G (both approximately 84 months).

[216] This enabled the calculation of differences (from the baseline situation) due to delayed deployment.

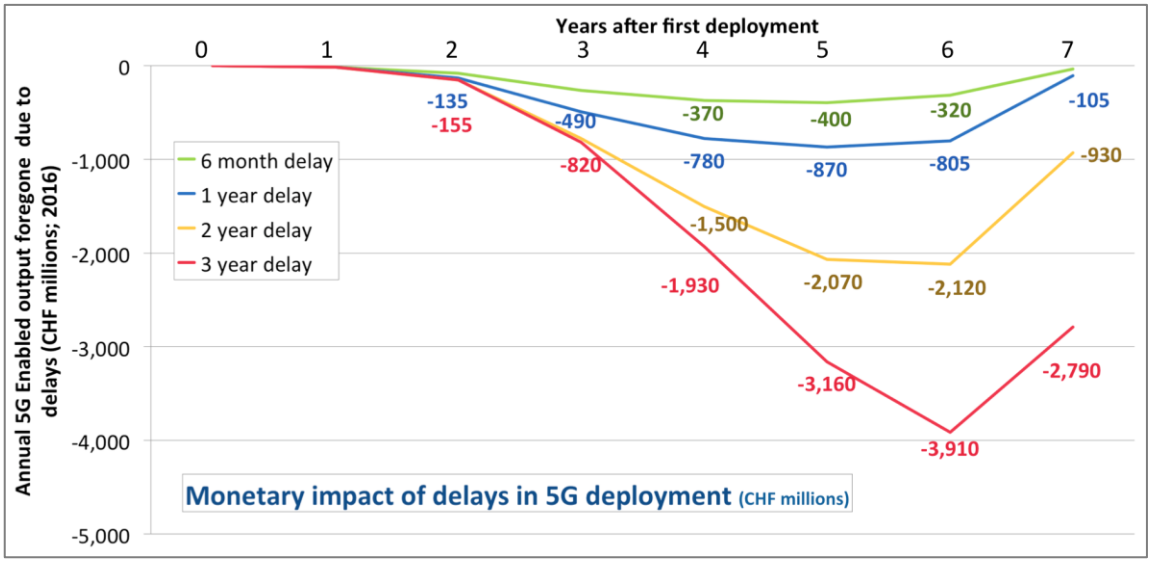

Figure 9 Economic impact of delays in 5G deployment

As the blue line in the graphic shows, a one year delay (five years after first mass market deployment) would lead to losses in 5G enabled output of CHF 870 million (in comparison with the baseline situation) in 2025. The graphic highlights that losses are made each year and therefore become cumulative over time. After six years of one-year deployment delays there are cumulative total losses of CHF 3.1 billion. As might be expected a deployment delay of three years increases losses – nearly five fold (in comparison with a one year delay). In 2026 annual losses in 5G-enabled output arising from a three year delay in deployment would reach CHF 3.9 billion (in comparison with the baseline situation, see the red line). Cumulative losses over the six years examined would be CHF 10 billion.

Since output per employee figures in Switzerland are available it is possible to convert 5G enabled output losses into the number of jobs that will be foregone under different scenarios. One-year deployment delays lead to 2,820 lost jobs in 2026 (five years after first mass market deployment). Three-year delays in deployment lead to 12,660 due to 5G enabled output foregone in 2026.

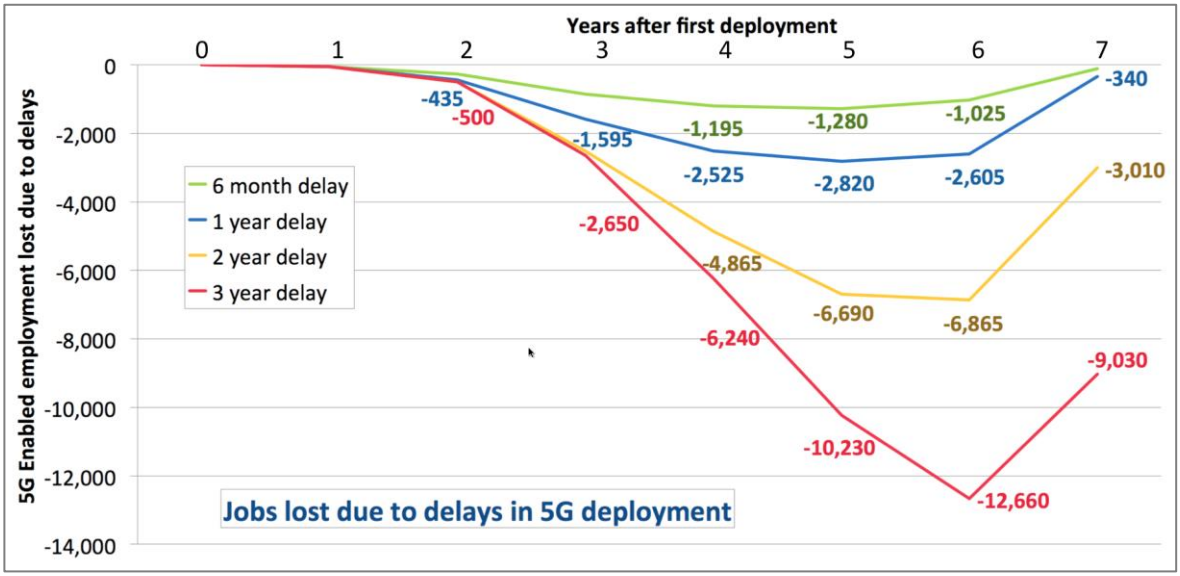

Figure 10 Jobs lost due to delays in 5G deployment

It must be highlighted that these figures only relate to losses in output. It is probable losing first mover advantage in new markets will compound these problems and difficulties are also likely to arise in regaining market share in established markets. The development of innovative ideas for utilising 5G capabilities and the creation of new business models might also be stifled.

Annex

Methodology: The international benefits realisation model

6.1. Introduction

Numerous studies provide insights to 5G impacts at different scales of analysis, over different time periods and for different 5G capabilities. This meta-analysis research[217], first developed in January and February 2018, used triangulation methods to develop an evidence based 5G benefit realisation model to investigate the impact of 5G capabilities on national economies. Triangulation is a powerful technique that facilitates validation of data through cross verification from two or more sources. By combining multiple studies and forecasts and using triangulation methods it has been possible to overcome problems usually associated with inherent biases and problems associated with using a single research method or utilising results from a single study.

[217] Research used meta-analysis to combine the results of multiple studies, more than 200 were reviewed for this study. The underlying logic is that there is a common truth behind all conceptually similar studies. Meta-analysis provides an estimate of the unknown common truth, it has the capacity to contrast results from different studies and identify patterns among study results, sources of disagreement among those results, or other interesting relationships that may come to light in the context of multiple studies.

6.2. Triangulation and impact timelines

To enable temporal (time) differences between studies forecasting 5G impacts to be investigated experts in Switzerland and from the Tech4i2 European study team provided forecasts about the impact of 5G between 2020 and 2045 for 21 use cases that represented the three key capability dimensions provided by 5G (these are Enhanced Mobile Broadband, Massive Internet of Things and Mission Critical Services[218]). Timeline forecasts were referenced against 16 industrial sectors[219]. In essence participants provided forecasts for 336 data points within a 21 by 16 matrix (21 use cases and 16 industrial sectors).

To provide a further basis for comparison forecasts were compared with previous Tech4i2 research for the European Commission which obtained technology adoption forecasts from more than 80 experts that attended workshops and online discussions (see European Commission. 2016[220]). Results from the previous EC study and this study were closely aligned.

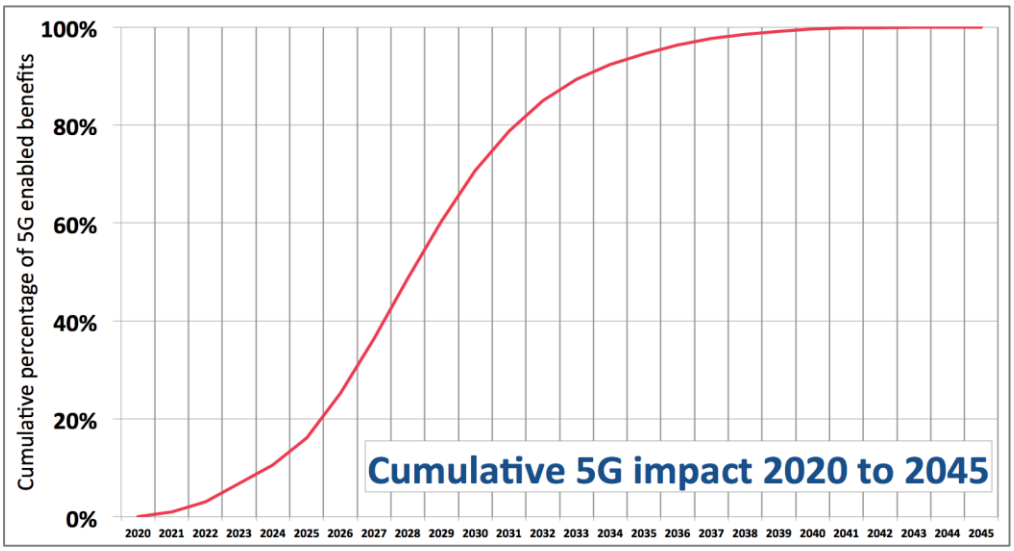

Figure 11 s-shaped adoption curve for cumulative 5G impact 2020 to 2045

This approach provided the study with an s-shaped adoption curve for the total impact of 5G across all sectors, see Figure 11. The aggregate baseline curve for 5G benefits was comprised of individual adoption curves for 16 industrial sectors, 21 uses cases and three core 5G capabilities. During analysis these additional curves provided considerable granularity when making forecasts by industrial sector or by 5G capabilities in Switzerland.

This baseline curve was vital in enabling comparison and triangulation of predictions about 5G impacts from several studies that used different years for forecasts.

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[218] This approach replicates the approach utilised in the Qualcomm sponsored IHS 2017 study. IHS. 2017. The 5G economy: How 5G technology will contribute to the global economy. https://www.qualcomm.com/invention/5g/economy

[219] Forecasts took account of different rates of technology adoption observed in different sectors. Gandhi P et al. 2016. Which Industries Are the Most Digital (and Why)? Harvard Business Review https://hbr.org/2016/04/a-chart-that-shows-which-industries-are-the-most-digital-and-why

[220] Tech4i2. 2016. Identification of the market for radio equipment operating in licence-exempt frequency bands to assess medium and long-term spectrum usage densities. SMART 2014/0012. https://ec.europa.eu/digital-single-market/en/news/identification-market-radio-equipment-operating-licence-exempt-frequency-bands-assess-medium.

For example a study sponsored by Qualcomm[221] forecast 5G global benefits of US$12.3 trillion. The study asserted that all benefits would be achieved by 2035, 15 years after the first 5G deployments in 2020. Tech4i2 and others[222] believe this is a very optimistic forecast for benefit realisation. Tech4i2 research for the European Commission highlighted that many technologies have long adoption periods[223]. For example, smart phones have the fastest adoption of technologies (that can be tracked using robust Eurostat data), but they did not reach a 100 per cent saturation point until 14 years after first deployment. As the cumulative 5G impacts graphic shows, the saturation point for 5G impacts estimated in this study is not expected until 2045.

It must be highlighted that 2035 is the end point, indicating saturation coverage for 5G, in the Qualcomm/IHS study. Research for this report estimates that 95 per cent of 5G impacts will be achieved by (the endpoint of) 2035. There is a ten year time difference in the saturation point for 5G between this research and the Qualcomm/IHS study. However, as noted above in this ten years only a further five percent of 5G enabled output is achieved.

The focus of the IHS study was on predicting the maximum value of 5G enabled output and not the year in which the benefits would be attained. This study therefore adopted the date of 2045 as the end point for IHS benefits[224]. For this reason Figure 12 shows two points (in green - 2035 and 2045) for the IHS study.

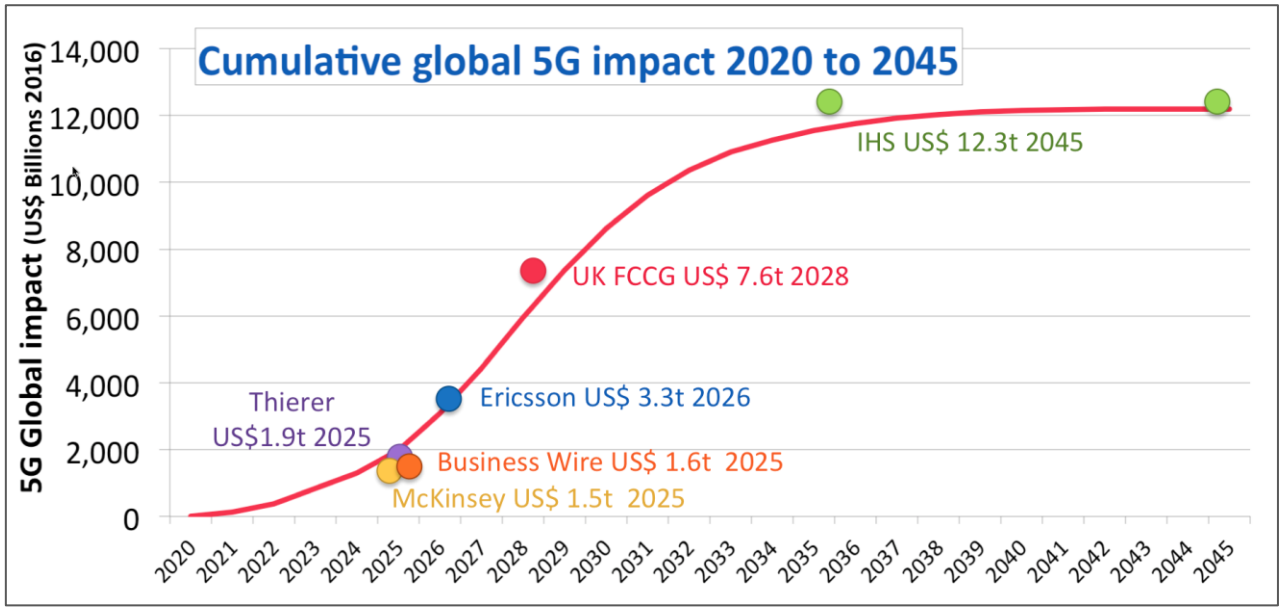

Figure 12 Cumulative 5G enabled impact 2020 to 2045

The IHS study forecasts 5G will be responsible for 4.6 per cent of industry output[225]. Few other studies forecast the economic value of a single mobile technology e.g. 5G, but many

[221] Ibid. IHS. 2017. Updated in Qualcomm. April 2018. What's next for 5G?: The US$ 12 trillion opportunity ahead https://www.qualcomm.com/media/documents/files/fierce-wireless-ebrief-5g-release-16.pdf

[222] Turner A 2018 Hype is public enemy number 1 for 5G. https://5g.co.uk/news/hype-is-public-enemy-number-1-for-5g/4340/

[223] Ibid. Tech4i2. 2016.

[224] The graphic provides two green pointers to indicate the US$ 12.3 trillion benefits is predicted by IHS in 2035 and by our study team in 2045.

[225] 4.6 per cent average across all sectors. Highest ICT 11.5 per cent, lowest Real Estate 2.4 per cent

estimate and forecast the contribution of mobile technologies to GDP now and in the future. These forecasts obviously combine the impacts or contribution to output from several generations of mobile services.

New generations of cellular standards have appeared roughly every tenth year since 1G systems were introduced in 1981[226]. For example 3G (first introduced in 1998) and 4G (introduced in 2008) are still prevalent in most countries. As previous descriptions have shown adoption of each mobile generation usually follows an s-shaped pattern. Each technology becomes the dominant or mass market choice as users upgrade from previous technologies. It is logical to assume that each generation probably attains the highest level of saturation in a market a few years (probably 3 to 5 years) after the launch of its successor generation. At this point most previous generation users will have upgraded and the level of adoption of the new generation mobile technology will be more limited. It seems reasonable to assume that each generation of mobile technology will make the largest contribution to industry output perhaps 13 to 15 years after launch. At this point predictions of estimates of the impact of all mobile technologies (contribution to GDP or output) are most likely to be dominated by the relevant generation of mobile technology. Bearing this cautionary note in mind it is worth briefly examining some of the many studies that provide insights to the contribution of all mobile technologies to GDP. It is also worth noting that estimates of impact have increased with each generation of mobile technology.

A review of more extensive forecasts of the overall impact of mobile technology provide a useful basis for comparison with the IHS study estimate of 4.6 per cent of industry output arising from 5G.

GSMA estimate mobile technology contributed 3.3 per cent to European GDP in 2018 increasing to 4.1 per cent in 2022[227]. Boston Consulting Group suggest mobile currently accounts for between 2 and 4 per cent of GDP in six countries which account for 47 per cent of global GDP, the figure in the US was estimated to be 3.2 per cent[228]. Orange Business Services estimate that mobile technologies generated 4.4 per cent of GDP globally in 2016[229]. They suggest this will rise to 4.9 per cent in 2020. The 2018 GSMA Mobile Economy report estimated that in 2017 mobile technologies generated 4.5 per cent of global GDP, this equates to $3.6 trillion of economic added value. By 2022 they forecast the mobile contribution would reach $4.6 trillion or 5 per cent of GDP[230]. A GSMA study in the Asia Pacific suggested mobile technologies made an even greater contribution to GDP of 5.4 per cent in 2017. This is forecast to rise to 6.5 per cent of economic value in 2022[231].

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[226] Sharma P. 2013. Evolution of Mobile Wireless Communication Networks-1G to 5G as well as Future Prospective of Next Generation Communication Network. International Journal of Computer Science and Mobile Computing. 2, 8. https://pdfs.semanticscholar.org/8e32/4078c7b0848c5e8c573861878cdbe417e89e.pdf

[227] GSMA. 2018. The mobile economy: Europe 2018. https://www.gsmaintelligence.com/research/?file=884c77f3bc0a405b2d5fd356689be340&download. 1 per cent direct contribution, 0.6 per cent indirect and 1.8 per cent in productivity gains.

[228] Bezera et al. 2015. The mobile revolution: How mobile technologies drive a trillion-dollar impact. A study of six countries (USA, Germany, south Korea, Brazil, China and India), which account for 47 per cent of global GDP. https://www.bcg.com/publications/2015/telecommunications-technology-industries-the-mobile-revolution.aspx

[229] Harris S. 2018. The trillion dollar rate: What 5G means to the global economy. https://www.orange-business.com/en/blogs/trillion-dollar-race-what-5g-means-global-economy

[230] GSMA. 2018. The mobile economy 2018 https://www.gsma.com/mobileeconomy/wp-content/uploads/2018/05/The-Mobile-Economy-2018.pdf

[231] GSMA. 2018. The mobile economy in Asia Pacific 2018 - 2022 economic value of $1.8 trillion at 2017 Asia Pacifc GDP (27.778 trillion) https://www.gsmaintelligence.com/research/?file=28401018963d766ca37d014fa9cbffb1&download

Some commentators suggest 5G will provide revolutionary technologies[232]. Greater impact from 5G in the IHS study - of 4.6 per cent, over the capabilities provided by 3G and 4G, does not therefore seem unreasonable in comparison with the other studies quoted above.

The remainder of this section triangulates studies from other esteemed organisations to develop the aggregate baseline curve for 5G benefits that was utilised in the 5G benefits realisation impact model. Figure 12 shows that there is a relatively high degree of temporal agreement between six studies about 5G impacts. Dots on the graphic indicate forecasts from studies (adjacent to the dot are details of the author, followed by the global 5G impact estimate and year for the forecast).

Ericsson (see the blue dot in Figure 12) predict 5G-enabled industry digitalization revenues of US$ 3.3 trillion for global ICT players in 2026[233]. This Ericsson forecast aligns well with the cumulative 5G impact model estimate of US$3.1 trillion of 5G enabled output in 2026.

The Future Communications Challenge Group; advising UK government about mobile impact, predict the value of mobile impact to the UK economy will be US$ 215 billion in 2028 (the red dot in Figure 12). This equates to 5G global impact of US$ 7.6 trillion[234]. This is a rather optimistic study. The cumulative 5G impact model estimates US$5.6 trillion of 5G enabled output in 2028.

Several studies provide forecasts for the impact of IoT applications at different times in the future. Forecasts by experts in this research and the European Commission study[235] estimate that IoT will contribute 33 per cent of 5G enable benefits in 2025 (the date of two IoT studies referenced in the graphic). Of the other two core 5G capabilities Enhanced Mobile Broadband provides 43 per cent and Mission Critical Services 24 per cent of 5G benefits in 2025; these percentages vary each year). It was therefore possible to extrapolate IoT forecasts to enable comparison with the overall baseline model. Figure 12 triangulates three IoT studies, all providing forecasts for 2025.

None of the IoT studies differentiate the benefits that derive solely from 5G. To enable comparison this research assumed that the impact of 5G on IoT applications should be assumed at the average rate of 5G impact across all sectors (4.6 per cent) applied in IHS research[236].

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[232] Future Communications Challenge Group. 2017. UK strategy and plan for 5G and digitisation: Driving economic growth and productivity. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/582640/FCCG_Interim_Report.pdf page 2.

[233] Ericsson. 2017. The 5G business potential. http://www.5gamericas.org/files/7114/9971/4226/Ericsson_The_5G_Business_Potential.pdf

[234] GSMA forecast 5G coverage will be 75 per cent in 2025 and 46 per cent of connections in the same year in Europe will be 5G. GSMA. 2017. The mobile economy: Europe 2017. https://www.gsmaintelligence.com/research/?file=89a59299ac2f37508b252124726a1139&download. Office for Budget Responsibility. 2018. Real GDP Growth. http://obr.uk/forecasts-in-depth/the-economy-forecast/real-gdp-growth/

Confidential access to subscription data suggests 60 per cent of connections will be 5G in 2028. It is therefore assumed (pro-rata) that 60 per cent of mobile benefits will be attributable to 5G, this equates to US$129 billion (215 x 60%). UK produced 1.71 per cent of global GDP in 2016. Thus US$ 129 billion of 5G benefits in the UK in 2028 equates to global impact of US$ 7.5 trillion. It should be noted that this study is exceedingly optimistic about impacts. It erroneously adopts global annual growth rates (of 2.74 per cent per annum 2021 to 2030) when UK growth rates have only reached that level once in the last ten years (2014; 3.1 per cent) and average GDP growth rates in the last ten years have been less than half the projected rate (average 1.2 per cent; 2007 to 2017). The UK Office for Budget Responsibility predicts growth will only pick up to 1.6 per cent in 2022.

[235] Ibid. Tech4i2. 2016.

[236] Ibid. IHS. 2017.

The McKinsey Global Institute produced one of the most widely quoted IoT impact studies[237] (the yellow dot in Figure 12). Their research predicted the maximum value of global IoT applications in 2025 would be US$11.1 trillion. Impact is greatest in factories and cities. Assuming 5G impacts of 4.6 per cent (from the IHS study) it is estimated that 5G enabled IoT benefits would be US$510 billion in 2025. The McKinsey forecast aligns with the cumulative 5G impact graphic which estimates US$640 billion of 5G enabled output in 2025[238].

A study by Thierer and Castillo[239] forecasting IoT impacts (the purple dot in Figure 12) in the same year as McKinsey estimated a global value of US$14 trillion in 2025. A Business Wire study estimated the global economic impact of IoT to be around $12.5 trillion in 2025 (the orange dot on Figure 12), with more than 100 billion connected IoT devices[240].

Once again assuming 5G impacts of 4.6 per cent it is estimated that 5G enabled IoT benefits of the two studies would be US$ 644 billion (Thierer) and 575 billion (Business Week) respectively in 2025. As noted previously the 5G impact model estimated 5G enabled impact at US$ 640 billion in 2025[241]. Thus the results are closely aligned.

The preceding review has focused on the overall benefits of 5G. In December 2018 GSMA published a report that forecast the socio-economic benefits of 5G services provided by mmWave Bands. This study forecast regional impact of mmWave spectrum of 2.9 per cent of GDP growth in Europe by 2034 and 2.3 per cent in the Americas[242] by the same date.

6.3. 5G benefits realisation model

Although the number of relevant studies suitable for triangulation is limited (and thus the number of data points is sub-optimal) the graphic does show relatively good alignment of the studies reviewed with the aggregate baseline curve for 5G benefits derived for this study. It is this curve and the underlying sectoral and 5G capability components that are used to develop the 5G benefits realisation model for Switzerland.

Qualcomm sponsored IHS research provided forecasts for the percentage of 5G enabled output for 16 industrial sectors at 2016 values. 5G enabled output was forecast to be highest (11.5 per cent) in the information and communications sector) and lowest in real estate (2.4 per cent). The average level of 5G-enabled industry output was 4.6 per cent. This percentage is lower than a study for UK government that predicted mobile impact of 5.7 per cent in 2030[243]. Thus by adopting the IHS estimate the study is taking a more conservative estimate.

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[237] Mckinsey Global Institute. 2015. The Internet of Things: Mapping the Value Beyond the Hype, https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world

[238] The graphic extrapolates the value of IoT benefits (with the previously described methodology [33 per cent of 5G capability benefits arise form IoT in 20205] to produce an estimate of total global 5G enabled output of US$ 1.53 trillion in 2025).

[239] Thierer A and Castillo A. 2015. Projecting the growth and economic impact of the Internet of Things. https://www.mercatus.org/publication/projecting-growth-and-economic-impact-internet-things

[240] Business Wire. 2015. R&D Cluster Benchmarking Research Report 2016: Economic impact of IoT by the end of 2025 is estimated to be around $12.5 trillion. https://www.businesswire.com/news/home/20161114006436/en/IoT-Cluster-Benchmarking-Research-Report-2016-Economic

[241] The graphic extrapolates the value of IoT benefits (with the previously described methodology [33 per cent of 5G capability benefits arise from IoT in 2025] to produce an estimate of total global 5G enabled output of US$ 1.93 trillion in 2025)

[242] GSMA. 2018. Study on socio-economic benefits of 5G services provided by mmWave bands. https://www.gsma.com/spectrum/wp-content/uploads/2018/12/5G-mmWave-benefits.pdf

[243] Future Communications Challenge Group. 2017. UK strategy and plan for 5G and digitisation: Driving economic growth and productivity. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/582640/FCCG_Interim_Report.pdf page 4. IHS research use output data, the FCCG study uses GVA

The IHS approach uses an output based methodology estimating the contribution of 5G to gross domestic product[244]. It is important to distinguish between GDP and GVA. Gross domestic product is the monetary measure of the market value of all the final goods and services produced in a country[245]. Gross value added measures the contribution to the economy of each individual producers, industry and sector in a country. Gross value added plus taxes on products minus subsidies on products equals gross domestic product. In Switzerland in 2016 gross domestic product was 2.03 times larger than gross value added. But there are considerable differences between sectors, for example the ratio is 1.3 in real estate activities, 2.8 in manufacturing and 4.5 electricity and gas.

Eurostat statistics for sectoral output in Switzerland in 2016[246] were utilised in the benefits realisation model (pro-rata with the sectoral impact proportions in the IHS study) to produce the total value of 5G-enabled output in each sector in 2045 to be forecast.

The total value of 5G-enabled output in 2030, the year examined in this study, is CHF 42.5 billion. By 2045 annual 5G-enabled output is forecast to reach CHF 61.7 billion.

6.4. Delays in 5G infrastructure deployment

The benefits realisation model provides insights to a potential reality that is likely to arise in Switzerland if 5G infrastructure is deployed at a similar rate to previous 3G and 4G technologies[247]. The model provides the baseline situation against which delays in deployment can be examined. The methodology, considering the impact of deployment speed on output, is similar (but rather more detailed) to the approach used by Australian Government in their 2018 study of the impact of 5G[248].

This study does not examine why delays might arise. There could be many reasons including CAPEX restrictions (capital expenditure that operators need to finance deployment activities), Health and Safety restrictions concerning exposure to non-ionising radiation from

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data. But since both are forecasting percentages or their respective statistics comparisons should be valid. Gross output is the total value of goods and services produced by an industry. Intermediate inputs are the foreign and domestically-produced goods and services used up by an industry in the process of producing its gross output. Value added is the difference between gross output and intermediate inputs and represents the value of labor and capital used in producing gross output. The sum of value added across all industries is equal to gross value added for the economy. Gross output includes sales to other industries, it can be duplicative in nature and 'double-count' some elements of outputs. In Switzerland in 2016 gross output was CHF 1.3 trillion; GVA was CHF 670 billion.

[244] Ibid IHS. 2017. Page 19

[245] Office of National Statistics. 2006. Economic Trends 627 Methodology Notes: Links between gross domestic product and gross value added

[246] Eurostat dataset code nama_10_a64.

[247] ReThink Research have surveyed more than 100 senior executives within mobile network operating companies to investigate short term strategies (to 2025) for 5G deployment. There will be heavier reliance on outsourcing and on open platforms to reduce cost and transfer cost further than ever from capex into opex. Operators will prioritize coexistence with 4G and architecture to prolong the life of existing investments. However, several operators plan to upgrade their Macro base stations first with 5G, because they see 5G as a medium-term replacement for 4G. Incentives spurring 5G deployment will arise in areas where there gaps in capacity or coverage and where there are opportunities to reduce total cost of delivering services and data. Additional catalysts will arise where deployment will support new revenue streams which would not be well addressed by 4G and where it will enable operators to penetrate a new market or geography or gain significant first mover advantage in existing ones.

[248] Australian Government Department of Communications and the Arts. 2018. Impacts of 5G on productivity and economic growth. The study only uses two time periods for speed of deployment – 'instant' or 'lagged'. https://www.communications.gov.au/publications/impacts-5g-productivity-and-economic-growth

wireless networking equipment[249], difficulties in obtain infrastructure and the perceived lack of return on 5G infrastructure investment.

To examine the impact of delays in deployment the study used previous adoption data (for 3G and 4G)[250]. This enabled the forecast of a (pro-rata) decrease in subscribers if 5G deployment was delayed by six months, 12 months, two years and three years. For example in Figure 13 a one year delay in deployment (the blue line) can be compared with the baseline situation (the black line) for subscriptions.

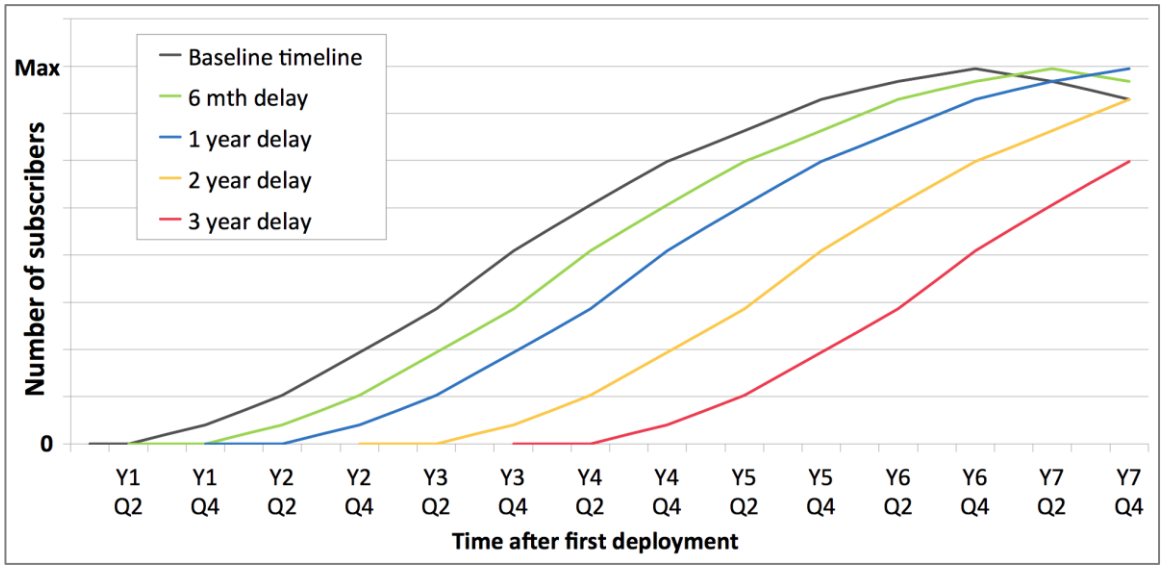

Figure 13 The impact of 5G deployment delays in Switzerland

Chapter 5 highlighted that 5G technology will be used by far more than just mobile phone handsets. Sensors and numerous Internet of Things devices will use 5G. 5G will also be used in autonomous vehicles, utilised for communication by mission critical operations and in many different situations and sectors. Nonetheless, it is expected (and assumed in the benefits realisation model) that the adoption of 5G by these devices will follow a similar subscription pattern to subscriptions to 3G and 4G handsets.

In calculating the impact of delays in 5G infrastructure deployment it is assumed that subscriptions rates (for those using mobile handsets and all connected devices) are related to deployment. Users will not subscribe unless a 5G service is available. When a service is available subscriptions will follow the adoption patterns for 3G and 4G[251]. Chapter 5 emphasised the quick mobile infrastructure deployment speeds in Switzerland compared with the rest of Europe. These were matched by relatively fast times to achieve the maximum level of mobile network subscriptions for 3G and 4G - both approximately 84 months, see Figure 13.

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[249] World Health Organisation. 2018. Electromagnetic fields and public health: Base stations and wireless technologies. http://www.who.int/peh-emf/publications/facts/fs304/en/ National Toxicology Program. 2018. Studies of cell phone radiofrequency radiation. https://ntp.niehs.nih.gov/about/org/sep/trpanel/meetings/docs/2018/march/index.html

[250] Access to confidential data was provided by a Swiss mobile operator.

[251] The chapter 5 highlighted relatively quick mobile infrastructure deployment speeds in Switzerland. Adoption patterns for 3G and 4G handsets were very similar. Adoption patterns were matched by relatively fast times to achieve the maximum level of mobile network subscriptions for 3G and 4G - both approximately 84 months.

The impact of 5G infrastructure delays was calculated by applying the percentage decrease in subscribers for the selected delay period with the baseline situation. For example, a one year delay in infrastructure deployment equated to 8.5 per cent fewer subscribers in 2022 from the baseline situation. This percentage was then applied to the overall level of benefits forecast (CHF 1.89 billion) in the baseline benefits realisation methodology. Thus, the reduction in 5G enabled outputs due to a one year deployment delay was estimated to be CHF 161 million in 2022 (CHF 1.89 x 8.5 per cent).

In 2025 the impact of a one year delay equated to 11 per cent fewer subscribers. Because the overall level of 5G enabled output forecast in 2025 was so much greater (CHF 9.45 billion) the value of the reduction in output was significantly larger (CHF 1.04 billion) than the 2022 figure.

Chapter 5 highlighted that some 5G core capabilities, most notably Massive Internet of Things benefits, could be provided by licence-exempt wireless technologies, such as WiFi. These will not require 5G infrastructure deployed by mobile operators. Obviously, 5G benefits for those using licence-exempt and other methods of wireless communication will be unaffected by delays in 5G infrastructure deployment undertaken by mobile operators.

The benefits realisation model was developed to take account of these differences by enabling estimates of the proportion of benefits provided by licence-exempt and other methods of wireless communication to be excluded from calculations about the impact of deployment delays. For example the model assumes that 50 per cent of benefits from Massive Internet of Things capabilities will be provided independently of 5G mobile operators and they will not be affected by delays in 5G infrastructure deployment. In comparison with the examples previously provided for a one year delay in deployment (reduction of CHF 161 million in 2022 and CHF 1 billion in 2025) the revised version of the model (with 50 per cent of Massive Internet of Things capability benefits 'protected') estimates a reduced level of 5G enable output foregone of CHF 135 million in 2022 and CHF 870 million in 2025). This adjustment[252] decreased the overall impact on output and jobs of a one year delay in deployment by 16 per cent.

Further sensitivity analysis was undertaken to examine the impacts of reducing the importance of other capabilities in the model. Excluding (only) 50 per cent of Mission Critical Services 5G capabilities from delay calculations reduced the overall impact on output and jobs of a one year delay in deployment by 13 per cent. Excluding 50 per cent of Mission Critical Services and Massive Internet of Things 5G capabilities led to a 29 per cent reduction in jobs and output.

The international benefits realisation model and methodology can be utilised at any level of investigation, for example global, international (e.g. EU28 Member States or North America) and for individual countries, such as this example in Switzerland. For further information or questions about the model and methodology contact info@tech4i2.com.

[252] To accommodate a 50 per cent reduction of Massive Internet of Things benefits because this 5G capability could be provided by licence-exempt wireless technologies, such as Wi-Fi, independently of 5G infrastructure and networks deployed by mobile operators.

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