Consultancy Study on Quantification of 5G's Contribution to the Economy of Hong Kong

Final Study Report

Transmittal Letter

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Office of the Communications Authority
29/F, Wu Chung House, 213 Queen's Road East
Wan Chai, Hong Kong

Dear Office of the Communications Authority,

On behalf of Ernst & Young Transactions Limited (EY), we would like to submit the Final Study Report for publishing on the Consultancy Study on Quantification of 5G's Contribution to the Economy of Hong Kong (the Study) to the Office of the Communications Authority (OFCA).

Purpose of the Final Study Report and restrictions on its use

The Final Study Report presents the overall objectives of the Study, methodology adopted, together with the findings, observations and assessments from the economic models performed for the Study. It summarises the development of 5G in Hong Kong, estimates the overall impact analysis of 5G to Hong Kong's economy based on the findings of the desktop research and consultations with industry stakeholders. The Final Study Report also summarises other benefits of 5G, including safety and environmental, based on research, and current and future use cases applied globally and locally.

In carrying out our work and preparing our reports for the Study, we have worked solely on the instructions of OFCA. We disclaim all responsibility or liability to any other party for all costs, loss, damage and liability that the other party may suffer or incur arising from or relating to or in any way connected with the contents of the Final Study Report, and the provision of the Final Study Report to the other party of the reliance.

Nature and scope of the services

In accordance with the contract agreement between the Government of the Hong Kong Special Administrative Region and EY, the Final Study Report covers the work outlined in the Consultancy Brief (Ref. No.: OFCA/WCH/R1646/2022).

Our study was completed on 7 December 2023 and the Final Study Report does not take account of event or circumstances arising after that date.

Yours faithfully,

Steve Lewis, Partner
Ernst & Young Transactions Limited

Glossary

2G	Second generation mobile communications
3G	Third generation mobile communications
3GPP	The 3rd Generation Partnership Project
4G	Fourth generation mobile communications
5G	Fifth generation mobile communications
AI	Artificial Intelligence
AR	Augmented Reality
AV	Autonomous Vehicles
BIM	Building Information Modelling
C&SD	Census and Statistics Department
CA	Communications Authority
CCTV	Closed Circuit Television
CIC	Construction Industry Council
CMHK	China Mobile Hong Kong Company Limited
DevB	Development Bureau
DWSS	Digital Works Supervision System
EdTech	Education Technology
eMBB	Enhanced Mobile Broadband
ERP	Enterprise Resource Planning
EY	Ernst & Young Transactions Limited
F&B	Food and beverage
FinTech	Financial Technology
FWA	Fixed Wireless Access
GDP	Gross Domestic Product
Government	Government of the Hong Kong Special Administrative Region
GSMA	GSM Association or Global System for Mobile Communications Association
HA	Hospital Authority
HIS	Hospital Information System
HKMA	Hong Kong Monetary Authority
HKT	Hong Kong Telecommunications (HKT) Limited
HTCL	Hutchison Telephone Company Limited
HVAC	Heating, ventilation, and air conditioning
ICT	Information and communications technology
IoT	Internet of Things
ITF	Innovation and Technology Fund
LTE	Long-term Evolution
mMTC	Massive Machine Type Communications
mmWave	Millimetre Wave
MNOs	Mobile network operators
MVNOs	Mobile virtual network operators
NDRC	National Development and Reform Commission
5G NR	5G New Radio
NSA	Non-Standalone
OECD	Organisation for Economic Co-operation and Development
OFCA	Office of the Communications Authority
OTT video	Over-the-top video streaming
R&D	Research and development
RFID	Radio Frequency Identification
SCED	Secretary for Commerce and Economic Development

Smart City Blueprint 2.0	Hong Kong Smart City Blueprint 2.0
SmarTone	SmarTone Mobile Communications Limited
SSSS	Smart Site Safety System
STEM	Science, Technology, Engineering and Mathematics
Study	Consultancy Study on Quantification of 5G's contribution to the Economy of Hong Kong
Subsidy Scheme	Subsidy Scheme for Encouraging Early Deployment of 5G
URLLC	Ultra Reliable Low Latency Communications
US	United States
UWB	Ultra Wideband
VR	Virtual Reality

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1. Executive Summary

1.1 Project scope

The scope of the Study is to quantify fifth generation mobile communications (5G)'s contribution to each of the 11 selected industries and the overall economy of Hong Kong in terms of (a) gain in Gross Domestic Product (GDP) and (b) number of new jobs to be created in the relevant value chains. The scope of work is divided into 3 phases:

1. Collection of information through desktop research, discussion with consultees, and questionnaires with associations and major companies in each selected industry, in addition to consultations with Mobile Network Operators (MNOs) and telecommunications equipment suppliers.

2. Building of economic models to evaluate 5G's contribution by 2027. Economic modelling has been undertaken to quantify the economic impact on each selected industry and the overall economy of Hong Kong resulting from adopting 5G use cases (i.e., Economic Model 1). One-off impacts from 5G network infrastructure investment have also been assessed to estimate the full picture of the economic contribution by 5G (i.e., Economic Model 2). Use case and network infrastructure investment are split into two economic models to calculate aggregated outputs, due to the significant difference between the two.

3. Identification of other benefits brought by 5G, either on quantitative or qualitative basis (including social benefits which are unquantifiable). Other benefits of 5G adoption have been assessed using desktop research and discussion with consultees.

The 11 industries selected by the Office of the Communications Authority (OFCA) and Ernst & Young Transactions Limited (EY) for detailed analysis are as detailed below:

- Construction
- Transportation and logistics
- Healthcare
- Media and ICT
- Retail and wholesale
- Financial services and insurance
- Accommodation and food services
- Properties and buildings facilities management
- Art, entertainment and recreation
- Education
- Smart utilities

1.2 5G network development in Hong Kong

Spectrum in low-, mid-, and high- bands are all required to support 5G use cases. Sub-1 GHz spectrum has strong propagation characteristics and is essential to build territory-wide outdoor coverage and to provide indoor coverage. Mid-band spectrum provides high-capacity city-wide 5G coverage, playing a core role in delivering applications that impact almost all industries of the economy, from healthcare to smart cities. Finally, spectrum in the high-band allows services with ultra-high speeds and the lowest latencies ever achieved by a mobile network technology, allowing applications such as high-resolution home streaming through Millimetre Wave (mmWave) Fixed Wireless Access (FWA) and in public spaces through mmWave. Indeed, the application of Augmented Reality (AR)/Virtual Reality (VR) and innovative metaverse-related services, cloud-based and virtual desktops are all applications that will benefit from mmWave connectivity in dense user hotspots.

Although the Government of the Hong Kong Special Administrative Region (the Government) is supportive of the development of 5G, the rollout of 5G network is still subject to challenges, such as the invariable difficulty in sourcing suitable premises for installation of more radio base stations. While 5G promises huge benefits like ultra-fast speed, low latency and Internet of Things (IoT) connectivity, the penetration of 5G devices and the public awareness of 5G's benefits still need to be enhanced. In terms of industry applications, many industries are applying new technologies backed by 5G to achieve a number of economic and social benefits, however, industry stakeholders believe the market still lacks applications with proven performance and a clear commercial case.

As several industry stakeholders mentioned, one aspect of 5G adoption is its role as a platform technology, which is an underlying standard that allows MNOs to build out networks first and application developers and industry players to build tailored solutions upon the networks thereafter. It takes time to implement the layered approach. While the 5G service penetration in Hong Kong is among the highest in the world, the business adoption is still slower than some industry players' expectations. The technology stack being built on the platform of 5G is still developing and will be adopted by industries over the coming years.

1.3   The economic impacts by 2027 of adopting 5G

Since the commercial launch of 5G services in Hong Kong in the second quarter of 2020, different parties have been working to promote and explore the benefits of 5G, including MNOs, government authorities, and enterprises across industries. Consultation with MNOs suggested that the overall 5G development in Hong Kong is still at an early stage with limited use cases among industries as of June 2023. Mobile subscription statistics published by OFCA illustrated that the proportion of 5G mobile subscriptions out of total number of mobile broadband subscriptions has increased from 12% at the end of 2021 to 25% in June 2023.[1] This figure is defined as the "5G subscription penetration rate" within the Ericsson Mobility Report published in June 2023 (and the term of "proportion of 5G subscriptions" is used in this report) and is forecasted to continue to increase with a positive outlook in Hong Kong.[2]

The Ericsson Mobility Report forecasts a regional proportion of 5G subscriptions[3] of 71% by 2028 among Hong Kong, Mainland China, South Korea, Japan and Taiwan.[4] Based on this and the consultations with MNOs and industry players for this Study, proportion of 5G subscriptions for Hong Kong of 60% by 2027 has been assumed.

Economic modelling has been undertaken to quantify the economic impact of adopting 5G in the 11 selected industries, specifically in terms of gain in GDP and number of jobs to be created. With the use of Economic Model 1, comparing with the base case scenario of having no development of 5G[5], an overall impact of 0.66% increase in GDP (HK$20,544 million) and a net change of 0.30% (11,317) in the number of jobs by 2027 are estimated due to the adoption of 5G. Other industries have not been assessed in detail, which include agriculture, fishing, mining and quarrying, manufacturing, import and export trade, professional and business services, public administration, ownership of premises, as well as other service activities. For the purpose of the economic modelling, only marginal economic impact is assumed for these industries. Summary of the economic impacts created due to 5G is presented as Table 1 below. Further details on the methodology and reference for the economic modelling are set out in Appendix A.

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[1] https://www.ofca.gov.hk/filemanager/ofca/en/content_108/wireless_en.pdf

[2] https://www.ericsson.com/49dd9d/assets/local/reports-papers/mobility-report/documents/2023/ericsson-mobility-report-june-2023.pdf

[3] "5G subscription penetration" is calculated as total 5G subscriptions divided by total mobile subscriptions (see pages 6, 38 and 39 of Ericsson Mobility Report).

[4] Figure 3 of the Ericsson Mobility Report indicates 5G subscription penetration of 71% in North East Asia.

[5] Given that the Economic Model 1 is built upon 2021 data, where only a minimal 5G impact was realised from industry use cases, the base case scenario is considered an approximation of having no development of 5G.

Table 1: Summary of economic impacts created due to adoption of 5G by 2027

Economic Model 1	Net Impact on GDP (incremental)		Net Impact on Job (incremental)	
	HK$MM	%	No.	%
Construction	1,482	1.42%	1,841	0.56%
Transportation and logistics	4,086	1.32%	1,440	0.52%
Healthcare	645	0.98%	877	0.33%
Media and ICT	945	0.91%	1,056	0.75%
Retail and wholesale	669	0.78%	716	0.27%
Financial services and insurance	4,593	0.66%	848	0.27%
Accommodation and food services	488	0.66%	765	0.28%
Properties and buildings facilities management	594	0.55%	433	0.25%
Art, entertainment and recreation	141	0.46%	162	0.20%
Education	161	0.42%	442	0.18%
Smart utilities	141	0.35%	23	0.15%
Other services	6,600	0.46%	2,714	0.19%
Overall (Bottom up)[1]	20,544	0.66%	11,317	0.30%
Overall (Top down)[2]	15,477	0.50%	n.a	n.a

Note: [1]Overall (Bottom-up) sums up the economic impacts of the 11 selected industries and other services estimated using a bottom-up approach at industry level

[2]Overall (Top-down) is the economic impacts on the overall economy of Hong Kong estimated by assuming 0.5% for the full rollout of 5G, i.e., the proportion of 5G subscriptions reaches 100%, based on the analysis from the GSMA study

*Numbers may not add up due to rounding

With existing 5G use cases and positive outlook for 5G rollout, the construction industry and the transportation and logistics industry are estimated to have the most significant impacts from 5G, in terms of percentage increase in GDP by 2027, among the 11 selected industries. The healthcare industry is also expected to benefit from 5G in terms of GDP, however, the impact expected to be realised by 2027 is not as significant as the above two mentioned industries due to the longer period of trial and implementation required and a relatively lower demand compared to other comparable cities globally.

In terms of net change in number of jobs, the media and ICT industry is estimated to have a large increase in employment in order to provide the underlying network and support use case implementation. The construction industry and transportation and logistics industry are also expected to have significant increase in employment due to the relatively higher rate of 5G adoption and existing use cases in these two industries, where additional employments are required to efficiently operate and maintain 5G-enabled applications.

Meanwhile, as presented in Table 2 below, Hong Kong's economy is already benefiting from the direct, indirect and induced impacts of the investment in 5G infrastructure. Based on the response from the MNOs being consulted, 5G infrastructure spending will continue at current levels (i.e., annual capital investment of HK$1,623 million on average) over the next five years. With the use of Economic Model 2, comparing to the scenario where there were no 5G infrastructure investment at all, 5G infrastructure investment expects to generate HK$1,449 million in GDP (approximately 0.05% of total GDP) and 2,302 jobs (approximately 0.06% of total labour market) in 2027, as presented in Table 2 below.

Table 2: Summary of economic impacts created due to the annual investment in 5G infrastructure

	GDP (HK$MM)	No. of Jobs
Annual investment in 5G infrastructure	HK$1,623 million	
Direct[1]	647	1,077
Indirect[2]	367	630
Induced[3]	435	595
Total	1,449	2,302

Note: [1]*Direct effect refers to direct economic contribution from revenue and value-add taxes*

[2]*Indirect effect refers to flow-on contribution generated by an industry purchasing domestic inputs*

[3]*Induced effect refers to flow-on contribution generated by an industry's employees purchasing domestic goods and services with their income*

*Numbers may not add up due to rounding

Therefore, having Economic Model 1 estimating the 5G's contribution against the base case scenario, and Economic Model 2 estimating the 5G's contribution against the scenario with no 5G investment, the results derived from both economic models can be summed up to estimate the aggregated 5G's contribution to the overall economy in 2027 as compared to the scenario with no 5G development.

The total incremental GDP contribution from 5G, aggregated from the result of Economic Model 1 and Economic Model 2, is estimated at HK$22.0 billion (0.71% of total GDP) and the total incremental job impact from 5G, aggregated from the result of Economic Model 1 and Economic Model 2, is estimated at 13,619 jobs (0.36% of total labour market).

The Study has also considered other benefits that 5G delivers to Hong Kong in relation to public safety, environment and user experience.

1.4 The role of government support

Although a positive outlook for Hong Kong's 5G uptake is expected, the rollout of 5G is facing several challenges to widespread adoption. At the time of writing this report, it is well-known that 5G can provide higher speed and lower latency compared to fourth generation mobile communications (4G) or Wi-Fi. However, many companies across industries have yet to identify the other technical benefits and how they can improve business performance by making use of 5G. They are therefore reluctant to adopt 5G or invest in exploring 5G solutions.

While the basic telecommunications infrastructure in Hong Kong is readily available for the use of 5G technology, the low demand for 5G services within some industries has prevented the vendors from providing more advanced devices, equipment and applications, which has led to a limited availability of 5G-specific solutions in the market. The density of base stations is also crucial for ensuring the coverage and capacity of 5G network. This means MNOs need to set up a significant number of base stations throughout Hong Kong, creating challenges in deploying 5G network in some areas, especially rural areas (where setting up new base stations could be difficult and time consuming), potentially impacting the overall deployment of the networks.

To realise the benefits of 5G, the Government can play a critical role to mitigate these challenges. For example, multiple funding schemes have been put into places by the Government to promote the adoption of 5G and co-fund industry pilot projects. In addition, the Government can promote the benefits of 5G to consumers and industries and continue to make available public facilities for setting up base station at nominal rents. It may take several more years before most industry players adopt 5G applications more broadly. With continued support to test new use cases, Hong Kong can achieve the estimated economic impacts by 2027.

2. Introduction

2.1 Overview of the Study

Since commercial rollout in Hong Kong commenced in April 2020, 5G services have developed rapidly, reaching 90% coverage of the population. Many industry sectors have aimed to utilize the unique benefits of 5G by investing in and developing innovative applications. The Government has also led initiatives to further promote development such as through the Subsidy Scheme.[6]

OFCA has appointed EY to undertake the consultancy study to assess 5G's contribution to the economy of Hong Kong (the "Study"), with a future outlook. The objectives of the Study are to assess how the adoption of 5G by consumer and in business operations could impact the economy of Hong Kong, with an in-depth focus on 11 selected industries. This is quantified in terms of gain in GDP and number of new jobs to be created in the selected industries and the overall economy of Hong Kong by 2027.

The result of the Study is expected to provide a better understanding of the potential social-economic benefits that 5G brings to Hong Kong. The below-listed 11 industries[7] are selected by OFCA. Selected industries for further analysis are as detailed below:

- Construction
- Transportation and logistics
- Healthcare
- Media and ICT
- Retail and wholesale
- Financial services and insurance
- Accommodation and food services
- Properties and buildings facilities management
- Art, entertainment and recreation
- Education
- Smart utilities

The structure of this report is outlined below:

- Chapter 3 provides an overview of Hong Kong's 5G network, including the spectrum bands, service providers, development of the network over time, and implications for industry use cases. It also addresses the challenges and opportunities that Hong Kong faces to increase the rate of deployment of 5G applications.

- Chapter 4 outlines the overall economic impact of 5G in Hong Kong, considering both 5G adoption by consumers and industries and direct investment into 5G infrastructure.

- Chapter 5 details economic impacts for each of the 11 selected industries. This covers the quantitative results from the assessment model, the status of 5G adoption in each industry, and a summary of the economic implications of industry applications. It also presents several examples of use cases in Hong Kong for each selected industry.

- Chapter 6 elaborates other benefits through adopting 5G, specifically public safety, environmental benefits and user experience. It details the economic implications of high-level use case applications across industries.

- Chapter 7 compares the key findings of this Study with the estimated economic impact quantified in other overseas economies through literature reviews.

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[6] https://www.ofca.gov.hk/en/industry_focus/industry_focus/5g_subsidy/index.html

[7] Please refer to Appendix A for the definition and economic summary of each selected industry.

▸ Chapter 8 provides the conclusions to the Study, including potential actions that could be taken to increase 5G adoption and its economic contribution.

▸ The appendices include the methodology of the modelling process, literature review comparing to international benchmarks.

2.2 Scope of work

The scope of the Study is to quantify 5G's contribution to each of the 11 selected industries and the overall economy of Hong Kong in terms of gain in GDP and number of new jobs to be created in the relevant value chains by 2027. The scope of work is divided into three phases:

1. Collection of information through desktop research, consultations and online questionnaires

2. Economic model building to evaluate 5G's contribution by 2027. One-off impacts from 5G network infrastructure investment have also been assessed to estimate the full picture of the economic contribution by adopting 5G

3. Identification of other benefits brought by 5G, including but not limited to social-economic benefits and other unquantifiable impacts

The collection of information includes consultation with associations and major companies in each selected industry, in addition to consultations with MNOs and telecommunications equipment suppliers. An online questionnaire was provided to industry associations to share with their members; however, due to the low response rate the economic model and quantitative analysis were based primarily on the information received during consultations. Desktop research into 5G use cases in Hong Kong and internationally has been undertaken, based on publicly available data and EY's network of telecommunications and industry specialists.

Use case and network infrastructure investment are split into two economic models to calculate aggregated outputs, due to the significant difference between the two (Figure 1). The use cases model (i.e., Economic Model 1) has been used to assess the economic impacts for each selected industry resulting from 5G adoption by 2027, compared to a baseline view of 2027, forecasted through the base case scenario of having no development of 5G (the 2027 Baseline View). Inputs utilized include data estimates from the Hong Kong Census and Statistics department (C&SD) and from Oxford Economics, as well as from industry consultations and desktop research. The model on network infrastructure (i.e., Economic Model 2) has been used to assess the direct impacts and supply chain impacts, such as indirect and induced activities, compared to a scenario of no 5G infrastructure investment at all. Inputs include data from C&SD and the Organisation for Economic Co-operation and Development (OECD).

Figure 1: Illustration of the two economic models proposed for the Study
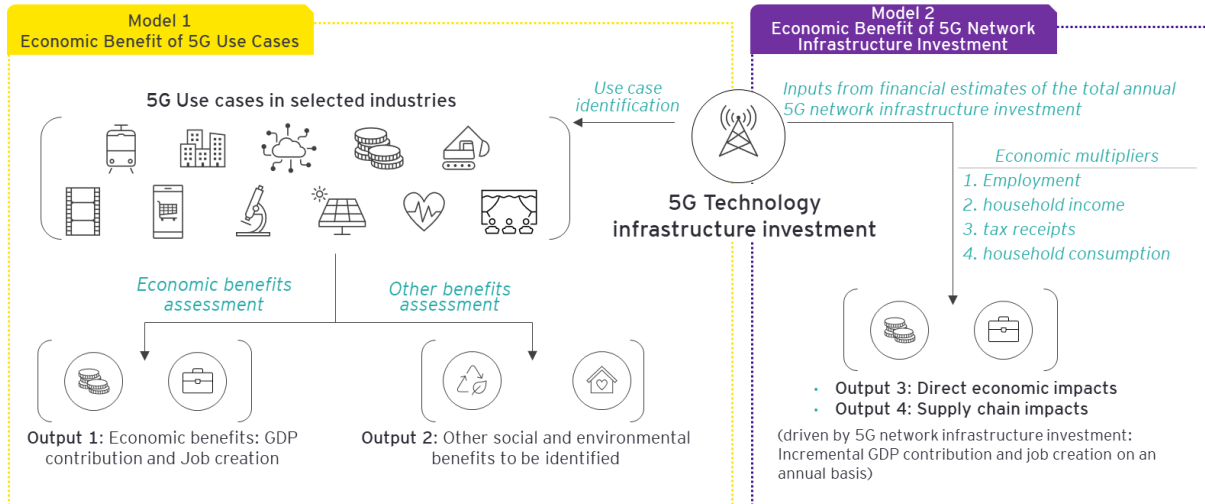
Other benefits of 5G adoption have been assessed by using desktop research and consultations. The impacts may be demonstrated with qualitative or quantitative perspectives. The details of the methodology and model assumptions have been explained in Appendix A.

3.   Hong Kong's 5G Network

5G supports very high data download speeds, ultra-low latency[8] and massive machine type communications (mMTC). 5G is expected to bring forth new services and applications as a more diverse range of suppliers and industries begin to adopt it.

The GSM Association (commonly referred to as the GSMA or Global System for Mobile Communications Association), estimates that by 2030, 5G is expected to generate US$960 billion in GDP on a global basis.[9] Given the step changes brought about by 5G, countries around the world are looking to the technology to help lead future economic growth. In Hong Kong, MNOs commenced commercial 5G network services on 1 April 2020.[10] At the end of October 2022, over 90% of the population is covered by 5G mobile networks.[11] 5G can provide speeds of up to 20 Gbps[12], which is more than 20 times faster than the theoretical maximum speed of 4G (1 Gbps[13]). Product developers and operators in various industries are exploring how 5G can impact the industries.

5G improves on the 4G services over several axis[14], including enhanced mobile broadband (eMBB), ultra reliable and low latency communications (URLLC) and mMTC.[15] The purpose is to support the expected growth in mobile-data traffic, as well as customizing 5G New Radio (NR) for automotive, logistics, public safety, media and manufacturing use cases.[16]

▸ eMBB services deliver significant speed benefits compared to 4G with theoretical speed of up to 100 times faster.[17] Even at the edges of cell site coverage, eMBB enables mobile broadband speed of up to 100Mbps.[18] The speed and quality of the mobile broadband will also be sufficient for home broadband connections using FWA. 5G FWA can represent as an alternative to traditional home broadband provided through fibre.

▸ URLLC enables very low latency and reliable data transfer which can support the delivery of critical applications such as remote surgery and autonomous vehicles (AV).

▸ mMTC supports the widespread deployment of IoT devices. Potentially, mMTC-based networks can support around 1 million IoT devices per square kilometre as they typically transmit small amounts of data on an intermittent basis. IoT devices can support use cases including smart sensor networks for enterprises and wearable devices for consumers.

eMBB can be seen as the first phase of 5G, which was encompassed in the 3rd Generation Partnership Project (3GPP) Release 15 standards update due for completion in the third quarter

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[8] Latency refers to the time lapse between when a base station sends data and when a destination device (e.g., mobile phone) receives it.

[9] https://www.gsma.com/spectrum/wp-content/uploads/2022/02/mid-band-5G-spectrum-benefits.pdf

[10] https://www.legco.gov.hk/research-publications/english/essentials-1920ise06-5g-technology.htm#endnote1

[11] https://www.ofca.gov.hk/en/consumer_focus/guide/general/hbs_enabled_by_5g/index.html

[12] https://www.legco.gov.hk/research-publications/english/essentials-1920ise06-5g-technology.htm#endnote1

[13] 1 Gbps is equal to 1 billion (1,000,000,000) bits per second. Bits per second (abbreviated bps or bit/sec) is a common measure of data transmission speed, specifying how much information (called bits) can be transmitted per second.

[14] https://www.3gpp.org/technologies/5g-system-overview

[15] https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/5g-nr-evolution

[16] Ibid.

[17] https://www.cisco.com/c/en/us/solutions/what-is-5g/what-are-5g-speeds.html

[18] Mbps (Megabits per second) is the unit of measurement for network bandwidth and throughput. It is used to show how fast a network or internet connection is. Each Mbps represents the capacity to transfer 1 million bits each second. https://www.techtarget.com/searchnetworking/definition/Mbps

of 2018.[19] Phase 2 of 5G goes beyond eMBB services to more transformational URLLC and mMTC applications which are included in Release 16 completed at the end of 2019.[20]

An overview of the three fundamental pillars of 5G (i.e., eMBB, URLLC and mMTC) is presented below and examples of typical use cases enabled by each type of 5G network are illustrated in Figure 2.

Figure 2: Characteristics of three fundamental pillars of 5G
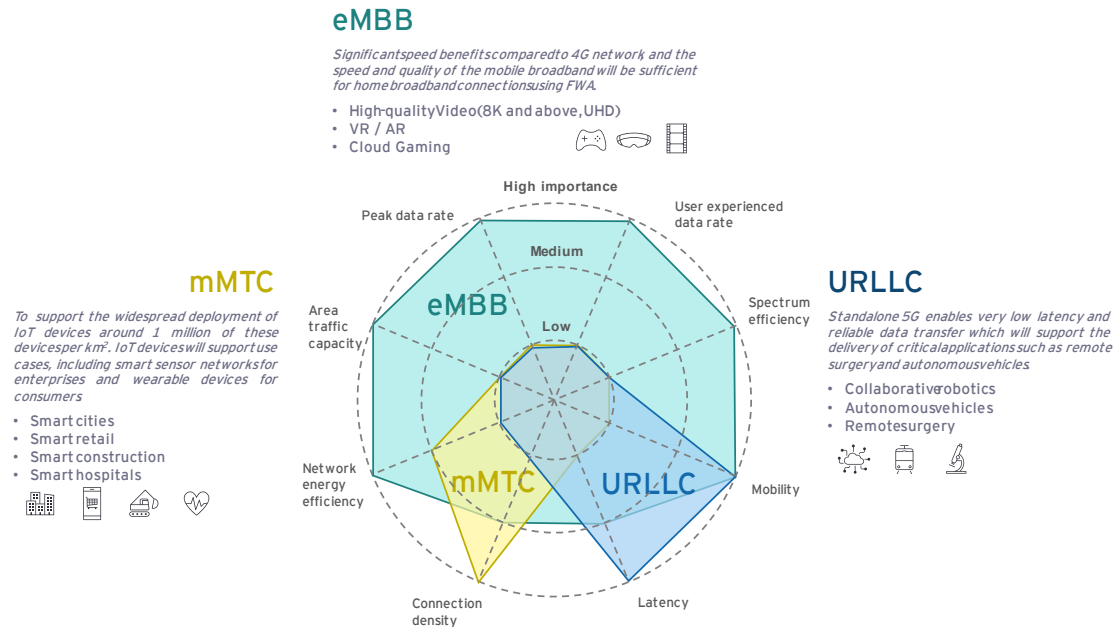
Source: Soos, Gabor & Ficzere, Dániel & Varga, Pal. (2020). Towards Traffic Identification and Modeling for 5G Application Use-Cases. Electronics. 9. 640. 10.3390/electronics9040640. EY

5G architecture includes two different types[21]: 5G Standalone (SA) and Non-Standalone (NSA). With NSA, 5G network utilises existing 4G Long-term Evolution (LTE) infrastructure. The MNOs apply 5G base stations onto existing core infrastructure to enhance speed and low latency. With 5G SA, an entirely new 5G infrastructure is necessary, completely separate from previous 4G network. NSA therefore has a more limited performance but it allows MNOs to use existing network architecture to deliver enhanced services. It is appropriate for applications such as consumer smartphone usage or certain IoT applications as well.

Dedicated 5G core architecture is needed to enable new use cases[22]. 5G SA has latency levels sufficient for URLLC, such as for AV and other safety-essential applications. Additionally, 5G SA can support a much higher concentration of connected devices than NSA, needed for massive IoT applications. Lastly, 5G SA is necessary to enable network slicing. "Slicing" the physical network into separate subnets allow customers to access 5G network tailored to the necessary latency, speed and other factors. In Hong Kong, the rollout of SA began in 2020 with an MNO's commercial 5G SA network. Its network slicing abilities enable enterprise clients to make use of a number of end-to-end secure networks to suit their demands.

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[19] https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/5g-nr-evolution

[20] https://5g.co.uk/guides/what-is-enhanced-mobile-broadband-embb/#What%20is%20eMBB?

[21] https://www.wirelesslogic.com/iot-glossary/5g-non-standalone-vs-5g-standalone/

[22] https://www.ericsson.com/en/ran/5g-sa?gclid=Cj0KCQjw8NilBhDOARIsAHzpbLDgH6KUv5nZx8bHeQhaExrFYIFQE_3xF-zU_oYzYIyamxyTnKIy2WsaAp5TEALw_wcB&gclsrc=aw.ds

3.1   Spectrum for 5G

The use of various bands of spectrum, i.e., radio frequencies used for wireless communications, varies among different generations of telecommunication technology. In general, the frequency spectrums utilised for 5G are grouped into three spectrum bands, namely high-band spectrum, mid-band spectrum and low-band spectrum. These spectrum bands have distinct characteristics and help MNOs achieve a balance between network reliability, spectral efficiency and coverage, as highlighted by Table 3 below.

Table 3: Characteristics of three key 5G spectrum bands

Type of spectrum	High-band spectrum (>6 GHz)	Mid-band spectrum (1-6 GHz)	Low-band spectrum (<1 GHz)
Strength	▶ Deliver the highest performance for 5G with data transmitting at ultra-high speeds of up to 20 Gbps	▶ Most popular band for 5G deployment ▶ Wide coverage with high data speed with capability to break through the obstacles of walls and buildings ▶ An optimal band for data speed and coverage	▶ Widest coverage and good penetration inside buildings ▶ Ideal for extending coverage, reach and reliability
Weakness	▶ Short range of transmitting and affected by physical obstacles	▶ Lower speed data transmission compared with high-band spectrum ▶ Shorter range than low-band spectrum	▶ Data speed up to around 40-50 Mbps, which is lower than other spectrum bands
Example of Frequency bands	▶ 26 GHz to 28 GHz	▶ 3.5 GHz	▶ 600 MHz and 700 MHz
Typical 5G applications	▶ Work and play in the cloud	▶ Smartphones ▶ Smart cities ▶ Wearables ▶ Pet care	▶ Industry automation ▶ Intelligent transport system

Source: Legislative Council of the Hong Kong Special Administrative Region[23]

5G NR is the first mobile technology to operate in high frequency mmWave spectrum in the 26 GHz to 28 GHz bands. While mmWave spectrum bands offer much larger bandwidths[24], they also suffer from much higher signal losses from physical obstacles such as buildings, walls and trees when compared with lower frequency bands. Besides, radio signals also tend to weaken over long distances. To respond to the above issues, small cells (the range of coverage of a base station) deployed in a more dense configuration are used to address this range-based attenuation. Figure 3 illustrates the coverage comparison of different spectrums.

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[23] https://www.legco.gov.hk/research-publications/english/essentials-1920ise06-5g-technology.htm#endnote1

[24] Bandwidth is the size of the band. For example, the frequency band 600-700 MHz has a bandwidth of 100 MHz; and the 26 GHz band (24.25-27.5 GHz) covers 3.25 GHz of spectrum. The latter band has a wider/larger bandwidth. The bandwidth determines how much data a portion of spectrum can carry, and a wider bandwidth can carry more data and support higher speed.

Figure 3: Coverage comparison of spectrum in free space
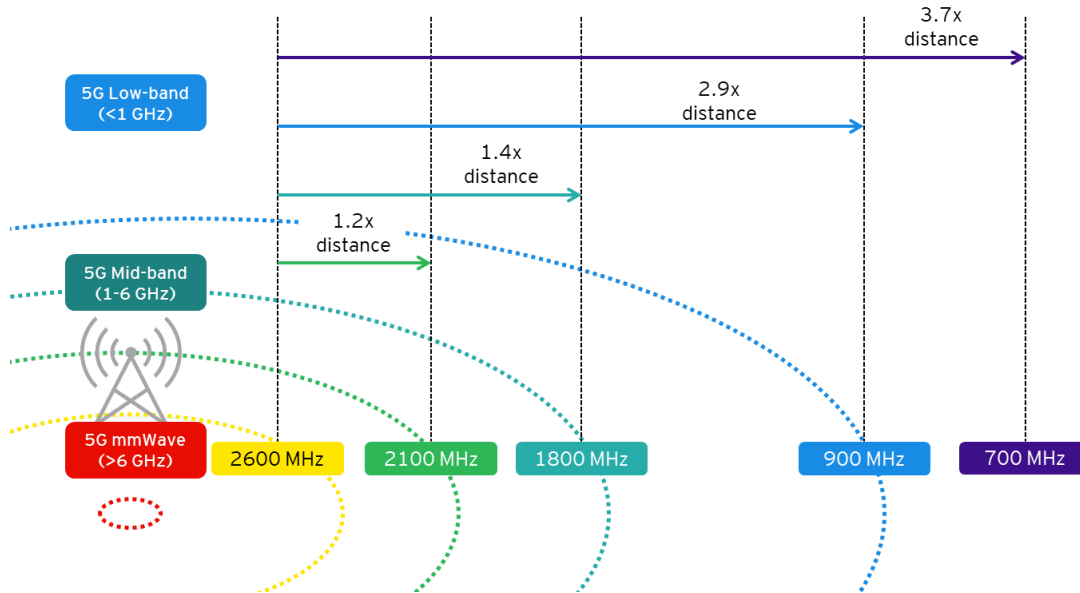
Source: Coleago[25], EY.

Typically, traditional mobile networks use macro cells, where base stations are designed to provide network coverage over a large area, usually mounted on ground masts, roofs or other existing structures. Small cells are another type of base station that are designed to operate closer to the user and can provide higher capacity by reducing the distance between the base station and the user. Small cells have a much smaller coverage area compared to traditional mobile macro cells[26].

To maximize performance, 5G services require the deployment of large numbers of small cells in fixed locations with high demand for mobile connectivity, such as stadiums, theatres, theme parks and subway stations. In addition, small cells are best installed in locations where the end user's line of sight is clear, such as street lights and traffic lights and the facades of buildings[27]. This has cost implications for MNOs to provide the supporting infrastructure and therefore deployment is being phased as demand increases.

3.2   Hong Kong 5G development

Hong Kong prepared for local MNOs' 5G network deployments as early as in late 2018. The Secretary for Commerce and Economic Development (SCED) and the Communications Authority (CA)[28] announced at the end of 2018 that there would be a total of approximately 4,500 MHz of spectrum available to the market for 5G services from April 2019. The amount of spectrum for 5G services is more than eight times the existing amount of 552 MHz of spectrum being used for Second Generation Communications (2G), Third Generation Mobile Communications (3G) and 4G services in Hong Kong.

According to the CA, among the total 4,500 MHz spectrum available for the provision of 5G services, 3,700 MHz of spectrum was in the 26 GHz and 28 GHz bands and allocated for the provision of large scale public mobile services across Hong Kong, while 400 MHz of spectrum was set aside for the provision of localised wireless broadband services that support innovative 5G services to specific groups of users on a geographical sharing basis.

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[25] https://www.gsma.com/spectrum/wp-content/uploads/2022/07/Low-Band-Spectrum-for-5G.pdf
[26] https://www.legco.gov.hk/research-publications/english/essentials-1920ise06-5g-technology.htm#endnote1
[27] https://www.legco.gov.hk/research-publications/english/essentials-1920ise06-5g-technology.htm
[28] https://www.coms-auth.hk/en/media_focus/press_releases/index_id_1824.html

The 3.5 GHz band is used by both existing satellite services and 5G mobile services. OFCA coordinated with the relevant MNOs to enable controlled deployment of spectrum in the 3.5 GHz band within the restricted zones where the Tai Po and Stanley satellite earth stations are located. OFCA administered a subsidy scheme, funded by successful bidders in the auction for the 3.5 GHz band, to support the upgrading of approximately 1,600 existing satellite master antenna television systems in Hong Kong. Figure 4 illustrates the key milestones of 5G development in Hong Kong.

Figure 4: Key milestones of Hong Kong's 5G development

Apr 2019
First batch of new radio spectrum was made available to the industry for the provision of 5G services, totaling 1,200 MHz

Second half 2019
First spectrum auction of totaling 380 MHz

Oct 2021
Conclusion of the spectrum auction

Dec 2021
Assigned 80 MHz additional spectrum to two MNOs

Apr 2020
Official launch of commercial 5G services

May 2020
Launched the Subsidy Scheme for Encouraging Early Deployment of 5G

Jun 2022
Assigned 70 MHz additional spectrum to four MNOs

Source: The CA

3.3   5G deployment by MNOs in Hong Kong

Public telecommunications services in Hong Kong are provided by the private sector. There are four MNOs in Hong Kong, namely, China Mobile Hong Kong Company Limited (CMHK), Hong Kong Telecommunications (HKT) Limited (HKT), Hutchison Telephone Company Limited (HTCL) and SmarTone Mobile Communications Limited (SmarTone), providing public mobile services including 5G services.

Table 4 details the new spectrum acquired by local MNOs for 5G deployment. Apart from using the new spectrum, MNOs can also re-farm their existing assigned spectrum (used for providing 2G/3G/4G services) to deploy 5G services.

Table 4: Amount of new spectrum acquired by MNOs for 5G deployment

Frequency band	CMHK	HKT	HTCL	SmarTone
700 MHz	20 MHz	20 MHz	20 MHz	10 MHz
3.3 GHz	20 MHz	30 MHz	30 MHz	20 MHz
3.5 GHz	60 MHz	50 MHz	40 MHz	50 MHz
4.9 GHz	80 MHz	40 MHz	nil	40 MHz
26/28 GHz	400 MHz	400 MHz	nil	400 MHz
Total	580 MHz	540 MHz	90 MHz	520 MHz

Source: OFCA

3.4   Implications for potential industry use cases

Low-Band

The assigned spectrum in the 700 MHz band, or the low-band, is expected to enable a wide range of use cases, as well as to help 5G signal reach indoor consumers, providing continuity of signal. One of the most important aspects of the 5G low-band is the opportunity to provide 5G coverage along roads and other transport links, as the need for 5G capacity along roads will increase

sharply in the next decade to serve connected vehicle use cases. This spectrum need is driven by general eMBB and mMTC use cases, including information, entertainment and diagnostics, as well as road safety-related communication.

Mid-Band

Hong Kong's spectrum assignment in the mid-band has ensured operators have access to an adequate amount of spectrum for the 5G rollout. Globally speaking, most of the eMBB and consumer-oriented 5G use cases today are enabled by spectrum in this band. Mid-band spectrum offers a balance of speed, capacity, coverage and penetration that is suitable for densely populated metropolitan areas where connectivity demand is high, a typical scenario for the Hong Kong reality.

5G mid-band enables applications that can be grouped under the eMBB 5G use case. Thanks to 4G LTE, this is an iterative enhancement of the mobile broadband which consumers are already familiar with. It includes mobile phones, tablets, hotspots, laptops and other wireless devices. The high-speed upload and download capabilities also support initial AR use cases and mobile work applications like virtual desktops or digital workspaces.

Furthermore, the 5G mid-band is crucial to enable a second set of applications, generally grouped under the mMTC use cases utilizing IoT. The most common use cases for massive IoT are:

▶ Industrial automation: where machines can interact with each other without human intervention. This allows companies to control large amounts of machinery or automate repetitive tasks remotely.
▶ Predictive maintenance: businesses can use it to predict when their equipment will break down, so they will know when it needs servicing or replacement before it breaks down.
▶ Remote monitoring: using sensors attached to machines (like those used in manufacturing), companies can monitor their production processes remotely via an application on their phones or tablets instead of having someone physically check on every machine every day.
▶ Smart cities: where devices such as parking sensors, lights, street lamps, heating systems, security cameras and waste management, can all be monitored and managed from a central hub.

High-Band (mmWave)

Hong Kong's approach toward licensing mmWave spectrum for 5G deployment for large-scale public mobile services and localised innovative wireless services will ensure two of the most innovative 5G use cases have the necessary infrastructure to be deployed.

The FWA use case is one of the most highly anticipated 5G-enabled applications, and this has already emerged in Hong Kong. FWA enables MNOs to deliver ultra-high-speed broadband to suburban and rural areas, supporting home and business applications where fibre is prohibitively expensive to lay and maintain and is also being promoted in Hong Kong as a cost-competitive alternative where fibre is already available. 5G FWA employs standardized 3GPP architectures and common mobile components to deliver ultra-high-speed broadband services to residential subscribers and enterprise customers. 5G FWA can provide a competitive alternative to fixed-line DSL, cable and fiber. This provides the means by which suburban and regional consumers can receive the bandwidth required to support high-definition media streaming services and high-speed Internet access. 5G FWA in the higher bands of the wireless spectrum can be used to quickly and cheaply deliver an alternative to wired broadband. In the millimetre wavelengths, 5G FWA can provide a level of service bandwidth capacity comparable to fibre optic-based services, benefitting residential and commercial premises in Hong Kong that do not have wired broadband access.

The second category of use cases which will be enabled by 5G mmWave is critical IoT with URLLC. This will include use cases with very little tolerance for latency or for interrupted or dropped signals. Finally, of the most immediate applications of 5G mmWave is the creation of

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private networks for manufacturing plants, logistics hubs and campuses/stadiums. Thanks to the localised deployment and high performance, these 5G mmWave-enabled networks allow for secure, reliable and flexible networks, allowing for manufacturing 4.0 and new sport/educational applications.

As in Table 5 detailed, Hong Kong MNOs and ecosystem players can access the spectrum in all three bands, providing the ground for deploying a wide range of 5G use cases.

Table 5: Summary of assignment arrangements for 5G spectrum in various frequency bands

Frequency Band	700 MHz band	3.3 GHz band	3.5GHz band	4.9 GHz band	26 GHz and 28 GHz bands	
					Large scale public mobile services	Localised innovative wireless services
Amount of available spectrum	70 MHz	100 MHz	200 MHz	160 MHz	3 700 MHz	400 MHz (on a sharing basis)
Spectrum classification	Low-Band	Mid-Band	Mid-Band	Mid-Band	High-Band	High-Band
Condition of use	Territory-wide use	Indoor use only	Territory-wide use*	Territory-wide use	Territory-wide use	Specified areas of no more than 50 km²
Assignment method	Auction	Auction	Auction	Auction	Administrative assignment	Administrative assignment
Amount of spectrum assigned	70 MHz	100 MHz	200 MHz	160 MHz	1 200 MHz	400 MHz (on a sharing basis)
Network and service rollout obligations for each assignee	At least 90% population coverage within 5 years	A minimum of 400 indoor base stations within 5 years	At least 45% population coverage within 5 years	At least 50% population coverage within 5 years	2 500 radio units within 7 years	Not applicable
Start date of use	Jun-2022	Dec-2019	Apr-2020	Dec 2019**	Apr-2019	Oct-2019
Economies using the band(s)	Mainland China, Europe, India, US	Mainland China, India, Macao, Taiwan	Mainland China, Australia, Europe, India, Macao, Singapore, South Korea, Taiwan, US	Mainland China, Japan, Macao, Russia	26 GHz: Australia, Europe, India, Singapore, US 28 GHz: Japan, South Korea, Taiwan, US	

Note: (*) Any use within the restriction zones of Tai Po and Stanley shall comply with the relevant guidelines and directions issued by the CA.
(**) Out of the total 160 MHz of spectrum in the 4.9 GHz band, 80 MHz of spectrum has been put into use since December 2019 while the remaining 80 MHz of spectrum has been put into use since December 2021.
Source: CA

3.5   Potential challenges to 5G network development

The rollout of 5G network is facing several challenges slowing down widespread adoption. While 5G promises huge benefits such as ultra-fast speeds, low latency and IoT connectivity, there are obstacles preventing telecom companies from fully realizing this vision.

According to the interviews conducted, MNOs in Hong Kong have provided essential infrastructure for both corporate and consumer users, with 5G network coverage reaching 99% of Hong Kong's population. However, MNOs mentioned that one of the main constraints is the availability of readily available 5G solutions for industry and the awareness of 5G benefits.

The general public often consider 5G as a supplement for 4G with higher speed and low latency, while remaining unclear about the broader benefits brought by 5G. If the data download and upload speeds of 4G are sufficient for daily use or operation, there is not a strong incentive to upgrade their smartphones to support 5G services. In addition, low demand from some industries means 5G equipment suppliers and application developers are hesitant to launch products that support 5G only services. This has a feedback effect, as industries are not being offered 5G solutions, demand continues to stay low. In addition, some local residents living in remote areas or places that lack optical fibre connections have sometimes been hesitant to support installation of 5G base stations due to concerns around data privacy (i.e., potential for tracking individuals' locations)[29] or radiation effects to health, etc.

In terms of industry applications, many industries are applying new technologies backed by 5G services to achieve a number of economic and social benefits. For example, some construction sites have been equipped with real-time and high-resolution cameras to capture and track individual movements for health and safety improvement. Transportation providers are using 5G to improve real-time positioning and scheduling, improving the safety of busy transport interchanges, and reducing delays of freight movements. Hospitals in Hong Kong have also begun trialling smart hospital applications which provide remote consultations for patients, improve the quality of training for surgeons and allow family members to tele-visit patients.

However, industry stakeholders believe the market still lacks applications with proven performance records, which potentially slowing down the implementation schedule of 5G applications. At the moment, MNOs and telecommunications equipment suppliers have to take the role of leading the development of 5G-enabled applications and nurturing various potential markets until they mature. Over time, IT departments within companies will have more experienced developers to launch new applications and products empowered by 5G, from which the market can grow.

MNOs also face challenges on the investment in 5G network infrastructure. At present, MNOs are required to pay rents to landlords for the space needed to install 5G base stations in private buildings. This cost, in addition to the time required for regulatory approvals, is an impediment to higher capacity networks being available to consumers and industry. It is worth noting that the Government will amend the Telecommunications Ordinance (Cap. 106) to the effect that MNOs may be authorised to enter new private buildings for setting up base stations without the need to pay rents to the landlords.

The Government has played an important role in promoting the benefits of 5G to consumers and industries. It has also been critical in funding pilot projects of new 5G use cases, with several companies consulted indicating successful projects under the Subsidy Scheme[30], now being rolled

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[29] ''The vision of 5G technology is "always available", i.e., constant connectively at anytime, anywhere, through the deployment of a large number of base stations and an omnipresence of smart lampposts, smartphones and other devices. The enormous amount of personal data so generated allows precise tracking and monitoring of individuals' locations instead of an approximation'', https://www.legco.gov.hk/research-publications/english/essentials-1920ise06-5g-technology.htm

[30] https://www.ofca.gov.hk/en/industry_focus/industry_focus/5g_subsidy/index.html

out across their business. In the short-term, it appears that a continuation of this government support would be warranted to overcome the obstacles to 5G adoption outlined above.

4. The Economic Impact on the Overall Economy

The proportion of 5G subscriptions and the adoption of 5G-enabled applications are the key drivers of any potential economic impacts of 5G to Hong Kong. The range of new services made available by 5G, as outlined in Section 3.4, not only improve productivity but also open up new opportunities in Hong Kong. This chapter details the estimated economic impacts on the overall economy from the adoption of 5G and impacts from direct investment of 5G infrastructure. Chapter 5 covers each of the 11 selected industries individually.

4.1 Hong Kong's 5G adoption

Since the commercial launch of 5G services, MNOs have invested in, and collaborated with enterprises, across various industries to bring about the benefits of 5G. At the same time, government authorities and organizations, such as Hong Kong Productivity Council, have also made efforts to support the research and development (R&D) of 5G-enabled applications. For example, as at the end of September 2023, the Subsidy Scheme launched by OFCA has supported the completion of over 110 5G-related projects.[31] Administered by the Innovation and Technology Commission, the Innovation and Technology Fund has approved funding of over 190 5G-related projects by September 2023.[32]

According to interviews with MNOs, the overall 5G development in Hong Kong is still in early stage with limited use cases implemented within industry. Focusing on mobile subscriptions, statistics published by OFCA illustrates that the 5G subscriptions accounted for 12% of the total mobile broadband subscriptions by the end of 2021. This proportion increased to 25% by June 2023[33], representing a relatively small share of the over 23 million total mobile subscriptions.[34] Proportion 5G subscription is defined as total 5G subscriptions divided by total mobile subscriptions[35]. The Ericsson Mobility Report[36] projects that the 5G transition will continue in 2023, alongside the recovery of revenue after the pandemic, expecting a regional proportion of 5G subscriptions of 71% by 2028 among Hong Kong, Mainland China, South Korea, Japan and Taiwan.

Apart from the consumer market, industry players in Hong Kong are exploring and investigating 5G-enabled applications to enhance productivity. With innovative ideas coming from local R&D centres and overseas use cases, 5G-enabled applications are appealing to many enterprises across industries. According to the interviews with MNOs and industry players, 5G will be increasingly used once real-life use cases are understood by industry with a clear commercial benefit, and industry has the knowledge and understanding to utilize the applications that are brought to market.

In Hong Kong, the Covid-19 pandemic has impacted the adoption curve of 5G in different ways. To illustrate, industries with businesses or activities that could be performed virtually, such as remote work and learning, the adoption curve was pushed forward due to the pandemic. This caused increased adoption, especially in technologies such as FWA. Given the urgent need of the applications, more resources were allocated to these industries, leading to a forward shift in the adoption curve.

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[31] https://www.ofca.gov.hk/filemanager/ofca/en/content_1217/completedprojects.pdf
[32] https://www.itf.gov.hk/en/funding-programmes/index.html
[33] https://www.ofca.gov.hk/filemanager/ofca/en/content_108/wireless_en.pdf
[34] https://www.ofca.gov.hk/en/news_info/data_statistics/key_stat/index.html
[35] According to OFCA, other indicator, i.e., 5G penetration rate, which refers to 5G subscriptions divided by population, was 75.9% as of June 2023
[36] https://www.ericsson.com/49dd9d/assets/local/reports-papers/mobility-report/documents/2023/ericsson-mobility-report-june-2023.pdf

On the other hand, for industries that were impacted severely, where activities could not be conducted virtually or businesses cash flow was curtailed, the Covid-19 pandemic has pushed out the adoption curve of 5G. For example, along with the stringent social distancing imposed, the overall daily average number of public transport trips in Hong Kong shrank approximately 40% from 12.4 million in 2019 to 8.9 million in 2020.[37] Other industries such as those related to retail and tourism were also severely impacted during the pandemic. As such, limited resources were available to explore and invest in 5G-enabled applications within the industries, resulting in an extended adoption curve. Figure 5 below illustrates the shift in adoption curve of 5G due to Covid-19 pandemic.

Figure 5: Adoption curve of 5G
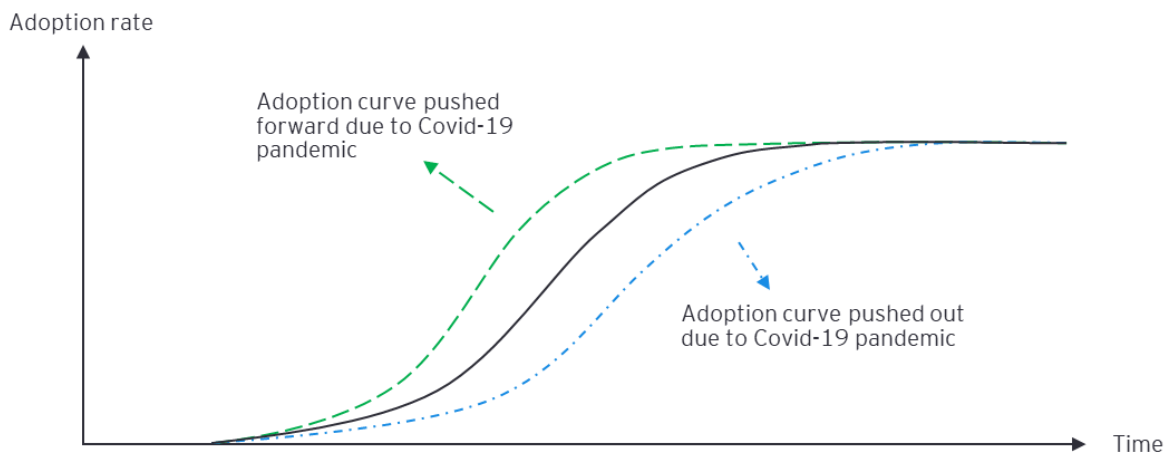
Graph for illustration purposes only, not drawn to scale
Source: EY analysis

Based on interviews conducted with industry experts and MNOs, 5G adoption is expected to accelerate from now until 2027 with many businesses moving to broad commercial adoption in some areas but without widespread adoption across the economy. Transportation, construction and healthcare are examples of industries where current trial adoption of 5G applications will likely become more mainstream by 2027. For the purpose of the Study, the adoption of 5G is measured by the proportion of 5G subscriptions to total mobile subscriptions in Hong Kong. Taking into consideration the Ericsson Mobility Report[38], the variation in 5G adoption across different industries and the limited or absence of manufacturing and mining activities in Hong Kong in which the take-up has been faster in other countries, the proportion of 5G subscriptions by 2027 is estimated to reach 60%.

One aspect of 5G adoption mentioned by several industry stakeholders was 5G's role as a platform technology. It is an underlying standard, on top of which MNOs are building out networks, application developers and industries then need to build tailored solutions. This layered approach takes time to develop and is one reason adoption may be slower than some industry expectations. An example of this is how high speed 5G through mobile devices and FWA has made video calls high quality and more reliable. It took some time for video conferencing software to catch up and provide products to the market, and it took the pandemic for different sectors to see the potential benefits from hybrid online/in-person education and healthcare. In many other industries, this technology stack built on the platform of 5G is still developing and will be adopted over the coming years.

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[37] https://www.legco.gov.hk/research-publications/english/2021issh27-covid-19-epidemics-impacts-on-transport-sector-20210603-e.pdf
[38] https://www.ericsson.com/49dd9d/assets/local/reports-papers/mobility-report/documents/2023/ericsson-mobility-report-june-2023.pdf

4.2 Economic models to quantify 5G's contribution

Given the difference of the nature between use case and network infrastructure investment, two economics models, Economic Model 1 and Economic Model 2, are used to quantify 5G's contribution to the economy of Hong Kong.

Economic Model 1 provides estimations of the economic benefit brought about through 5G use cases in each selected industry by the incremental impact on GDP and net change of jobs between a base case scenario and the 5G impact scenario. The base case scenario is based on actual economic data up to December 2021. Supported by the views of various industry players, 5G impacts realised from industry use cases as of December 2021 are relatively insignificant. As a result, the 2027 Baseline View, forecasted through the base case scenario, is considered an approximation of having no development of 5G.

Under Economic Model 1, a bottom-up approach is used to estimate 5G contribution to the Hong Kong's economy based on the implementation of 5G use cases at the industry level. The economic impacts modelled are then cross-checked using a top-down approach with reference to literature review, where 5G impact on the overall economy is assessed as a whole. The input assumptions for the modelling are based on all available information sources, including consultations with MNOs, industry associations and major companies in the selected industries, literature reviews and research papers, in an attempt to reflect the actuation situation in Hong Kong as closely as possible.

Economic Model 2 provides estimations of the incremental impacts of the 5G network infrastructure investment on GDP and number of jobs both directly and across the supply chain and wider economy by using the Input-Output methodology. It is worth noting that the economic impacts estimated by Economic Model 2 are annual benefits and do not accumulate over time. Such benefits will only continue when 5G network infrastructure investment continues.

With reference to the annual reports published by the MNOs and consultations with MNOs, investment in 5G network infrastructure began before the official launch of 5G and has continued consistently up to the present time, with plans for ongoing investment at a similar level for the next five years. As such, the impact of the 5G network investment that has already occurred as of December 2021 has been accounted for in the economic data published by C&SD, and as a result, has been captured in the base case scenario. Therefore, using Economic Model 2, the scenario where there are no 5G infrastructure investment at all is estimated by deducting the 5G impact from the base case scenario.

Hence, while Economic Model 1 quantifies the future 5G's contribution on the current GDP and employment, Economic Model 2 quantifies the increase in GDP and employment from the level of having no 5G investment. The aggregated economic impact on the overall economy of Hong Kong, in terms of change in GDP, can be estimated by summing up the results obtained from Economic Model 1 and Economic Model 2 by 2027.

Further details on the methodology and reference for both economic models are set out in Appendix A.

4.3 The economic impact on the overall economy due to the adoption of 5G (using Economic Model 1)

The Study focuses on the economic impacts on the 11 selected industries. When focusing on GDP and job creation, the economic model assumes the output composition, which includes the proportion of intermediate consumption and value added, for each industry remains unchanged. Additionally, as 5G adoption grows, the economic impacts on GDP and job are expected to become increasingly material over time. Based on the economic model, considerable cumulative benefits would be realised in Hong Kong between the official launch of commercial 5G services (i.e., 2020) and 2027.

Unlike other economies, Hong Kong has a relatively mature and highly skilled workforce, with limited or no mining, manufacturing and agriculture activities. Due to tightness of the current labour market, the adoption of 5G can help optimize the allocation of manpower. By implementing 5G-enabled applications, companies seek to have enhanced productivity through either increased output or labour saving. By doing so, labour productivity is expected to improve when proportion of 5G subscriptions increases due to higher adoption of 5G-enabled applications. There is also likely to be net increase in employments due to the demand for the technical staff to implement and operate the 5G-enabled applications. As a result, a net increase of 11,317 jobs (0.30%) is estimated on the overall economy of Hong Kong by 2027. Supported by current and foreseeable adoption of 5G use cases in each selected industry, a 0.66% increase in GDP is estimated for the overall economy of Hong Kong by 2027, representing an additional HK$20,544 million in GDP.

The degree of adoption of 5G varies across industries in Hong Kong. While some industries, such as healthcare, have implemented a number of 5G-enabled applications with pilot projects rolling out, some industries, including smart utilities, are relatively slow in adopting 5G solutions. Aligning with the results modelled, the impacts of 5G vary across industries and are mainly influenced by proportion of 5G subscriptions, 5G use cases and the size of the industry. The transportation and logistics industry and construction industry, representing 7.3% and 4.0% of Hong Kong's GDP respectively, are expected to benefit the most from the adoption of 5G by 2027. Please refer to Table 6 below for breakdown of the 11 selected industries. More details on the economic impacts of 5G on industry level will be discussed in Chapter 5.

Table 6: Summary of economic impacts created due to adoption of 5G by 2027

Economic Model 1	Net Impact on GDP (incremental)		Net Impact on Job (incremental)	
	HK$MM	%	No.	%
Construction	1,482	1.42%	1,841	0.56%
Transportation and logistics	4,086	1.32%	1,440	0.52%
Healthcare	645	0.98%	877	0.33%
Media and ICT	945	0.91%	1,056	0.75%
Retail and wholesale	669	0.78%	716	0.27%
Financial services and insurance	4,593	0.66%	848	0.27%
Accommodation and food services	488	0.66%	765	0.28%
Properties and buildings facilities management	594	0.55%	433	0.25%
Art, entertainment and recreation	141	0.46%	162	0.20%
Education	161	0.42%	442	0.18%
Smart utilities	141	0.35%	23	0.15%
Other services	6,600	0.46%	2,714	0.19%
Overall (Bottom up)[1]	20,544	0.66%	11,317	0.30%
Overall (Top down)[2]	15,477	0.50%	n.a	n.a

Note: [1]Overall (Bottom-up) sums up the economic impacts of the 11 selected industries and other services estimated using a bottom-up approach at industry level

[2]Overall (Top-down) is the economic impacts on the overall economy of Hong Kong estimated by assuming 0.5% for the full rollout of 5G, i.e., the proportion of 5G subscriptions reaches 100%, based on the analysis from the GSMA study

*Numbers may not add up due to rounding

The economic impacts modelled are cross-checked by using a top-down approach. With reference to a GSMA study conducted by Bahia, K., Castells, P. and Pedros, X. (2020) on global rollouts of 2G, 3G and 4G conducted in 2020.[39] This provides an assumption of 0.05% increase in GDP for every 10% increase in 5G adoption. Further details on the methodology and reference for the economic modelling are set out in Appendix A. Assuming the full rollout of 5G could contribute to the economy with an approximate 0.5% increase in GDP, the result is broadly consistent with the overall benefits realised from the adoption of 5G-enabled applications in each of the selected industries. The result of the top-down approach is a useful comparison to determine if the results are reasonable when compared to other methodologies applied to calculate economic impact of 5G, it should not be used to compare if the estimated impacts for Hong Kong are greater than or less than the average country.

Figure 6 illustrates the impact on GDP of adopting 5G on the overall economy using the above-mentioned approaches, compared to the base case scenario[40] by 2027. The bottom-up approach used to estimate the incremental GDP of adopting 5G in Hong Kong yields a result that is slightly higher than the GDP impact obtained from the top-down approach. This result can be largely attributed to the continuous potential that 5G is expected to bring about in Hong Kong. Consultations with MNOs and telecommunications equipment suppliers suggest that the 5G development in Hong Kong would be accelerated once it moved into the second stage, which is

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[39] https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=54165922&file=121120-working-paper.pdf

[40] Base case scenario refers to the forecast of GDP and jobs by 2027 if there was no development of 5G

expected to begin in 2025. This acceleration is expected to result in significant benefits, including increased productivity, higher GDP growth and the creation of new job opportunities.

Figure 6: GDP impact on Hong Kong's economy in 2027
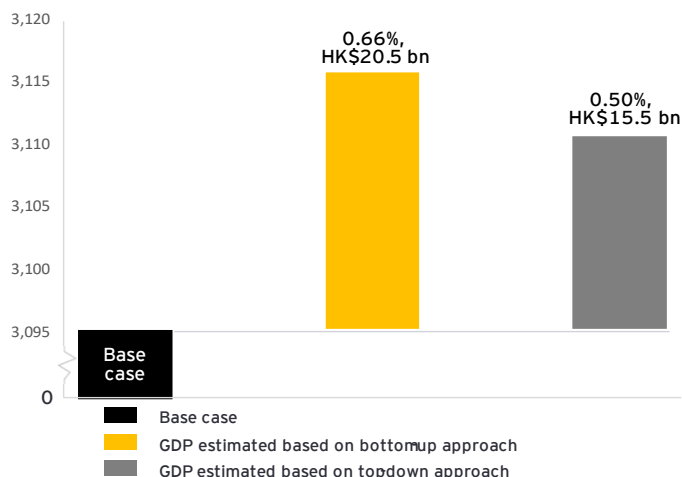
4.4 The economic impact on the overall economy due to direct investment in 5G infrastructure (using Economic Model 2)

As detailed in Section 3.3, in Hong Kong, 5G services are provided by the four MNOs and 23 MVNOs, with the latter not owning any network infrastructure. Prior to the official launch of 5G services, the MNOs have made significant capital expenditure for 5G infrastructure in Hong Kong. Based on the consultations with the MNOs, direct investment in 5G infrastructure has remained stable over the past few years and is forecasted to maintain at similar level until at least 2027. As such, the one-off impact arising from direct investment in 5G infrastructure is already accounted in current GDP figures and has been factored into the base case scenario. Economic Model 2 seeks to estimate the magnitude of the contribution of annual capital investment of the MNOs on GDP and employment on the overall economy of Hong Kong. Further details on the Economic Model 2 are set out in Appendix A.

Economic multipliers are used to calculate the GDP and employment contribution from the annual capital investment estimates. These multipliers have been derived from the Hong Kong Input-Output (International Standard Industrial Classification of All Economic Activities Rev 3.1[41]) table sourced from the OECD, which is based on a number of information sources including Hong Kong National Accounts.

It is worth noting that, although the ICT industry initiated and paid for the construction of 5G infrastructure, the associated economic benefits, including GDP and job creation, are captured by different industries involved in the building activities, where the money is being spent. For example, to build 5G infrastructure, investment is made to (a) the construction industry for building the necessary infrastructure for base stations including towers etc.; (b) the computer, electronic and optical products industry for supplying the required telecommunications and digital equipment; (c) electrical equipment industry for supplying the components for the antennas and supporting telecommunications equipment and power supply; and (d) the telecommunications industry for network planning and other related services and products. This expenditure results in increases in GDP for the services and goods provided by the four industries mentioned, and the creation of jobs due to labour required to perform such activities.

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[41] International Standard Industrial Classification of All Economic Activities (ISIC) Revision 3.1

On the other hand, the ICT industry realises additional economic benefits from the 5G infrastructure when it is put into use, for example, to offer 5G services. Such economic benefits are identified and quantified in Economic Model 1 discussed in Chapter 4.3 and Chapter 5.

Based on the annual reports published and interviews conducted with MNOs, capital investment in 5G infrastructure is forecast to be consistent at approximately HK$1,623 million per year for the next five years. As presented in Table 7 below, this level of capital investment in 5G infrastructure contributes to a total of HK$1,449 million in GDP (approximately 0.05% of total GDP) and 2,302 jobs (approximately 0.06% of total labour market).

Table 7: Economic impacts to Hong Kong's economy due to direct investment in 5G infrastructure

| Economic Model 2	Unit	41T43: Construction	26: Computer, electronic and optical products	27: Electrical equipment	61: Telecommunications	Total
Annual Investment in 5G Infrastructure						
Share	%	20%	30%	20%	30%	100%
Annual Investment	HK$MM	325	487	325	487	1,623
GDP						
Direct	HK$MM	125	131	119	271	647
Indirect	HK$MM	100	125	34	109	367
Induced	HK$MM	132	114	75	113	435
Total	HK$MM	358	370	228	493	1,449
No. of Jobs						
Direct	No.	335	223	244	275	1,077
Indirect	No.	186	222	55	167	630
Induced	No.	181	156	103	155	595
Total	No.	702	601	402	597	2,302

*Numbers may not add up due to rounding

The direct, indirect and induced effects generated on Hong Kong's GDP from the direct investment in 5G infrastructure are examined below and summarised in Figure 7 below.

In terms of the direct effect, the annual capital expenditure is estimated to contribute HK$647 million of Hong Kong's GDP through spending on infrastructure. Of this total, HK$125 million is estimated to go through the construction industry, HK$131 million to computer, electronic and optical products, HK$119 million to electrical equipment industry, and HK$271 million to telecommunications industry.

In terms of the indirect effect, the four industries above require goods and services from their suppliers which create an additional round of GDP increase. These indirect effects are estimated to contribute an additional of HK$367 million to Hong Kong's GDP. The indirect GDP will be generated from the direct industries' purchasing goods and services from industries within Hong Kong's economy and all subsequent downstream purchases.

In terms of induced effect, the industries providing goods and services for the 5G infrastructure related activities and all downstream industries make wage payments, leading to consumer spending. The effect of workers spending their wages on domestic goods and services within Hong Kong's economy is estimated to contribute HK$435 million to Hong Kong's GDP.

*Figure 7: GDP contribution of 5G from Economic Model 2*
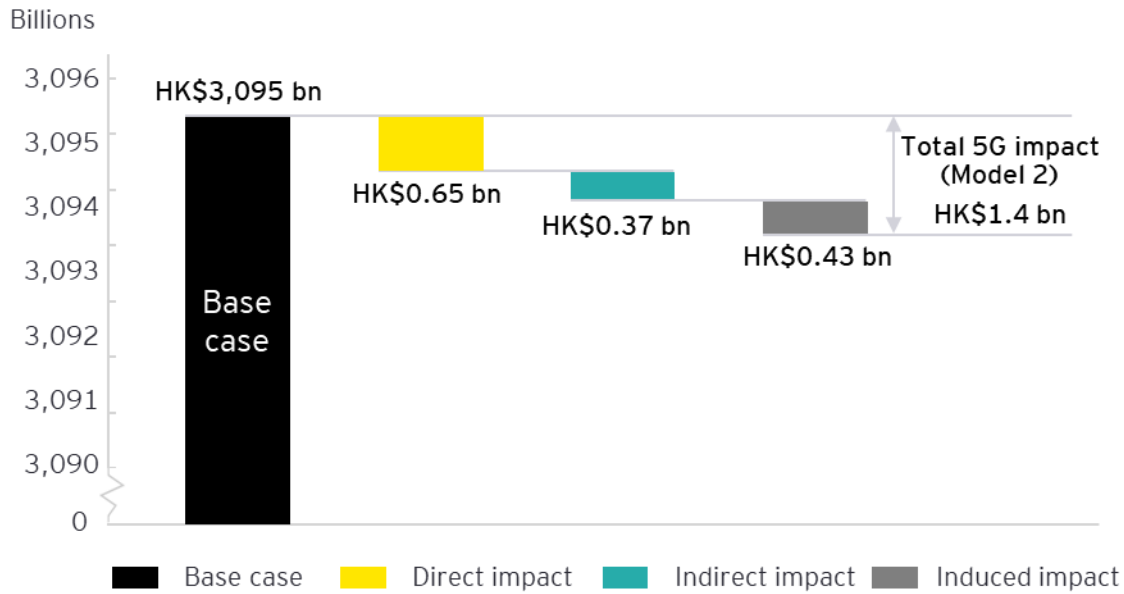
Overall, for every HK$1 million of direct investment in 5G infrastructure in Hong Kong, it will generate GDP of HK$0.89 million. This lower impact as compared to the amount of spending can be largely explained by the lack of manufacturing activities in Hong Kong. Most of the hardware and equipment required for 5G infrastructure are imported from overseas, which reduces the economic impact on Hong Kong's economy. The impact of this investment is already captured in Hong Kong's GDP data, so should not be seen as future increase in economic activity but a continued contribution.

4.5   Aggregation of the results from the two economic models

Figure 8 below illustrates the projection of 5G's contribution to Hong Kong's GDP by 2027 under Economic Model 1 and Economic Model 2, respectively, as well as the aggregated incremental GDP contributed from 5G by 2027.

Figure 8: Aggregated GDP contribution of 5G from Economic Model 1 and Economic Model 2
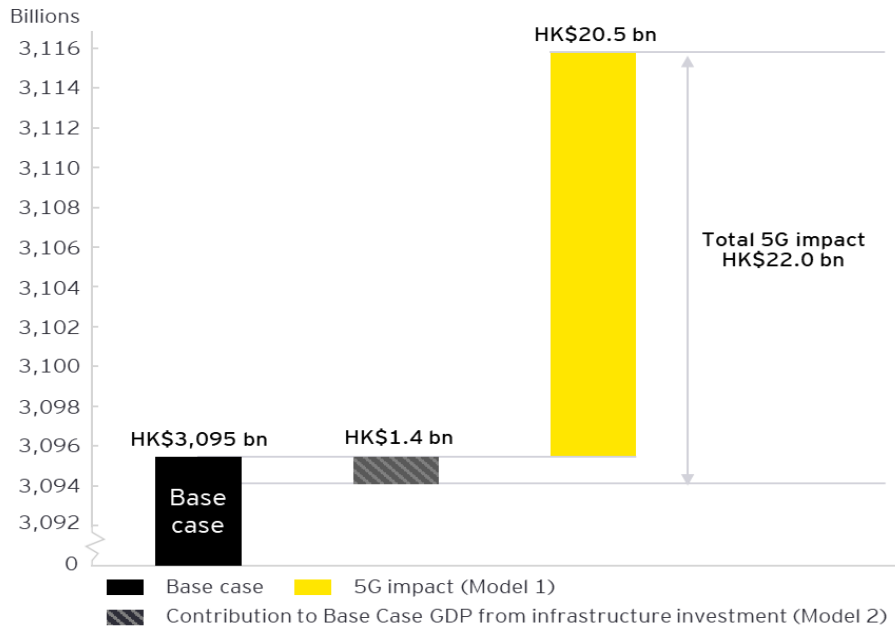
*Numbers may not add up due to rounding

Economic Model 1 estimates the potential increase in GDP from base case scenario based on increased adoption of 5G. This is estimated at HK$20.5 billion by 2027. Economic Model 2 estimates how much incremental of GDP is due to the 5G infrastructure investment which accounts for around HK$1.4 billion. Based on this, the total economic contribution of 5G in terms of incremental GDP by 2027 is around HK$22.0 billion.

Figure 9 demonstrates the overall incremental job impact of 5G to Hong Kong's economy. It is also the aggregation of the results from Economic Model 1 and Economic Model 2, which is estimated at 13,619 jobs.

Figure 9: Aggregated employment contribution of 5G from Economic Model 1 and Economic Model 2
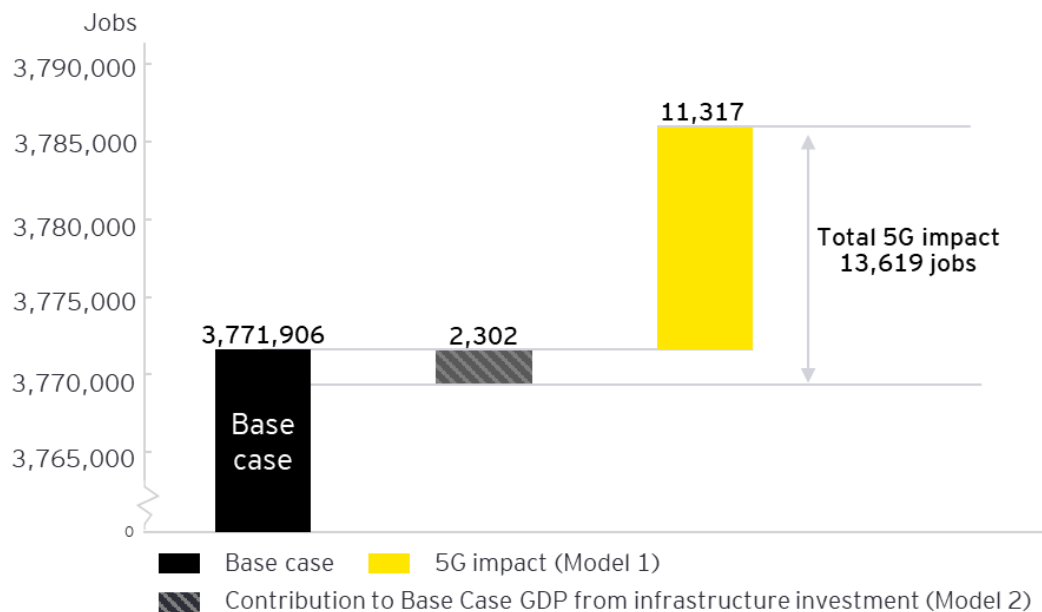
5.   The Economic Impact on Selected Industries (Using Economic Model 1)

5G-enabled applications are applied in both the consumer and business markets in Hong Kong and provide applications and services that go beyond those previously available using 3G/4G or Wi-Fi connectivity. This has the potential to drive economic growth in Hong Kong in cases where it opens up services or operating methods that were not previously possible. Through the three fundamental pillars of 5G detailed in Chapter 3, the use of 5G-enabled applications does not only improve productivity at the sector level (such as the introduction of robotic and IoT solutions in the daily operation of hospitals) but also create new opportunities (such as development of smart city and AV) that may benefit society as a whole.

In this chapter, how 5G has been, and is planned to be, applied in the selected industries in Hong Kong is summarised. Primarily, this draws from the consultations and questionnaires undertaken with industry groups, combined with desktop research of 5G uses cases in Hong Kong and globally. The results for local economic impact from adopting 5G is illustrated through the incremental impact on GDP and number of jobs in the selected industries by 2027. Further detailed information on the methodology of the economic analysis is detailed in Appendix A.

5.1   Construction

The impact of 5G on the industry by 2027 against the 2027 Baseline View is:

+1.42% | HK$1,482 million
Increase in GDP

+0.56% | 1,841
Increase in employment

The adoption of 5G-enabled applications may bring significant impact on the construction industry by 2027, with a 1.42% (i.e., HK$1,482 million) increase in GDP and a 0.56% (i.e., 1,841) increase in employment. Given the understating of labour shortages in the industry as discussed during the interviews with the industry stakeholders, 5G provides an opportunity to increase productivity, therefore allowing a greater output from the industry without growing the labour force.

Findings from interviews with industry stakeholders indicate that many digital tools and technologies, such as remote tower crane operations, smart site operations, Radio Frequency Identification (RFID) for asset tracking, Building Information Modelling (BIM) and drones have been implemented on some construction sites and have brought benefits such as real-time monitoring of workers and equipment, improved safety and increased productivity per worker. However, the industry is not widely aware of how 5G technology can benefit their daily operations, over and above a 4G network and/or Wi-Fi solution. Therefore, the level of investment on 5G across the construction industry varies across companies.

Digitalisation in construction has been promoted by the Development Bureau (DevB) long before the launch of 5G services in Hong Kong. The latest digital solutions in the Hong Kong construction industry include BIM, Common Data Environment, Digital Works Supervision System (DWSS) and Smart Site Safety System (SSSS) backed by IoT.

As a consequence, construction projects generate large volumes of data, such as high-resolution images, laser scans (point clouds), complex 3D models and video footage, which are required to be captured and shared with project team members to support with decision making, which may be in the construction site and away from the site office. This volume of data is expected to rise in the future, with the developments in areas that include, but are not limited to, Digital Twins that connect physical assets to their digital counterpart, AR, VR and Mixed Reality that can be

used for remote site inspections or the ability to overlay design over the physical world to assess if construction has taken place in accordance with the design, as well as the increasing use of robotics, such as AV for the movement of materials around a construction site.

The collection of certain construction data is also mandated on capital works contracts with pre-tender estimates exceeding HK$30 million through the adoption of BIM uses and DWSS.[42] DevB also requires new DWSS projects to upload site data in real time to the integrated Capital Works Platform, which will become a big data platform of construction for planning and monitoring of public works.

Construction sites looking to capture, process and share this amount of data require large volume of data transmission within construction sites as well as between the sites and the back office. Existing solutions, such as Wi-Fi, require careful consideration due to the lack of existing infrastructure in some remote areas, the temporary nature of construction sites, and physical obstacles that can interfere with Wi-Fi signal (such as thick concrete walls in high rise construction). Given the dynamic nature of construction sites, including the construction of new works and the potential movement of a site office, it can be challenging to establish a fixed line internet connection to support Wi-Fi across the entirety of a construction site. The peak data speed and latency support by 4G may not always be sufficient to transfer the data that is needed on a construction site. As a consequence, communication and collaboration on construction projects can be impeded.

5G can potentially break through the limitation of Wi-Fi and 4G connection mentioned above. 5G technology guarantees indoor network connection with micro base stations installed in the internal space of construction sites. Besides, 5G SA can provide an independent and private network with security and privacy data transmission for digital solutions applied to construction projects. As one component of the broader digitalisation agenda which is being pursued in the construction industry, 5G technology is not expected to bring revolutionary changes to the industry all at once, but it lays a foundation and creates a new platform for other technologies applied in the construction industry, such as BIM, IoT, 3D printing, Artificial Intelligence (AI), cloud computing as well as big data, which make up an ecosystem for smart construction in the long term.

In addition, MNOs and telecommunications equipment suppliers have been promoting solutions to construction firms. As seen in the examples of use case below, these partnerships are expected to move the industry forward in terms of productivity.

Examples of 5G use case

5G Smart construction
In 2021, a multi-purpose sports venue operating company, an engineering company together with HKT announced to deploy a dedicated 5G network infrastructure for the 28-hectare construction site.[43] Targeted for completion in 2024[44], the project is Hong Kong's first construction site with dedicated 5G network infrastructure.

The dedicated 5G network infrastructure, which consists of 5G base stations, numerous 5G routers and Wi-Fi access points, enables the real-time collaboration among roughly 2,000 site staff and allows large files with data to be transmitted at ultra-high speed. BIM also runs on the 5G network.

Tower cranes are equipped with 4K HDR cameras which can be zoomed in to capture and track individual movements in real time, and this enables remote monitoring and improves safety of

[42] https://www.devb.gov.hk/filemanager/technicalcirculars/en/upload/1392/1/C-2023-02-01.pdf
[43] http://www.pccw.com/assets/Common/files/press-release/2021/Feb/20210203e%20HKT%20KTSP%20Hip%20Hing.pdf
[44] https://kaitaksportspark.hk/en/timeline/

the construction site. HKT also developed a 5G mobile management system for the site, allowing remote monitoring, real-time collaboration, robotics, and IoT to be integrated in the system, and this has greatly enhanced the efficiency of the construction site.

SSSS

The DevB issued a Technical Circular in late February 2023 to set out the policy on the adoption of the SSSS to enhance the safety performance in public works projects.

According to the Technical Circular, the key components of SSSS include high resolution video cameras with at least 5X optical zoom, remote sensing systems, reliable automation systems, such as Closed Circuit Television (CCTV) system, facial recognition system, AI system, RFID, IoT, etc. The cameras of SSSS are required to be able to "continuously transmit wireless encrypted live-streamed video signal to a control platform for recording, viewing, and monitoring".[45]

The policy also points out that for site telecommunication networks, more than one type of telecommunication networks available in the market, including Wi-Fi, broadband network, 4G/5G network, LoRa and Ultra wideband (UWB), etc., should be adopted for the SSSS and able to support the connection for 7 X 24hrs. Given 5G can provide ultra-high speed with low latency, 5G technology is considered to gradually play a key role in the construction industry.

Remote site inspection

A Memorandum of Understanding between CMHK and an engineering firm on 5G-based "Smart Construction Site"[46] covers the development of: (1) Smart boundary management solutions that are capable of monitoring key indicators such as vibration, displacement and site environment in real-time, uploading data at regular intervals, providing real-time warnings of emergencies and photo inspection, as well as conducting remote VR video inspection through 5G panoramic cameras. (2) Unmanned aerial systems that can monitor remotely, acquire and analyse live HD video in real-time, greatly improving the efficiency of site survey and project progress monitoring. (3) Progress management system that can capture changes in progress, monitoring of progress and timely corrections. In addition, a complete construction file can be archived to record and display the entire construction process.

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[45] https://www.devb.gov.hk/filemanager/technicalcirculars/en/upload/1393/1/C-2023-03-01.pdf

[46] https://eshop.hk.chinamobile.com/en/about_us/media_centre/NewsPDF/20210419pr.html

5.2 Transportation and logistics

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The impact of 5G on the industry by 2027 against the 2027 Baseline View is:

+1.32% | HK$4,086 million
Increase in GDP

+0.52% | 1,440
Increase in employment

</div>

Supported by 5G, new use cases and enhancement of existing traffic solutions will improve the efficiency of transportation and logistics services in Hong Kong. In addition to the economic impacts on GDP and employment, 5G-enabled applications can help introduce automation to mitigate some of the labour force challenges that were raised by stakeholders in the industry. The adoption of 5G-enabled applications may bring a significant impact on the transportation and logistics industry by 2027, with a 1.32% (i.e., HK$4,086 million) increase in GDP and a 0.52% (i.e., 1,440) increase in employment.

As part of the Smart City Blueprint 2.0, the Government is committed to the sustainable development of Hong Kong's transport system, supporting technology advancement and industry development in vehicle-to-everything and AV, and ultimately connected Avs, as well as enhancing walkability[47]. The adoption of 5G helps drive the initiatives forward with enhanced capabilities and new opportunities for innovation and development. As of June 2023, various organisations have been working closely with MNOs to explore the possibility of 5G-enabled services and applications within the industry, including trials of smart 5G communication system, remotely controlled or autonomous transport/logistics services, real-time routing and navigation and so on.

With real-time information sharing via high-quality video streams, transport operators can monitor different operating environments and locations simultaneously and identify potential risks in a timely manner. This can be on-board public transport, at interchanges or at depots. For passengers, availability of real-time information, such as waiting times, occupancy rates, can help make trips faster and on-board 5G access can provide a more productive and enjoyable journey. In the port sector, automation of the container carrying trucks and remote control of port equipment can free up manpower for better use, potentially creating additional economic value.

Based on interviews with the key industry players, the use of 5G in the transportation and logistics industry in Hong Kong is still in its early stages. Only marginal 5G-enabled applications will be adopted industry-wide by 2027. Given that Hong Kong's transportation system is highly privatized, many operators require a strong commercial business case before adopting 5G. Moreover, smaller-scale operators, such as minibus operators, might not have sufficient resources to explore and upgrade to 5G-enabled applications. With limited local or comparable use cases, other industry players are reluctant to adopt 5G, with a view that their current communications systems using 4G and Wi-Fi are sufficient. The logistics industry has a large number of small and medium-sized enterprises operating in the industry, which might not have the capital or capabilities to implement the new technology. Hong Kong's older building stock is also more difficult to retrofit for smart warehousing solutions using 5G, compared to the purpose-built large distribution centres in other countries.

Nonetheless, in a long run, it is believed that a large impact from 5G will be realised when proportion of 5G subscriptions increase. One of the major step-changes that 5G may offer is Avs. Some pilot operations are anticipated in the next few years at dedicated test areas such as the

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airport, container port, West Kowloon Cultural District[48] or Hong Kong Science Park[49]. As these solutions for autonomous transport involve the coordination of technology, regulations and public acceptance, the major benefits may come after 2027.

Examples of 5G use case

5G-enabled cameras
By uploading and sharing real-time data through cameras, 5G enables staffs in control rooms to monitor traffic and demand for public transportation. Adopted by one of the bus companies in Hong Kong, the 5G-enabled cameras enable more efficient deployment of buses and continuous data collection and analysis. As a result, 5G helps improve operational efficiency through better schedule and timetable design, lower labour costs, and shortened passenger waiting time.

Autonomous truck
Connecting to the key operating systems of the port, autonomous trucks can reduce wastage by optimizing truck movement around the yard and minimizing the number of shuffles needed for delivery. By doing so, operating costs can be saved from less manpower required to operate equipment and higher operational efficiency.

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[48] https://www.westkowloon.hk/en/press-release/west-kowloon-cultural-district-to-introduce-autonomous-vehicle-in-the-district
[49] https://www.hkstp.org/news-room/hkstp-and-urbansystems-embark-on-autonomous-vehicle-trial-to-advance-hong-kong-s-smart-city-innovation/

5.3 Healthcare

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The impact of 5G on the industry by 2027 against the 2027 Baseline View is:

+0.98% | HK$645 million

Increase in GDP

+0.33% | 877

Increase in employment

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In the healthcare industry, 5G is largely being adopted in Hong Kong to improve training of medical professionals and to improve patient experience. Through 5G-enabled applications, the healthcare industry is expected to have a 0.98% (i.e., HK$645 million) increase in GDP and a 0.33% (i.e., 877) increase in employment by 2027.

Reliable and high-speed 5G connectivity has the potential to improve healthcare outcomes by enabling "smart hospitals" to improve patient outcomes and operational efficiency.[50] Smart hospitals have been implemented in both public and private hospitals in Hong Kong. Some hospitals build up an entire integrated Hospital Information System (HIS) using a combination of technologies including Wi-Fi, 4G, LTE and 5G. The HIS can integrate the end-to-end patient journey from an appointment booking via mobile application or call centre, consultation of nursing care, diagnosis, treatment, all the way to discharge. The system also links third party systems such as laboratory, specimen tracking, radiology, Vendor Neutral Archive, pharmacy related systems and ERP systems. The HIS relies primarily on the broadband connectivity plus Wi-Fi, so the benefits attributable to 5G are limited to some specific use cases as explored below.

One such use case being applied in Hong Kong that was discussed during the industry consultation, is using 5G network to transmit 4K ultra high-definition medical videos and images from operating theatres. This allows remote specialist clinicians to review them in real time and to provide training to medical students.

5G-empowered IoT sensors are also applied in the operations of hospitals in Hong Kong. For example, pick-to-light[51] for drugs dispensing applies visual aids for the accurate picking of medications and distributes the medications to patient-specific dispensing basket. Machine-controlled processes reduce the risk of misdistribution by manual distribution, improve the efficiency of operation and release labour for more productive tasks.

Another significant use case of 5G network in smart hospitals is real-time location tracking backed by UWB. This use case enables wayfinding for inpatients in the hospital building and that allows patient location services to the hospital staff. It can also give geo-fencing alert if the patient should not leave some areas. This use case performs better in a 5G network environment[52].

Although benefits such as efficiency improvements and easier daily operations are acknowledged by industry stakeholders, consultees also commented that it would take a long time for developers to launch more use cases for healthcare industry, as it takes time for most of the 5G-enabled applications to enter the market from trial or launch stage and accumulate sufficient proven record of performance data and benefits. For example, though robotic surgery has been

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[50] https://www.gsma.com/iot/wp-content/uploads/2022/02/2022-02-GSMA-APAC-5G-Case-Study-HKT-CUHKMC-5G-Smart-Hospital.pdf

[51] "Pick-to-light", or "pick-by-location" is a type of order-fulfillment technology that employs alphanumeric displays and buttons at storage locations to guide the manual "picking" and recording of drugs. It is designed to improve picking accuracy and efficiency. https://www.techtarget.com/searcherp/definition/pick-to-light#:~:text=Pick%20to%20light%20is%20order-fulfillment%20technology%20that%20employs,manual%20%22picking%22%20and%20recording%20of%20items%20for%20shipment.

[52] https://www.ericsson.com/en/reports-and-papers/5g-and-wi-fi-path-toward-superior-indoor-connectivity

tested in laboratory environments, most hospitals are still adopting a wait-and-see approach and will not implement in practical operation without proven results. This is the major concern for one of the stakeholders when talking to the further investment plan on 5G use.

While further 5G use cases for healthcare market are still being explored, the Government is also pushing forward the healthcare infrastructure backed by 5G network for the city. The Hospital Authority (HA) has put forwarded Strategic Plan 2022-2027[53] proposing to change the service model towards the provision of "Smart Care" with the support of "Smart Hospital", which aims to apply information technology, digital solutions and AI infrastructure to enhance the operational efficiency. As of 2022, many smart projects have been developed in hospitals in Hong Kong. 5G-enabled telemedicine, such as remote physician and family tele-visit, and virtual consultations, has been put into service. Looking forward, more and more intelligent use cases enabled by 5G will improve the experience for the public and uplift the efficiency of operation.

Examples of 5G use case

Remote monitoring and video conference
5G-enabled remote monitoring and supervision of operations with video conferencing has been developed in operating theatre in some of the hospitals in Hong Kong. This application allows the doctors who are conducting the operation to invite other experts with more experience to remotely monitor the progress of surgery and provide real-time guidance to the doctors and improve surgical efficiency. It also aids in training of new surgeons who can view the operations with multiple HD cameras.

5G telehealth system[54]
Together with HKT, one of the leading private hospitals in Hong Kong launched a 5G telehealth platform. This platform allows hospitals to provide remote medical consultation services. Users of the application can book appointments with available doctors after completion of a simple registration. Consultation will take place in-app at the scheduled time. Further, the system can also arrange the delivery of prescribed medicine, medical certificate and medical referral letter, etc., to the user's designated address in Hong Kong. Use cases such as this also show the benefits of FWA 5G connections as enabler of new use cases. As individuals without access to broadband connections to their home could use FWA to take undertake remote consultations.

Smart hospital[55]
One of the private hospitals in Hong Kong has fully equipped with 5G network. 5G network with ultra-high speeds of over 1Gbps and extremely low latency of less than 10ms helps deliver an immersive experience through a combination of extremely high-quality ultra-HD 4K video, 3D imaging, VR, AR and multi-camera view. Medical images such as those obtained from endoscopy, ultrasounds, CT scans and X-ray of a high resolution can be transferred in real time via 5G for remote medical consultation and training purposes.

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[53] https://www.ha.org.hk/haho/ho/ap/HA_StrategicPlan2022-2027_Pamphlet_Eng_211216_1.pdf

[54] https://www.hkt.com/assets/Common/files/press-release/2020/Jul/20200729e%20DrGo%20telemedicine%20platform%20launch.pdf

https://www.cpr.cuhk.edu.hk/en/press/development-of-cuhk-medical-centre-into-hong-kongs-first-digital-smart-hospital/

5.4   Media and ICT

The impact of 5G on the industry by 2027 against the 2027 Baseline View is:

+0.91% | HK$945 million
Increase in GDP

+0.75% | 1,056
Increase in employment

The Media and ICT industry has been one of the first to benefit from 5G. Low latency and wide bandwidth made possible by 5G have been immediately applicable to media services, e.g., TV, Over-the-top video streaming (OTT video) and broadcasting, as well as other areas such as gaming, digital advertising, and remote work, improving consumer experience and thus increasing revenue. The adoption of 5G may result in a 0.91% (i.e., HK$945 million) increase in GDP and a 0.75% (i.e., 1,056) increase in employment by 2027.

The ICT industry is fundamental for developing and promoting 5G technology. The industry contains the upstream such as infrastructure/equipment providers and the MNOs which manage this network infrastructure and interface with consumers. Before the launch of 5G, network integrators together with MNOs started heavy investment into R&D on 5G technology, anticipating high returns and future potential in the technology. This rollout has led to a greater than 90% coverage of Hong Kong population. As ICT includes telecommunications activities themselves, 5G rollout has contributed directly to economic impact of the industry.

Within ICT, a main 5G use case is the implementation of 5G FWA as substitute to fibre broadband. In areas where fibre may be prohibitively expensive to introduce, FWA availability is able to serve the same purpose in enabling high speed and high-definition connectivity. The infrastructure required is standardized 3GPP architecture, lowering costs significantly, while providing competitive services. Higher levels of access to internet connectivity will increase inclusion for many, allowing opportunities for growth. 5G deployment using mid-band spectrum enables both good coverage and data throughput, as well as low latency. With the implementation of this infrastructure, there is a significant one-off contribution to the ICT industry with the added revenue streams from FWA customers. Forecasts demonstrate that by 2027 there will be an estimated 192 million 5G FWA connections globally.[56] The FWA technology is useful to both households and enterprise. For households, 5G FWA may provide previously unavailable speeds, while for businesses it may become more cost effective to connect using FWA.

Additionally, OFCA has subsidized a completed use case to adopt technologies over the 5G network to replace microwave transmitting stations, to improve video live stream/television quality. The use case utilizes High Efficiency Video Coding wireless video transmitters, video transceiving platform and live streaming mobile application to enhance quality and improve operational efficiency.

Future use cases of 5G in ICT will be created through the release of 5G-Advanced, which is the next planned release of technical enhancements to the protocol. This will allow MNOs to offer improved services, and industry uses would be able to utilize this technology for real-time/automated applications. Improvements in 5G-Advanced include enhanced positioning with sub-10 cm accuracy, enhanced coverage, and enhanced multi-cell uplink. The provision of these new technologies will support the applications that could have a larger economic benefit of the ICT industry.

The current status of 5G Implementation in media industry is more advanced than other industries in Hong Kong such as buildings facilities management industry and retail industry, since the improvement in video streaming etc. has made an immediate impact to their customers

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[56] https://www.ericsson.com/en/reports-and-papers/mobility-report/dataforecasts/fwa-outlook

experience. In the media industry, consumers have subscribed to 5G service plans for ultra-high speed data transmission. Although the pandemic had negatively impacted many industries, it also stimulated the market demand for stable and smooth connection for digital media such as OTT video and remote work, increasing adoption of 5G in the market. Additionally, internet advertising has remained on trend with consistent increase in revenue in Hong Kong, made more engaging with smooth 5G connection such as in video advertising or search results.

Within media industry, an example of 5G use case is OTT video streaming. The high-quality video streaming available due to 5G improves consumer experience, aided by network stability. Consumers desire to have more immersion increases demand for higher quality and low latency when viewing live events, and smooth viewing experience will increase traffic on viewing platforms. The use of video advertising alongside drives revenue for the industry, since it is commonplace on many platforms to incorporate advertisements periodically throughout the video content. Within ICT industry, remote work possibilities have increased due to the Covid-19 pandemic, when most if not all communications were remote. Low latency and high-quality video allow for a realistic interaction, improving the overall experience and creating more work opportunities, therefore leading to greater economic benefit.

Even without the Covid-19 pandemic, IoT sensor and AR/VR technology have been fast-developing and applied in gaming industries. The equipment of motion sensing game, also known as "somatic game", can capture the position or action of the players and interact with the scene shown on the screen.

Before 5G is available, most AR/VR equipment require connection by Bluetooth or cable. However, 5G breaks through technical barriers that 4G or other technologies cannot tackle. For example, deep immersive experience requires 8K-12K high definition of screen, which requires at least 120-140Mbps speed of data transmission, and 4G network cannot fulfil such requirements. Under the circumstance, equipment developers have to sacrifice the quality of image, which makes the player dizzy when playing and greatly hurts the gaming experience. 5G technology also makes operation of portable VR equipment viable. Previously, VR equipment with sufficient computing capability is generally expensive and heavy, while portable VR equipment may have to sacrifice part of computing capability. However, high speed data transmission of 5G technology enables real-time VR computing, data storing and rendering to move to the cloud, which frees the players from "heavy helmets" and saves the hardware cost for developers.

Examples of 5G use case

Gaming event empowered by 5G network

CMHK launched a cloud-based gaming platform in 2021.[57] The cloud-based gaming platform allows users to play games on remote servers through 5G network, without requiring high-end hardware, as the servers handle the processing and graphics rendering. The gaming platform's library of games includes a variety of types, such as racing games, shooting games, strategy games, sports games, etc. The platform is designed to provide players with a seamless experience, with low-latency gameplay and high-quality graphics.

One of the advantages of cloud-based gaming is that it allows players to access the latest games without having to purchase expensive hardware. Additionally, the platform offers a social gaming experience, with multiplayer games and the ability to connect with other players from around the world. The platform's cloud-based e-sports games are also designed to be scalable, which means that the platform can accommodate high volumes of players without compromising on performance. This makes it an ideal solution for large-scale gaming events and competitions.

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[57] https://eshop.hk.chinamobile.com/en/about_us/media_centre/NewsPDF/20210722pr.html

5G FWA Implementation[58]

In Hong Kong some premises, e.g., old tenement buildings, are not served by fibre broadband services due to expense and difficulty in laying infrastructure. As these buildings are often in urban areas with sufficient mobile network coverage, fixed networks utilising 5G mobile network infrastructure are a possible solution. 5G's unique low latency and high speed create a viable alternative fixed network to fibre broadband. In areas affected by signal degradation such as due to building materials, installing Customer Premise Equipment with external antenna can rectify much of the issue. Utilising the significant coverage of 5G network in Hong Kong to increase connectivity to households and even enterprises increase revenue streams.

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[58] https://www.ofca.gov.hk/en/consumer_focus/guide/general/hbs_enabled_by_5g/index.html

5.5   Retail and wholesale

The impact of 5G on the industry by 2027 against the 2027 Baseline View is:

+0.78% | HK$669 million
Increase in GDP

+0.27% | 716
Increase in employment

In Hong Kong, the retail and wholesale industry has started to experience some benefits from 5G through the use of IoT for monitoring facilities and customers movements and AR/VR to improve the retail experience. Through various 5G-enabled applications, the retail and wholesale industry is expected to have a 0.78% (i.e., HK$669 million) increase in GDP and a 0.27% (i.e., 716) increase in employment by 2027.

For retail businesses, most of the existing 5G-enabled applications target to provide consumers a better experience, such as immersive retail, in-store assistance and smart mirror. Over the past few years, the Covid-19 pandemic has significantly stimulated contactless operations and e-commerce in Hong Kong. Further driven by the development in digital payments, consumer behaviour has noticeably shifted towards an online, contactless manner. As one of the completed projects[59] under the Subsidy Scheme[60], real-time online sales is an example of the 5G use cases in the retail industry. With the ability to enable live video streaming from any location, regardless of whether it is indoor or at temporary venues, 5G can facilitate online product sales and promotions for merchants. By doing so, the overall shopping experience for customers can be enhanced and potentially increase sales for retailers.

Based on interviews with industry players, multiple 5G solutions are being explored in the retail industry. For example, human-like AI assistance is expected to answer shoppers' queries about shopping malls, stores, or products. Automated checkouts allow buyers to make purchases in one go, simply by walking in and completing the transaction, providing greater convenience and better experience. Moreover, according to a research report[61] published by an industrial organisation in Hong Kong, 5G-enabled applications can be utilized to enhance overall operational efficiency from the perspective of shop owners and developers, for example, by adopting video-based monitoring systems, information on foot-traffic can be collected and analysed for more efficient store layout for customer visits.

At the end of 2020, one of the leading property developers in Hong Kong announced to introduce 5G-enabled applications to its shopping malls[62]. For example, leveraging IoT technology, smart restroom solutions with sensors to automatically detect the occupancy, can be developed. The information collected is then made available for the public through a mobile application and screens within the shopping malls, providing a smart queuing feature.

For the wholesale industry, 5G can help enhance the operational efficiency of the businesses through various technologies, such as real-time inventory tracking, robotic solutions and IoT. Based on the same research report published by an industrial organisation in Hong Kong[63], warehouse can transport goods automatically through robotic technologies. Equipped with connected sensors, these robots can identify products and their respective quantities, ensuring desirable inventory levels are maintained. Similar 5G-enabled applications can also be applied for

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[59] https://www.ofca.gov.hk/filemanager/ofca/en/content_1217/completedprojects.pdf

[60] https://www.ofca.gov.hk/en/industry_focus/industry_focus/5g_subsidy/index.html

[61] https://www.smefund.tid.gov.hk/english/tsf/deliverables/t20001026_researchreport_5G.pdf

[62] https://www.hkt.com/assets/Common/files/press-release/2020/Dec/20201210e%20HKT%20HLD%20TGT.pdf

[63] https://www.smefund.tid.gov.hk/english/tsf/deliverables/t20001026_researchreport_5G.pdf

predictive equipment maintenance by tracking the real-time status of equipment and comparing it against forecasted indicators.

Nonetheless, despite the potential benefits identified, interviews with MNOs and industry stakeholders indicate that the adoption of 5G is still limited in the industry. This is primarily due to the lack of applications that require the ultra-high speed, low latency or dedicated bandwidths supported by 5G networks. Instead of saving labour costs through automation and robotic technologies, companies are more interested in providing more value-added services with the use of 5G while keeping the same labour size. In many cases, applications like self-checkout and AI assistants are provided as a secondary option for the consumers, while the traditional in-person checkout and information counters remain in place. Having said that, it is commonly believed that as new needs are identified, the adoption rate of 5G will increase along with the development of new applications over the next few years.

Examples of 5G use case

5G customer flow analytic system
Supported by 5G, AI video analytics and edge computing can be used to collect and analyse real-time data on customer flow and shopping behaviour. This data can be used to develop more efficient layouts and merchandising strategies that can improve wayfinding and minimize crowding. By optimizing traffic flow, customers can have a more enjoyable shopping experience, which can lead to increased customer satisfaction and potentially higher revenue for shop owners. This project is also funded by OFCA's Subsidy Scheme[64].

5G smart malls[65]
Partnering with SmarTone, one of the major property developers in Hong Kong launched 5G smart malls in 2021, which offers an innovative shopping experience while enhancing operational efficiency. One of the 5G solutions introduced in these smart malls is the 5G Robot, which goes beyond the traditional robots operating in shopping malls by featuring internal laser radar and 3D motion-sensor cameras that can detect obstacles on the floor and report them to relevant department for timely solutions. Other applications, including 5G Smart Restroom, are also introduced to help improve operational efficiency while ensuring the health and safety of both customers and tenants.

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[64] https://www.ofca.gov.hk/en/industry_focus/industry_focus/5g_subsidy/index.html
[65] https://www.shkp.com/en-US/media/press-releases/shkp-and-smartone-collaborate-to-launch-5g-smart-malls-optimizing-shopping

5.6 Financial services and insurance

> **The impact of 5G on the industry by 2027 against the 2027 Baseline View is:**
>
> **+0.66% | HK$4,593 million**
> Increase in GDP
>
> **+0.27% | 848**
> Increase in employment

5G can benefit the financial services and insurance industry by improving productivity, efficiency and security. Further developing use cases can make a positive economic impact on GDP, while having labour cost savings. By implementing 5G, the financial services and insurance industry is expected to have a 0.66% (i.e., HK$4,593 million) increase in GDP and a 0.27% (i.e., 848) increase in employment by 2027, mainly due to enhanced digital operations.

The financial services and Insurance industry has often been an early adopter of digital technology, such as ATM machines, e-banking, or e-wallets for financial services.[66] Strictly speaking, 5G alone may not immediately create revolutionary solutions of financial services. Internal processes for the institutions mainly rely on wired connectivity and Wi-Fi which is unlikely to change in the short term. However, capability of high speed, high reliability and low latency of data transmission empowered by 5G opens a range of value-added services that can be provided to both Business-to-Business and Business-to-Consumer customers. However, it remains to be seen if this step change of technology can be translated to similar changes to the industry as online trading, mobile banking and other previous digital solutions provided.

Facing the rapid development of technology and its growing impact on the banking industry, the Government has released initiatives to encourage the industry to explore benefits brought by technology. For example, Hong Kong Monetary Authority (HKMA) announced a series of initiatives in September 2017, which aims to improve the quality of banking products and services for customers by embracing the opportunities brought by the coordination of banking and technology, to transform Hong Kong to a new era of smart banking.[67] Likewise, the Government's initiative of Hong Kong Smart City Blueprint 2.0 (Smart City Blueprint 2.0)[68] also outlines its commitment to assisting the development of financial technology (FinTech), such as encouraging the performance and stability of virtual banks.

Industry participants in Hong Kong have been actively embracing digital transformation and 5G technology and have been collaborating with MNOs on the R&D of digital solutions and 5G use cases, such as mobile applications for their business. For example, a leading bank partnered with CMHK to deploy 5G use cases for smart financing in 2020.[69] HKT deployed a smart banking mobile application for a regional bank in 2021.[70] MNOs are also optimistic about FinTech solutions and have been delivering a series of mature applications.

Unlike other industries, the financial services industry generally requires more stable network that support higher transmission speed and lower latency to ensure fast transaction settlement and data safety. For this reason, most institutional level banking and trading are undertaken through wired networks. 5G SA network can meet such requirements which offer private and stable network without sacrificing data transfer rates. For most of the requirements of the financial services industry, there is no reason to move from wired to wireless networks. However, 5G allows new services to be provided to customers using mobile technology. VR solutions can be deployed over 5G services to create portable professional tools for bankers, e.g., mobile trading

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[66] How 5G Will Enhance the Finance Industry (att.com)

[67] Hong Kong Monetary Authority - Smart Banking (hkma.gov.hk)

[68] https://www.smartcity.gov.hk/modules/custom/custom_global_js_css/assets/files/HKSmartCityBlueprint(ENG)v2.pdf

[69] https://v.icbc.com.cn/userfiles/Resources/ICBC/haiwai/Asia/download/EN/2020/press20200629e.pdf

[70] https://www.businessgo.hsbc.com/en/article/smart_mobile_application_en

desks, which can enable VR glasses and 5G for use by professional traders even outside usual workplace, as demonstrated by a completed use case[71] under OFCA's Subsidy Scheme.

5G applications specific for the insurance industry in Hong Kong are relatively rare and involve wider industry stakeholders, including insurance companies, MNOs and hospitals. One of the use cases for the insurance industry is options for customers to receive professional medical care at home through 5G-empowered telemedicine services. For example, an insurance company, HKT, together with a hospital launched a hospital-supported telemedicine service in the insurance industry in Hong Kong in early December 2020[72], which was expected to be convenient for the clients of the insurance company, especially during the Covid-19 pandemic.

Overall, there are a number of 5G use cases being trialled in the financial services and insurance industry in Hong Kong, but these represent only marginal improvements to user experience compared to early innovations in the industry. However, given the importance of the industry to Hong Kong, even marginal improvements in productivity of employees and customer service can lead to substantial impacts to Hong Kong's economy by 2027.

Examples of 5G use case

5G-enabled FinTech solution for a regional bank in Hong Kong[73]
A regional bank in Hong Kong and HKT announced to form a strategic partnership to drive 5G-empowered FinTech innovations in early 2021, when the 5G network and the FinTech landscape were evolving rapidly in Hong Kong. The bank was planning to launch an application which is a remote account opening mobile application which was developed by HKT and was running as a pilot trial under the FinTech Supervisory Sandbox of HKMA.

The application deployed the Low-Code Application Platform with shorter development time and ease of development compared to traditional application development approach. The new approach facilitates the rapidly changing business needs and enables quicker digital transformation.

The mobile application also deployed the emerging identity verification technology "Electronic Know Your Customer", which allows customers to handle account opening, credit card and personal loan application, etc. without coming to the physical branch of the bank. The mobile application was launched in May 2021[74]. Starting from the mobile application, the bank also cooperated with HKT on robotic process automation, cloud computing and chatbots to improve operation efficiency and enhance customer experience.

Next-Gen 5G ATM[75]
In June 2020, a leading bank cooperated with CMHK to present an all-rounded customer experience by merging 5G technology and FinTech into its flagship branch in Central, Hong Kong.

The flagship branch is equipped with 5G-empowered facilities, which allow customers to open new bank accounts efficiently in a semi-automated manner. Customers only need to fill in the personal information with designated iPads, and the data will be instantaneously shared to the branch's terminal. Customers are then instructed to scan their ID Cards and proofs of address, complete facial recognition registration and provide signatures. All their information will be transmitted to the bank's backend system in real time, allowing the staff to simultaneously

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[71] https://www.ofca.gov.hk/filemanager/ofca/en/content_1217/completedprojects.pdf

[72] https://www.hkt.com/assets/Common/files/press-release/2020/Dec/20201202e DrGo x GHK for AIA HK.pdf

[73] https://www.hkt.com/assets/Common/files/press-release/2021/Jan/20210121e HKT Fubon.pdf

[74] https://www.hkma.gov.hk/media/eng/doc/other-information/ac-opening/20210520e1.pdf

[75] https://v.icbc.com.cn/userfiles/Resources/ICBC/haiwai/Asia/download/EN/2022/press20220721e.pdf

perform approval process. The overall process is streamlined into just a few minutes, reducing the queuing time.

Telemedicine services initiated by a local insurance company[76]
A local insurance company, HKT and a local hospital together launched a telemedicine service supported by a hospital in the insurance industry. In the comfort of their homes, users can book appointments and receive video consultation services provided by the hospital via HKT's one-stop telemedicine platform, while prescribed medicine will be delivered to the users' designated addresses, usually within four hours. The use case allows users to receive quality, convenient and efficient professional medical consultation services with peace of mind, without the need to leave home during the pandemic.

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[76] https://www.hkt.com/assets/Common/files/press-release/2020/Dec/20201202e DrGo x GHK for AIA HK.pdf

5.7 Accommodation and food services

The impact of 5G on the industry by 2027 against the 2027 Baseline View is:

+0.66% | HK$488 million
Increase in GDP

+0.28% | 765
Increase in employment

The accommodation and food services industry in Hong Kong has seen an increasing trend towards adopting 5G-enabled applications in recent years. Focusing on providing higher quality of services and better operational management, the adoption of 5G-enabled applications may result in a 0.66% (i.e., HK$488 million) increase in GDP and a 0.28% (i.e., 765) increase in employment by 2027.

Impacted by the Covid-19 pandemic and related travel restrictions, an increasing number of hotels are exploring the option of offering hospitality experiences to local citizens through "Staycations". As such, hotels begin innovating and incorporating technology-enabled features, which help differentiate themselves from one another through better experience, to attract potential guests.

Since 2021, a number of hotels in Hong Kong have started adopting 5G-enabled applications in cooperation with MNOs. In addition to providing guests with an ultra-high-speed network, these hotels offer various innovative solutions to improve guest enjoyment and engagement, such as smart self-check-in and check-out, in-room control system, digital concierge services. Moreover, with the ability to be effective through thick barriers, indoor connectivity can be enhanced through 5G, which enables continuous development towards "smart restaurant", targeting every activity happening within the restaurant from self-ordering to self-checkout. With the support of 5G, the application of IoT and automation enables the industry to achieve greater control and flexibility while improving the quality of services and safety.

Funded by OFCA's Subsidy Scheme, CMHK has supported a local company in the development of AR Smart Glasses solutions[77] incorporated a number of innovative technologies, such as video streaming, big data, AI and more. This Smart Glasses has been adopted by certain companies in the food and beverage (F&B) industry to strengthen their monitoring process and ensure food quality. According to the cases sharing article published by CMHK[78], the use of Smart Glasses in the kitchen has significantly reduced the production delays. By incorporating 5G, low-latency real-time long-distance monitoring is enabled, even under moving environments. This allows for real-time monitoring of the entire food preparation process, from food production and packaging to logistics. As a result, the adoption of such 5G-enabled applications is expected to increase productivity and ensure stable food quality.

However, based on interviews with the MNOs, the need for ultra-high speed and ultra-low latency connections in the accommodation and food services industry might not be as significant as other industries. Utilizing AI and robotics technologies, services provided can be supported by 4G or Wi-Fi, even though it may not provide optimal efficiency. While resorts, which typically have large site areas, may have higher innovation potential and can potentially maximize both social and economic benefits of the 5G within the industry. It should be noted that Hong Kong does not have resort style hotels due to the city's characteristic. This may include autonomous feeder services, resort-wide broadcasting and other possibilities. Even though there is an increasing trend to shift towards 5G-enabled applications and automation, some expect this transition to take place gradually over the next 10 years.

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[77] https://corp.hk.chinamobile.com/en/detail/5G-smart-glasses.html

[78] Ibid.

Examples of 5G use case

5G Robot in hospitality
By leveraging 5G, hotels incorporate advanced chatbots and AI to provide assistance and respond to guests' inquiries by connecting to the cloud. In addition, service robots are able to move around the hotel, operate elevators and navigate to the guest room who require delivery services. Adopted by a number of hotels in Hong Kong and world-wide, robotics services enable better use of manpower, especially during night time. As a result, the adoption of 5G can help improve operational efficiency along with better user experiences by shortening waiting time.

Inventory management for F&B industry[79]
With the use of IoT, 5G can be deployed to enhance the efficiency of inventory management. Connected sensors and cameras can collect data related to food inventory for real-time detection and analysis. For example, the applications can detect the level of remaining inventory and send alerts when stock is low in a timely manner. Additionally, the data collected on the amount of weekly consumption can be used to predict consumption patterns, enabling more efficient inventory restocking and better forecasting and planning in relation to inventory management. Although 5G-enabled inventory management application has not yet been implemented industry-wide, a survey conducted by an industrial organisation in Hong Kong found that over 40% of respondents are likely to invest in such applications.[80]

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[79] https://www.smefund.tid.gov.hk/english/tsf/deliverables/t20001026_researchreport_5G.pdf
[80] Ibid.

5.8 Properties and buildings facilities management

The properties and buildings facilities management industry in Hong Kong has seen an increasing trend towards adopting 5G-enabled applications in recent years. Focusing on providing higher quality of services and better operational management, the adoption of 5G-enabled applications may result in a 0.55% (i.e., HK$594 million) increase in GDP and a 0.25% (i.e., 433) increase in employment by 2027.

The general level of mobile-enabled technology adopted in the properties and buildings facilities management industry in Hong Kong is relatively high. Many property management companies have adopted mobile-enabled technology to improve operational efficiency and customer experience. However, according to the industry stakeholders, 5G-enabled applications and the corresponding benefits are still limited with most solutions still utilizing 4G or broadband with Wi-Fi connectivity.

Currently, some of the key 5G-enabled applications utilized in the properties and buildings facilities management industry in Hong Kong include smart building management systems, IoT sensors, and real-time monitoring systems. These advancements empower property managers to supervise and monitor building systems, such as heating, ventilation, and air conditioning (HVAC) and lighting, from a remote location and expediently address any problems that arise. The level of adoption of 5G-based applications does not vary significantly among small, medium, and large property management firms in Hong Kong. Instead, the degree of implementation and coverage is influenced by the size and intricacy of the properties.

According to stakeholders in the properties management industry, observed benefits brought by 5G-enabled applications in Hong Kong include increase of productivity and user experience. For example, real-time monitoring systems and smart building management systems enable the facility manager to quickly identify the issues, reducing downtime and improving tenants' satisfaction. IoT sensors for monitoring temperature and humidity and real-time energy monitoring system also provide tenants better indoor environment and assist facility managers to optimize energy efficiency and save energy cost. VR and AR technology is also developed for virtual tours and virtual properties management, which has played a key role for property transaction market during social distancing period.

Improving the efficiency of daily operations for buildings facilities management assists the industry tackling the challenge of shortage in manpower. The adoption of digital solutions allows the savings from routine tasks of building and property management. Safety for employees also gets improved with the application of robots for security patrol with real-time transference of actual building environment.

Potential obstacles in implementing 5G are comprised of regulatory hurdles, substantial expenses associated with R&D, and cautious attitudes among company leaders. The regulatory environment in Hong Kong can be intricate, posing a potential barrier to the swift adoption of novel technologies. Moreover, the considerable costs associated with R&D and deployment may discourage certain properties management firms from embracing 5G-based applications if the commercial benefits cannot be clearly articulated. Furthermore, the cost competitiveness of the industry means many property management companies may be hesitant to invest in new technologies unless the potential advantages are clear.

Examples of 5G use case

Smart building management

The implementation of 5G technology can facilitate the functioning of IoT devices, such as sensors and cameras, which can gather information on building usage, occupancy and energy consumption. This data can be analysed in real-time to enhance building performance, minimise energy consumption and enhance occupant comfort.

For example, a new commercial smart building coming up in Hong Kong will feature 5G-enabled solutions provided by CMHK. These solutions will enhance the visitor experience, operational and environmental efficiency of the building.[81]

Virtual property tours

5G can be applied to enable virtual property tours, allowing prospective tenants to explore properties remotely and in real-time. This can help to reduce the need for physical property visits and improve the efficiency of the rental process.

Real-time maintenance and repairs

The utilization of 5G technology can facilitate the instantaneous monitoring of building systems, such as HVAC and electrical systems, enabling maintenance teams to promptly detect and resolve issues as they occur.

Enhanced security and surveillance

5G can be applied to enable high-quality video surveillance and facial recognition technology, which can help to improve building security and reduce the risk of crime.

A local convention centre has deployed a smart robot that combines 5G network and AI technologies. It is equipped with a 360-degree 4K high-definition surveillance camera, infrared detection camera, and a sensor system for detecting smoke and fire.[82]

A drone company and CMHK have signed a Memorandum of Understanding with the aim of fostering 5G connectivity of drones used for applications such as infrastructure monitoring and surveillance.[83]

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[81] https://eshop.hk.chinamobile.com/en/about_us/media_centre/NewsPDF/20220622pr.html

[82] https://www.tw-media.com/international/hong-kong-convention-and-exhibition-centre-captain-c-robot-enhances-security-and-operational-efficiency-130823

[83] https://www.skydrone.aero/blogs/news/sky-drone-partners-with-china-mobile-hk-on-5g-innovation-project-for-connected-drones

5.9 Arts, entertainment and recreation

<table>
<tr><td colspan="2">The impact of 5G on the industry by 2027 against the 2027 Baseline View is:</td></tr>
<tr><td>+0.46% | HK$141 million
Increase in GDP</td><td>+0.20% | 162
Increase in employment</td></tr>
</table>

The art, entertainment and recreation industry in Hong Kong has seen an increasing trend towards adopting 5G-enabled applications in recent years. Focusing on providing higher quality of services and better operational management, the adoption of 5G-enabled applications may result in a 0.46% (i.e., 141 million) increase in GDP and a 0.20% (i.e., 162) increase in employment by 2027.

Hong Kong has a thriving art and entertainment industry, which was growing until 2019 before being impacted by social unrest and the pandemic. The infrastructure for art, recreation and entertainment in Hong Kong is diverse and dynamic and consist of a mix of public and private facilities such as museums, galleries, sports venues, performing venues. Diversified venue offerings have brought out a thriving art, recreation and entertainment industry.

Typically, art, recreation and entertainment activities require physical involvement of participants, which brings real and immersive experience. For example, museums display physical collections to the public in exhibition halls, and art festivals and events, such as concerts, performing or sports competitions, gather people in physical venues.

However, social distancing during the Covid-19 pandemic has changed the public behaviours and lifestyles. The demand for real time live streaming and virtual programmes with AR/VR technology suddenly burst. Museums started to launch virtual tour of exhibitions. Live concerts moved to online platforms. Benefits of 5G came to the vision field of the public. Ultra-high speed of data transmission by 5G network guarantees the smooth of online art activities, such as live concert and online auctions. Without capacity limitation of venues, more people are allowed to participate in the events, generating more revenue for event hosts.

5G-empowered technology also has the potential to revolutionize the theme-park entertainment industry by enabling new and innovative use cases that enhance visitor experience. 5G can support real-time queue management systems that allow visitors to know the wait times for rides and attractions, helping visitors plan their day more efficiently and reduce frustration of long queues. Location based services supported by 5G network allow visitors to navigate the park more easily and find information about rides, attractions and events in real-time.

For now, the network of local theme entertainment attractions is still likely based around 4G LTE to provide Wi-Fi and connectivity. But within the next few years, they will likely join other attractions in transitioning to 5G to stay competitive and offer the latest digital experiences for visitors.

Examples of 5G use case

Art tech empowered by 5G mobile broadband network
An art event was launched with digital platform and offline exhibitions to hold the event in a hybrid format to cater to the pandemic context. Its live platform includes various digital solutions, such as online viewing rooms, livestreamed videos, virtual tours, multilingual VIP

and public walkthroughs.[84] 5G service in the exhibition centre enables real time activities with high speed and low latency network.

5G themed interactive exhibition

SmarTone launched a 5G experience pop-up event. The exhibition consists of multiple zones spanning approximately 5,000 square feet. From smart homes, AI recognition, industrial safety devices to ultra-smooth e-Learning, it showcases a profusion of 5G applications with photo-worthy hotspots and exciting 5G experiences.[85] The spot offers both adults and children an opportunity to learn more about 5G and enjoy family fun together. Technology fans can also dive into innovative technologies in interactive games.

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[84] https://doc.irasia.com/listco/hk/hthkh/press/p220525.pdf
[85] http://web.archive.org/web/20230225171433/https://sky100.com.hk/en/more/experience/5g-lab/

5.10   Education

The impact of 5G on the industry by 2027 against the 2027 Baseline View is:

+0.42% | HK$161 million
Increase in GDP

+0.18% | 442
Increase in employment

Smart People, as one of the six smart pillars outlined in Smart City Blueprint 2.0[86], is proposed to nurture young talent by providing enhanced IT training to students through the provision of funding for the IT Innovation Lab in Secondary Schools programme. Investment in IT infrastructure at campuses is expected to increase in response to the Smart People initiative. In the education industry, 5G is adopted in an attempt to improve teaching efficiency and foster talent. Through 5G-enabled applications, the education industry is expected to have a 0.42% (i.e., HK$161 million) increase in GDP and a 0.18% (i.e., 442) increase in employment by 2027.

In response to the threat brought by the Covid-19, remote learning was implemented broadly using online platforms. This introduced many students to online classes and e-learning platforms. With the pandemic over, most of the learning has returned to the classroom, however many secondary and tertiary education facilities are utilizing hybrid online/in-person learning.

Stakeholders in the education industry have become more aware of the need to implement education technology (EdTech) and the role 5G can play in facilitating this. On the demand side, end users require stable network connections with low latency to run real-time classes, webinars, or online learning video programmes, and this can be easily realised by 5G. On the supply side, system integrators, hardware suppliers, MNOs and software developers are also investing and developing 5G-enabled EdTech solutions to cater the market.

Based on the projects completed in OFCA's Subsidy Scheme[87], 5G-enabled AR/VR technology is one of the key areas that Hong Kong companies are trialing new products. One example of the projects funded under the Subsidy Scheme involves AR/VR-based learning materials in a cloud-based server which is connected by a 5G network. This could enable students to use specially designed mobile applications and devices to access the learning materials. 5G-enabled live streaming platforms are also used for promotion of science via online workshops, sharing sessions and seminars. Apart from immersive learning experience by AR/VR headsets, 5G also enables interactive field trips, which allow researchers to timely upload data collected at field and conduct further analysis at labs, improving the overall efficiency.

Consultations with industry stakeholders indicate that 5G implementation at local school campuses is still limited as most of the campuses in Hong Kong are connected to internet through IT in Education, WebSAMS and Wi-Fi 900, which are all funded by the Government. Given the large number of connections required at the same time, IT specialists within the education industry indicated that Wi-Fi could prove a more reliable connection for mobile devices, at least for now. Nonetheless, the industry seems supportive of having 5G connections in schools for two main reasons: (1) to teach high-technology skills such as IoT; and (2) to serve as a backup connection, for areas not covered by Wi-Fi or for live broadcasting.

Aligning with other examples in Appendix B, the education industry in Hong Kong tends to experience greater social benefits than those of a purely economic nature from the adoption of 5G. Findings from the consultation show that the adoption of 5G in the education industry in Hong Kong may remain limited by 2027, with minor economic benefits being realised.

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[86] https://www.smartcity.gov.hk/vision-and-mission.html

[87] https://www.ofca.gov.hk/filemanager/ofca/en/content_1217/completedprojects.pdf

Examples of 5G use case

5G Campus Pilot School Initiative by CMHK[88]
In 2021, CMHK launched the 2nd "5G Campus Pilot School Initiative" with the theme of "Digital Campus", aiming to bring 5G technology into the 50 selected schools and enhance campus facilities and information technology. The initiative consists of 5G smart classrooms, 5G live classes, 5G AI e-learning platform and visits to 5G laboratories. Students can experience smart campus applications developed under the 5G concept and learn more about the future development of 5G. The 5G AI e-learning platform uses big data to track learning progress and help tackle students' learning difficulties in real-time.

5G Smart Hydroponic Planting System[89]
Consists of 4K cameras and sensors, 5G-enabled smart nurturing facilities allow students to monitor the plants on live stream. As part of the learning experience, the facilities equipped with AI to analyse the growing environment and provide advice on how to care for the plants. Similarly, 5G-enabled smart facilities are also available for raising animals, such as turtles in colleges. Supported by these 5G-enabled applications, increased knowledge retention and better understanding could be achieved.

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[88] https://eshop.hk.chinamobile.com/en/about_us/media_centre/NewsPDF/20210715pr.html
[89] https://www.smartoneholdings.com/about/media_centre/press_release/press/2022/11/2022_11_23_475.pdf

5.11 Smart utilities

The impact of 5G on the industry by 2027 against the 2027 Baseline View is:

+0.35% | HK$141 million
Increase in GDP

+0.15% | 23
Increase in employment

The key benefits of 5G in the smart utilities industry can be realised through automation and remote monitoring in both consumer-facing and back-end areas. This has the potential to improve operational efficiencies and productivity. However, the industry is hesitant to move many of its wired critical systems to 5G at this stage due to concerns over stability and data security. For this reason, the economic impacts are relatively modest compared to other industries. Through 5G-enabled applications, the smart utilities industry is expected to have a 0.35% (i.e., HK$141 million) increase in GDP and a 0.15% (i.e., 23) increase in employment by 2027.

The smart utilities industry is undergoing a number of changes, especially in the transformation to lower carbon energy generation, which often translates to more variable power supply and increase challenges to match demand and supply. According to Ericsson[90], 5G-enabled applications for utilities can improve utilisation of the generation infrastructure with real-time monitoring and early fault detection. This can be through a combination of robotic systems, drones and sensors to improve data collection and reduce human error, thereby preventing outages and creating a safer environment. On the demand management side, smart metering systems can enhance energy management with real time pricing assisting to smooth out demand peaks.

Globally, many jurisdictions have been proposing strategic plans for 5G based technology for the utility industry, advocating the industry to deploy 5G applications in daily operations. For example, European Commission released the Service Oriented Grid for the Network of the Future to encourage the industry to implement the application of deep intelligence techniques, industry grade data analysis and visualisation tools, advanced sensors, an advanced power measurement unit and 5G based ICT to provide fine grained visibility and control of power networks using end-to-end automation in a virtualised environment[91]. The National Development and Reform Commission (NDRC), the National Energy Administration, together with the Ministry of Industry and Information Technology of Mainland China also jointly published the Implementation Plan for 5G Applications in the Energy Field[92], encouraging the industry to develop 5G use cases that are replicable and easily applicable for the industry at large.

Through consultation with the industry stakeholders and MNOs, the adoption of 5G applications in the smart utilities industry remains limited. For example, electricity companies tend to use in-house wired communication systems through the generation and transmission assets. Given the criticality of these systems, companies are cautious about transitioning to a wireless network. Even though high level of security can be assured with the use of network slicing under 5G technology, a back-up plan in the event of critical situation and the costs of implementation will be two of the major concerns for companies adopting 5G. Even in the area of smart meters which require a wireless connection, data transmission rates are low so consultees suggested that LTE or 4G connectivity was sufficient.

Other constraints that hinder industry stakeholders to implement 5G include the heavy investment and unclear Return on Investment. Nonetheless, looking forward, the Government's Smart City Blueprint 2.0 depicts a smart Hong Kong with smart utilities empowered by 5G use

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[90] https://www.ericsson.com/4a651d/assets/local/enterprise/reports/connected-energy-utilities-report.pdf
[91] https://cordis.europa.eu/project/id/774613
[92] http://www.nea.gov.cn/2021-06/11/c_1310003081.htm

cases exclusive for the industry, such as connected EV charging stations, smart meters, and connected building energy management, etc. These initiatives are in the process of testing and implementation, and characteristics of 5G (URLLC and mMTC) will certainly play an important role as development continues. Therefore, most of the quantitative economic benefits from 5G in smart utilities may not be realised until after 2027.

Examples of 5G use case

Internal infrastructure monitoring

Low-band 5G frequencies have been adopted internationally by companies in similar industries to enable a high density of IoT sensors to transmit comprehensive environmental information in real-time at scale. This information has great benefits in enabling immediate analysis of the information provided regarding utility systems, such as water pipes and pumps. With 5G connecting the sensors and central data algorithms, a more rapid response to any flagged issues would be possible due to the high speed of 5G network.

6. Other Benefits of Adopting 5G

As mentioned in some of the industry use cases in Chapter 5, very often, the adoption of 5G-enabled applications has a significant impact on industries and society in terms of safety, environment and user experience. Apart from the economic impacts, this chapter highlights the other benefits of 5G on each selected industry and the overall economy of Hong Kong.

6.1 Safety

The adoption of 5G-enabled applications has helped improve safety via automation, connected cameras and sensors, as well as other tracking, detection and warning systems in Hong Kong.

5G implementation enables automation in many industries, improving accuracy and safety in industrial processes. Combining the use of 5G with AI systems, many tasks can be carried out with minimal human involvement, since the advanced algorithms can make use of the data collected from connected devices to produce precise analysis for the decision-making process. This can remove humans from dangerous situations altogether with improved warning systems. For example, the technology of AV relying on 5G also has positive implications for safety. 5G increase operational efficiency of public transport, and will improve pedestrian safety by decreasing unpredictable vehicle driving with precise coordination. Another example of automation is in the construction industry, where construction equipment can be connected through 5G, using IoT sensors to alert and avoid collisions or accidents onsite by reacting instantaneously to information transmitted through the network, relying on the high speed and low latency of 5G. These examples are currently being trialled in Hong Kong and have potential for industry-wide safety improvements if deployed across the industry.

Another application of 5G with safety implications is connected camera systems or similar data collection apparatus/devices. With these systems, safety can be enhanced due to the real-time transmission of footage, so any security breaches or emergencies can be responded rapidly. In the construction industry, CCTV transmitting live video to an analytics system can detect breaches of safety protocol or potential hazards, not only responding to incidents but also preventing potential dangers as well. Additionally, 5G connected surveillance systems provide even greater safety benefits if mobile devices, such as through connected drones, are used. This application is suitable for surveillance in a large area, such as outdoor concerts and sporting events.

A significant 5G use case for improving safety is a port company deployment of 5G at container terminals with HTCL, which has become the first 5G connected terminals in Hong Kong. Out of three pilot projects[93] involving 5G, the AI-powered CCTV security system with intruder detection features strengthens container terminal safety as well as security.[94] Since late 2022, this system has supported security at the gatehouse to reduce operating costs and improve safety performance.

6.2 Environment

The implementation of 5G provides opportunities to improve environmental monitoring and management, with high-level applications such as environment monitoring systems, video analytics systems and building connectivity.

5G brings many benefits on environmental monitoring and management, specifically the application of mMTC which is a 5G technology that can collect a large amounts of small data packets from a large number of devices (such as IoT sensors) simultaneously. It has useful

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[93] The three pilot projects include building a secure and reliable communications channel via 5G to control remote rubber-tyred gantry cranes and a CCTV system with AI intrusion detection features at the gatehouse to strengthen the terminals' security; and another CCTV system on quay cranes to monitor berth traffic and operations on vessels.
[94] https://www.hit.com.hk/en/Media-Centre/Press-Release/Hpht-Implements-5g-Technology.html

applications to monitor environmentally sensitive areas such as wetlands. The data transfers need to cover a wider area considering the environments observed may not have many 5G towers, making it most suited to low-band 5G. However, there is no indication of widespread use of 5G in Hong Kong at this stage.

5G connected video analytics systems can assist environmental protection. Fully connected sensors or video data allow more rapid response and better understanding of the issues faced, such as urban waste dumping. At disposal sites, garbage bin filling status can be monitored regularly through the use of 5G so that waste collection can be arrange promptly to prevent unnecessary use of refuse trucks. Additionally, another capability is monitoring the type of waste placed in the bin, sending alerts when the wrong category of waste is disposed (e.g., unclean food packaging disposed in recycling). This could be of particular use in Hong Kong with the introduction of the new Municipal Solid Waste Charging Scheme.

6.3 User experience

5G network connectivity brings great benefits on the aspect of user experience over many industries, such as through immersive VR/AR experiences, increased range of connectivity/remote activities, as well as AI and 5G integration. These may not be able to be quantified in terms of economic benefits, but they do improve the quality of the life for the people of Hong Kong.

Immersive experiences have been piloted in several industries. AR technology can support immersion into real life activities, due to relatively advanced 5G network rollout for smartphones and other devices. For example, AR lenses can create a shared experience for attendees in live events, and additionally allow them to commemorate the event with unique footage. Other applications include 5G broadcast events, using technologies such as VR on the consumer end to simulate a more engaging experience. For example, VR devices can allow for 360-degree views of a live or pre-recorded event, and 5G has both the low latency and high bandwidth to transmit the large amount of data required in near real-time. Additional immersive experiences can include content creation including art and music, with tools like motion capture, volumetric video capture, and AR/VR utilising 5G's large bandwidth to support data intensive files.

Additionally, 5G's improved quality in connectivity can provide many benefits on user experience. Consumers can enjoy high-speed internet connection on their journeys on public transportation with their current usage of 5G, thus creating a more pleasant experience for them through providing a wide variety of entertainment possibilities. Separately, event or exhibition broadcasts through 5G can provide hybrid platforms, which were utilized greatly during the pandemic. Viewers can use their own devices to receive livestreams of these events in high quality.

In the accommodation industry, increased levels of automation and advanced amenities provided to guests, such as smart rooms connected to mobile applications allowing for temperature or light control, or convenient room services deliveries, improved guest experience.

AI and 5G used in tandem are at the forefront of user experience innovation, with the high bandwidth and low latency supported by 5G enabling data transmission at the speed and quality necessary for effective AI utilization. In both food and accommodation industries in Hong Kong, smart robots have been implemented to improve the check-in experience in addition to performing room services delivery for hotel guests and other hotel chores, or by serving food in restaurants. The autonomous ability of the robot supported by AI decreases waiting time for customers.

7. International Benchmarking

Literature reviews were conducted to compare the estimated economic impact resulting from the implementation of 5G technology in Hong Kong with that of various overseas economies.

As one of the highly developed economies with a sophisticated telecommunications market, Hong Kong is expected to enjoy a relatively large economic benefit from the implementation of 5G. Based on estimates from Economic Model 1 and Economic Model 2, Hong Kong is expected to have a GDP impact of 0.71%. This places Hong Kong slightly below South Korea, estimated at 0.73%, and Japan, estimated at 0.78%, but above the UK, estimated at 0.57%. Table 8 below summarises the key information from published reports as well as internal research paper.

Table 8: Summary of the 5G's economic contribution to GDP in various economies

	Jurisdiction	Year	% GDP growth	5''s contribution to GDP (in billion)	Total GDP* (in billion)	Year of report issued	Approach
1	USA[95]	2028	0.90%	$ 198	$ 22,054	2021	Network infrastructure investment + use cases
2	China[96]	2027	0.49%	$ 100	$ 20,596	2021	Use cases
3	Japan[97]	2027	0.78%	$ 37	$ 4,753	2021	Use cases
4	South Korea[98]	2027	0.73%	$ 14	$ 1,913	2021	Use cases
5	India[99]	2027	0.44%	$ 20	$ 4,574	2020	Use cases
6	UK[100]	2025	0.57%	£ 13	£ 2,285	2020	Network infrastructure investment + use cases
	Hong Kong	2027	0.71%	HKD 22.0	HKD 3,095		Network infrastructure investment + use cases

*GDP forecast based on Oxford Economics.

Despite the variation in 5G adoption rates, the different economic impacts contributed by 5G can primarily be explained by two factors: 1) the approach and methodology of each study, and 2) the economic composition of each economy.

Among the studies, different methodologies are identified. In the cases of the USA, China, Japan, and South Korea, economic activities utilizing 5G are captured without distinguishing the specific economic impact attributed only to 5G. Meanwhile, in the cases of China, Japan, and South Korea, the estimation of 5G economic impact was assessed based on the potential impacts of 5G applications alone. It is worth noting that the economic impact from direct investment is relatively small and, thus, should not significantly affect the results for the purpose of benchmarking.

In addition, as discussed earlier, Hong Kong has a unique economic composition, with a focus on financial services, transport and logistics, and professional services, with limited or no mining,

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[95] https://api.ctia.org/wp-content/uploads/2021/01/5G-Promises-Massive-Job-and-GDP-Growth-in-the-US_Feb-2021.pdf

[96] https://www.pwc.com/gx/en/industries/technology/publications/economic-impact-5g.html

[97] Ibid.

[98] Ibid.

[99] https://www.gsma.com/spectrum/wp-content/uploads/2020/11/mmWave-5G-in-India.pdf

[100] https://newscentre.vodafone.co.uk/app/uploads/2020/06/Vodafone-5G-Report-final.pdf

manufacturing, and agriculture activities. Due to this distinct economic composition, the implementation of 5G would be expected to be slightly lower in Hong Kong than economies such as Japan and South Korea, which have substantial manufacturing sectors.

The results for the USA, with an estimated GDP growth of 0.9%, were estimated using a slightly different methodology by including all economic activities related to 5G. Therefore, the USA result is not directly comparable to those of Hong Kong. In contrast, based on the report issued in 2021, China is expected to have a relatively lower economic impact, with an estimated GDP growth of 0.49%. However, considering the forecast of CNY1.2 trillion direct 5G network investment by 2025[101] and China's economic structure, it is anticipated that 5G would make a higher economic contribution in terms of GDP. Nonetheless, with limited details provided in the report and a lack of other publicly available information, the comparison between Hong Kong and China might not be valid.

It is worth noting that each study was conducted based on the available information at the time, and the estimation of the scale of benefits may be uncertain, depending on factors such as support from local government, network operators, and industry players, the overall economic environment, and other key assumptions. In the context of this Study, the 5G contribution to the economy of Hong Kong, i.e., 0.71% increase in GDP, aligns broadly with its position relative to the other economies mentioned.

[101] https://global.chinadaily.com.cn/a/202208/13/WS62f6eabca310fd2b29e71f2a.html

8. Conclusions

5G not only has the potential to deliver higher data download and upload speeds, but also enable a range of new applications and solutions. Aggregating the potential economic impacts arising from 5G use cases, i.e., the result of Economic Model 1, and the economic impacts brought about by 5G infrastructure investments, i.e., the result of Economic Model 2, 5G is expected to create an addition of HK$22.0 billion GDP and 13,619 jobs to Hong Kong's economy.

Under Economic Model 1, the proportion of 5G subscriptions in Hong Kong is estimated to reach 60% by 2027, based on current views from industry players, MNOs and telecommunications equipment suppliers, and the projection from the Ericsson Mobility Report. Based on the economic analysis outlined in Chapter 4, this level of 5G adoption would contribute a 0.66% (i.e., HK$20,544 million) increase in GDP and a 0.30% (i.e., 11,317) increase in jobs to be created. With continuous efforts from the Government and different parties across industries, the proportion of 5G subscriptions could significantly increase when 5G-enabled applications get mature and evolve over time.

As illustrated in Figure 10, the construction industry is expected to experience the highest percentage increase in GDP (i.e., 1.42%, equivalent to HK$1,482 million) among the 11 selected industries, followed by the transportation and logistics industry with a 1.32% increase (equivalent to HK$4,086 million). This is mainly due to the positive industry outlook for 5G rollout, with off-site construction, IoT and robotic applications, and other 5G-enabled applications in these two industries. For the purpose of the Study, marginal economic impact is assumed for other services, which includes agriculture, fishing, mining and quarrying, manufacturing, import and export trade, professional and business services, public administration, ownership of premises, as well as other service activities.
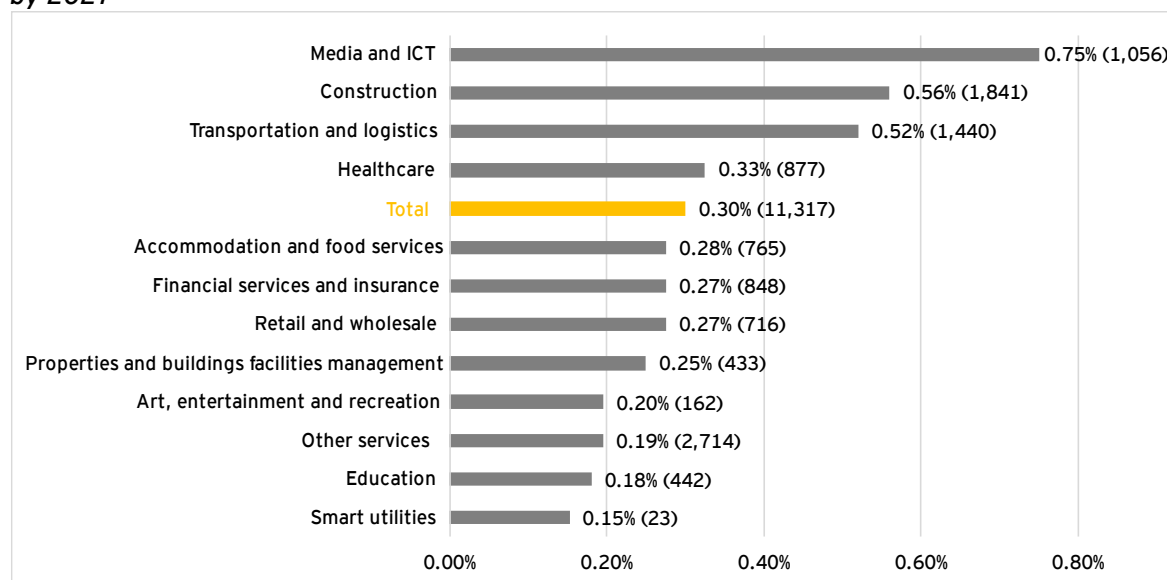
Figure 10: Increase in GDP in each of the selected industry due to 5G adoption by 2027
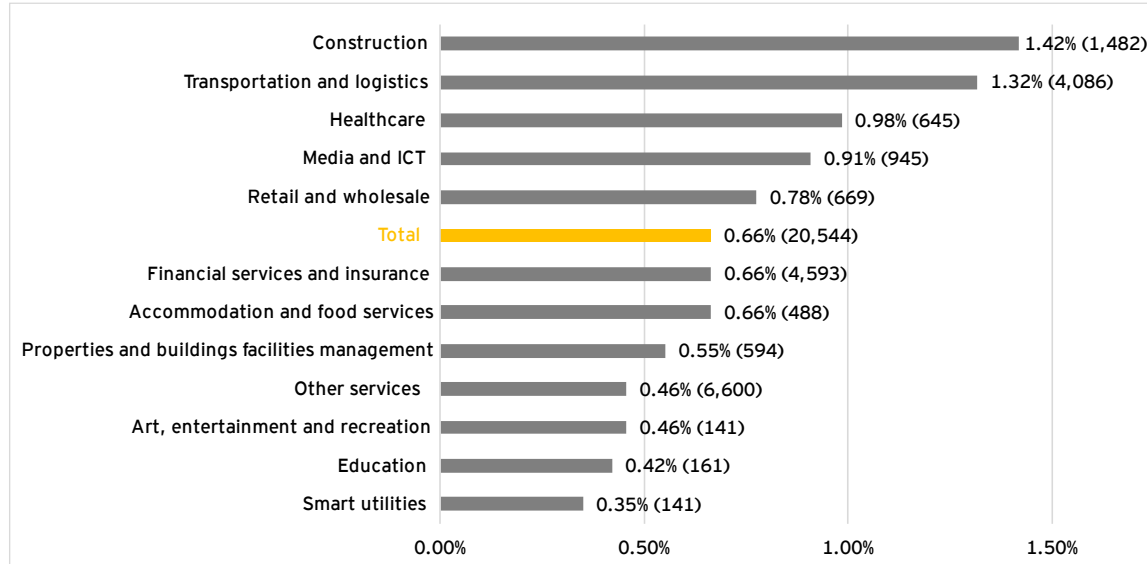
*The value of increase in GDP is presented in the bracket (in HK$ million).

The estimated net change in number of jobs is illustrated in Figure 11. The media and ICT (i.e., 0.75%, equivalent to 1,056 jobs), construction industry (i.e., 0.56%, equivalent to 1,841 jobs) and transportation and logistics industry (i.e., 0.52%, equivalent to 1,440 jobs) are expected to have the most additional employment as they are significantly sized industries in Hong Kong and will likely see large adoption of 5G technologies. Both industries will require additional employments to operate and maintain 5G-enabled applications. Due to labour shortages, it is unlikely to decrease working level staff even if 5G increases labour productivity.

Figure 11: Net change in the number of jobs in each of the selected industry due to 5G adoption by 2027

Industry	Net change
Media and ICT	0.75% (1,056)
Construction	0.56% (1,841)
Transportation and logistics	0.52% (1,440)
Healthcare	0.33% (877)
Total	0.30% (11,317)
Accommodation and food services	0.28% (765)
Financial services and insurance	0.27% (848)
Retail and wholesale	0.27% (716)
Properties and buildings facilities management	0.25% (433)
Art, entertainment and recreation	0.20% (162)
Other services	0.19% (2,714)
Education	0.18% (442)
Smart utilities	0.15% (23)

*The number of jobs created is presented in the bracket.

Under Economic Model 2, with an estimated capital investment of HK$1,623 million per year over the next five years, 5G infrastructure investment expects to contribute a 0.05% (i.e., HK$1,449 million) in GDP and a 0.06% (i.e., 2,302) increase in jobs to Hong Kong's economy in 2027.

Although a positive outlook for Hong Kong's 5G uptake is expected, the rollout of 5G network is facing several challenges to widespread adoption. As mentioned earlier, these challenges include a lack of industry awareness of the benefits of 5G network and hesitancy in offering 5G-only services and applications.

At the time of writing this report, it is well-known that 5G network can provide higher speed and lower latency compared to 4G or Wi-Fi. However, having no solid evidence in justifying the actual benefit of 5G-enabled applications beyond speed, many companies across industries are reluctant to adopt 5G or invest in exploring 5G solutions and conducting trials to examine the impact.

While the basic infrastructure in Hong Kong is available for the use of 5G technology, the low demand of 5G-only services at the current stage has prevented the vendors or solution providers from upgrading or provide more advanced handsets, equipment and applications in large scale. This has led to a limited availability of 5G-specific solutions in the market.

The density of base stations is also crucial for ensuring the efficiency of 5G networks. This means that MNOs need to locate and negotiate a significant number of base station locations throughout Hong Kong. This has created challenges in deploying 5G network in some areas, especially the rural areas, potentially impacting the overall efficiency and effectiveness of the network.

To realise the benefits of 5G, the Government can play a critical role to mitigate these challenges. For example, multiple funding schemes have been put into places by the Government to promote the adoption of 5G and co-fund industry pilot projects. In addition, the Government can promote the benefits of 5G to consumers and industries and continue to make available government facilities for base station at nominal rents. It may take several more years before the majority of industry players roll out 5G applications more broadly. However, with continued support to test new use cases, Hong Kong can achieve the estimated economic impacts by 2027.

Appendix A   Methodology and Reference

A1. Approach and methodology on Economic Model 1

<u>Bottom-up Approach</u>

Economic impacts are estimated by the incremental impact on GDP between the base case scenario and the 5G impact scenario. To quantify the 5G impact, the following assumptions were obtained through industry consultations and literature review and applied to the model:

- ▶ Proportion of 5G subscriptions by 2027

- ▶ Labour cost savings delivered through implementing 5G technologies

- ▶ Change in ratio of labour to non-labour costs in each industry

- ▶ The impact of 5G technologies on job creation

- ▶ The change in proportion of low, semi, high skilled labour due to the adoption of 5G technologies

Consultations with MNOs, industry associations and major companies in the selected industries were conducted to collect detailed information and insights of the industry. Literature reviews on international 5G use cases and research papers were undertaken to gain a better understanding of the 5G technologies and the 5G-enabled applications. The input assumptions for the modelling a based on all the information sources, in an attempt to reflect the actuation situation in Hong Kong as closely as possible.

Assumptions and inputs adopted for Economic Model 1 are summarized in Table 9 and Table 10 below.

Table 9: Economic assumptions

Assumption	Index for real GDP growth from 2021 to 2027	Index for employment growth from 2021 to 2027	Skill Mix (%) (High)	Skill Mix (%) (Semi)	Skill Mix (%) (Low)
Construction	0.95	1.01	28%	52%	20%
Transportation and logistics	1.54	0.93	40%	49%	11%
Healthcare	1.21	1.15	36%	30%	34%
Media and ICT	1.05	1.06	40%	49%	11%
Retail and wholesale	1.23	0.91	41%	54%	6%
Financial services and insurance	1.18	1.07	79%	19%	1%
Accommodation and food services	1.62	1.12	13%	73%	13%
Properties and buildings facilities management	1.01	1.05	20%	74%	6%
Art, entertainment and recreation	1.11	1.10	36%	30%	34%
Education	1.06	1.11	36%	30%	34%
Smart utilities	1.10	1.03	44%	37%	18%
Overall	1.13	1.03	41%	41%	18%
Source	*Oxford Economics*	*Oxford Economics*	*C&SD*	*C&SD*	*C&SD*

Table 10: 5G impact assumptions*

	Labour productivity improvement	Job creation	Proportion of 5G subscriptions
Construction	2.00%	0.80%	70.00%
Transportation and logistics	2.00%	0.80%	65.00%
Healthcare	1.50%	0.50%	65.00%
Media and ICT	1.20%	1.00%	75.00%
Retail and wholesale	1.40%	0.50%	55.00%
Financial services and insurance	1.20%	0.50%	55.00%
Accommodation and food services	1.20%	0.50%	55.00%
Properties and buildings facilities management	1.10%	0.50%	50.00%
Art, entertainment and recreation	0.70%	0.30%	65.00%
Education	0.70%	0.30%	60.00%
Smart utilities	0.70%	0.30%	50.00%
Other services	0.70%	0.30%	65.00%

*Assumptions are estimated based on consultations, survey results and literature review on similar studies.

Base Case scenario

In order to estimate the potential impact of the 5G by 2027, it is necessary to first forecast the size and structure of the Hong Kong with no development of 5G, i.e., the 2027 Baseline View. This is referred to the 'business as usual' or 'base case' scenario. In order to do this, the following activities are performed:

▸ Collation of historical, current, and forecast GDP and its component parts, employment, and population using data from a range of sources. These sources include Oxford Economics, the C&SD, and other external data sources.

▸ The current GDP and employment figures for Hong Kong already incorporate some benefits of 5G technologies that have been deployed in Hong Kong. After the consultations with MNOs, technology integrators and key industry players, even though 5G services has been launched for three years, the adoption of 5G is mostly limited to the consumer market through mobile network connectivity, with limited benefits realised from other economic sectors. Therefore, the base case scenario for year 2021[102] has not been adjusted to reflect current impacts and it is considered as an approximation of having no development of 5G.

▸ Forecast out to 2027 and will include some assumptions for technological evolution (either implicitly or explicitly) and improvements in efficiency and productivity as a result.

5G impact scenario

5G impact scenario of the economy by 2027 is modelled by factoring the impact of 5G adoption into the base case scenario. The economic impacts of 5G adoption used the following input variables:

▸ Increase if output for each industry driven by improved labour productivity from adopting 5G technology. Given the tight labour market in Hong Kong, all labour productivity improvements were assumed to lead to increased output, rather than constant output with lower labour input costs.

▸ Proportion of 5G subscriptions out to 2027 – based on industry consultation and 3rd party forecasts.

▸ Job creation to fulfil the technical skills required to implement and maintain 5G applications.

The outputs of the economic model were changes in GDP and jobs across the 11 selected industries by 2027.

The economic impacts created due to the adoption of 5G are illustrated in Figure 12 below.

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[102] The most updated available data for conducting the modelling for the Study.

Figure 12: Illustration of 5G impact on GDP
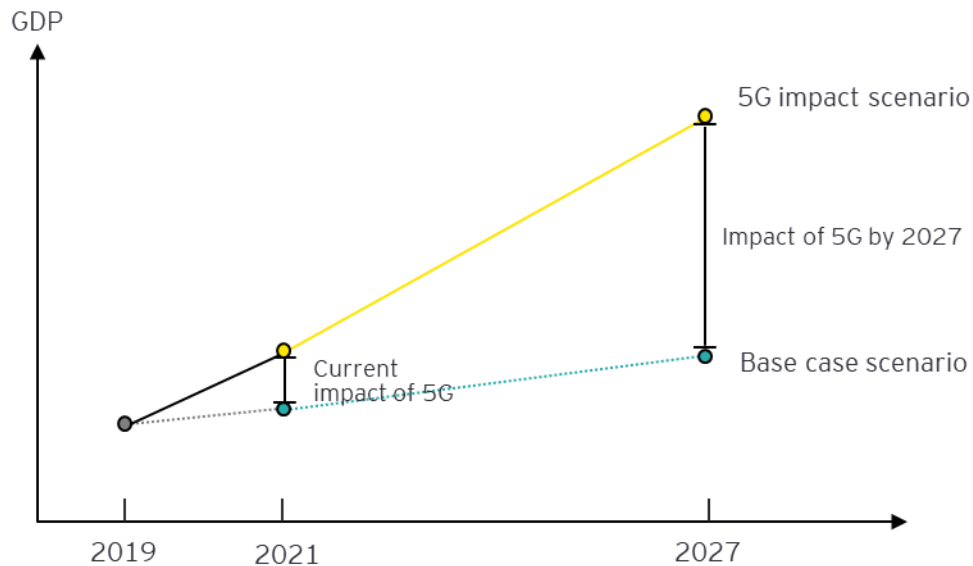
Top-down Approach

The economic impacts modelled are cross-checked using a top-down approach. With reference to a GSMA study conducted by Bahia, K., Castells, P. and Pedros, X. (2020) on global rollouts of 2G, 3G and 4G conducted in 2020.[103] This study showed that significant economic impacts were observed where mobile connectivity is first available. The study showed that for every 10% increase in mobile adoption, there will be 1% increase in GDP on average. When transitioning between 2G to 3G and 3G to 4G, there are still incremental benefits to GDP but considerably smaller than the initial benefit of mobile connectivity. As a result, based on over 20 years of historic data, the GSMA study derived a GDP impact of 0.08%-0.2% for every 10% increase in 4G connectivity from 3G. Taking into consideration that Hong Kong is one of the highly developed economies with over 200% of mobile subscriber penetration and proportion of 4G subscriptions of over 80% by the end of 2021, conservatively, an assumption of 0.5% increase in GDP for the full rollout of 5G has been estimated based on the analysis from the GSMA study. This is considered a conservative estimate for two reasons: firstly, it takes a lower end of the estimate range and secondly, the potential impacts of the transition from 4G to 5G could be significantly more transformational than the move from 3G to 4G.

$$Total\ Benefit_t = GDP_t * (\alpha_t - \alpha_{t-1}) * \beta$$

Where $t = time$

$\alpha = 5G\ penetration\ rate$

$\beta = 5G\ productivity\ impact, the\ impacts\ per\ connection\ on\ GDP\ = 0.5\%$

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[103] https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=54165922&file=121120-working-paper.pdf

A2. Approach and methodology on Economic Model 2

Economic benefits brought about due to investment in 5G network infrastructure are estimated based on the direct impacts and the supply chain impacts associated. Direct impacts are driven directly by the 5G network infrastructure investment. Supply chain impacts are driven by the indirect and induced activities across the whole supply chain of the 5G network infrastructure. Indirect impacts are generated when an industry purchases input goods and services, generating revenue for other businesses. Induced impacts are generated when an industry's employees spend their wages and salaries on household consumption, providing revenue for other businesses.

The Study relies on the Hong Kong Input-Output tables generated by OECD, to calculate indirect and induced economic multipliers.

In input-output tables, there will generally be four multipliers generated – output, GDP, income and employment. For the purpose of evaluating the capital expenditure for deploying 5G network infrastructures and its economic contribution to Hong Kong's economy, the Study focuses on the multipliers for GDP and employment for the economic impacts on the overall economy in Hong Kong.

In order to utilise the multipliers from the input-output table, the spending on 5G infrastructure is categorized into OECD industry classifications.[104] Based on the nature of the capital expenditure concerned, the following OECD classifications are identified for this Study:

- ▸ 41T43: Construction

- ▸ 26: Computer, electronic and optical products

- ▸ 27: Electrical equipment

- ▸ 61: Telecommunications

To obtain the direct, indirect and consumption industry multiplier to obtain a result. These direct impacts on industries will be used to calculate indirect impacts on downstream industries using the economic multipliers derived from input-output tables. Specifically,

$$Indirect\ (industrial)\ impact \\ = expenditure\ within\ industry\ *(indirect\ multipler - direct\ multiplier)$$

$$Induced\ (consumption)\ impact \\ = expenditure\ within\ industry\ *(induced\ multipler - indirect\ multiplier)$$

Unlike the economic impacts estimated by Economic Model 1, the impacts of investing in 5G network infrastructure do not accumulate over time, meaning that annual benefits are measured. The benefits only continue as long as the infrastructure investment continues. Another consideration for Economic Model 2 is that the level of infrastructure spending is expected to remain consistent from 2021 and 2022 levels to 2027. Therefore, the current Hong Kong GDP figures already capture the contribution for 5G infrastructure investment, as do the 2027 Baseline View used for Economic Model 1. Since it is already factored into the 2027 Baseline View, the result obtained from Economic Model 2 are not presented as potential increments in GDP or jobs by 2027. By deducting the Economic Model 2 results from the 2027 Baseline View, an approximation of the GDP or number of jobs could have been without any 5G infrastructure investment at all can be derived.

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[104] https://www.oecd.org/sti/ind/2stan-indlist.pdf

The economic contribution due to 5G network infrastructure investment estimated using Economic Model 2 include the following

▸ The incremental impact on GDP on an annual basis

▸ The incremental impact on employment supported on an annual basis

It is worth noting that, the latest release of OECD Input-Output tables was issued in 2021 with the latest information up to 2018.[105] Therefore, the 2018 Hong Kong input-output tables have been used for this analysis. The multipliers calculated are based on the relationship between different sectors of the economy per dollar of output. As the multipliers are based on the relationships between industry (how much of industry x's output is used by industry y), the nominal values used in the input-output tables are not critical, the important element is the economy structure. As high-income, developed economies such as Hong Kong have relatively stable industry structures, it is common that some statistics departments internationally only update the tables every 4 to 5 years. Therefore, it is not considered to be an issue to utilize input-output tables up to 5 years old.

The OECD multipliers adopted for Economic Model 2 are summarized as Table 11 below.

Table 11: OECD multipliers

	41T43: Construction	26: Computer, electronic and optical products	27: Electrical equipment	61: Telecommunications
GDP				
Direct	0.4	0.3	0.4	0.6
Indirect	0.7	0.5	0.5	0.8
Induced	1.1	0.8	0.7	1.0
Employment				
Direct	1.0	0.5	0.8	0.6
Indirect	1.6	0.9	0.9	0.9
Induced	2.2	1.2	1.2	1.2

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[105] https://stats.oecd.org/Index.aspx?DataSetCode=IOTS_2021

A3. Results from Economic Model 1

The results derived from Economic Model 1 are summarised in Table 12 below.

Table 12: Summary of economic impacts created due to adoption of 5G by 2027

Economic Model 1	Base Case		5G Impact		Net Impact on GDP (incremental)		Net Impact on Job (incremental)	
	GDP (HK$MM)	Job (No.)	GDP (HK$MM)	Job (No.)	HK$MM	%	No.	%
Construction	104,375	328,699	105,857	330,540	1,482	1.42%	1,841	0.56%
Transportation and logistics	310,210	276,889	314,296	278,329	4,086	1.32%	1,440	0.52%
Healthcare	65,479	269,749	66,124	270,626	645	0.98%	877	0.33%
Media and ICT	104,049	140,761	104,994	141,817	945	0.91%	1,056	0.75%
Retail and wholesale	86,173	260,456	86,841	261,172	669	0.78%	716	0.27%
Financial services and insurance	691,347	308,486	695,940	309,334	4,593	0.66%	848	0.27%
Accommodation and food services	73,484	278,093	73,972	278,858	488	0.66%	765	0.28%
Properties and buildings facilities management	107,359	173,360	107,953	173,793	594	0.55%	433	0.25%
Art, entertainment and recreation	30,795	82,938	30,936	83,100	141	0.46%	162	0.20%
Education	38,077	245,348	38,238	245,790	161	0.42%	442	0.18%
Smart utilities	40,010	15,124	40,150	15,147	141	0.35%	23	0.15%
Other services	1,444,035	1,392,003	1,450,635	1,394,717	6,600	0.46%	2,714	0.19%
Overall (Bottom up)[1]	3,095,393	3,771,906	3,115,936	3,783,223	20,544	0.66%	11,317	0.30%
Overall (Top down)[2]	3,095,393	3,771,906	3,110,870	n.a	15,477	0.50%	n.a	n.a

Note: [1]Overall (Bottom-up) sums up the economic impacts of the 11 selected industries and other services estimated using a bottom-up approach at industry level

[2]Overall (Top-down) is the economic impacts on the overall economy of Hong Kong estimated by assuming 0.5% for the full rollout of 5G based on the analysis from the GSMA study

*Numbers may not add up due to rounding

Appendix B   Literature Review

In this chapter, literature review based on international use cases is conducted to assess the quantifiable impacts that 5G use cases could have on each of the selected industries and the overall economy.

B1. Summary of 5G use cases

Table 13 below summarises the 5G use cases in Hong Kong and globally, focusing on the selected industries. Use cases highlighted in the column of "Use case example" are identified in Hong Kong.

Table 13: Summary Table of Use Cases

Industry	Application area	Use case example
Financial services and insurance	In-branch experience	Next-gen bank branches, Popup branches
	Telebanking	Interactive customer service, Virtual bank visits, Financial inclusion, Video conferencing, Next-gen ATMs
	Transaction processing	Security
	Facilitating payments	Facial recognition, Payments through wearables
	Product discovery and marketing	Immersive marketing
	Product personalization	Insurance underwriting, Usage based premium setting, Pay as you use / need insurance, Hyper-personalized offerings
	Backend processes	Detecting fraudulent insurance claims, Automated insurance claim processing, Facilitating large / complex transactions
	Stock trading	High frequency trading
Construction	Site design	Holographic blueprints, 3D models
	Smart construction	Remote site inspection, Remotely managed / autonomous construction equipment, Construction site safety / security, Supply chain visibility, Synchronized 3D printing
Education	Access to learning	Remote learning / holographic telepresence, Assisted learning for the visually impaired
	Learning outcome	Immersive learning, Tailored learning
	Smart campus	Immersive learning and facility maintenance
	Administrative tasks	Attendance monitoring, Online proctoring
Healthcare	Telemedicine	Remote patient monitoring, Remote physician / family visits, Virtual consultations / telemedicine
	Teleassistance	Remotely guided / robotic surgery, Remote diagnosis
	Emergency care	Connected ambulances
	Telecare	Medical rehabilitation / therapy, Chronic disease monitoring
	Analytics aided decision making	Clinician decision support, Video analytics for behavioural recognition
	Patient assistance	Virtual assistant for in-patients, Telenavigation for the visually impaired
	Medical imaging	Remote collaboration, Therapy planning
	Clinician training	Immersive learning
	Hospital administrative and housekeeping tasks	Automated handling of medical waste, Drone deliveries of medical supplies, Asset tracking in hospitals, Search and rescue of missing patients
	Digital fitness	Immersive training

Industry	Application area	Use case example
Smart utilities	Smart city / utilities	Power grid monitoring / power balancing, Power grid maintenance / repair, Water quality monitoring, Water loss / leak detection, Waste management
Transportation and logistics	Smart ports	Operations management, Autonomous container trucks, Remotely operated / semi-autonomous cranes, Precision positioning / asset tracking, Predictive maintenance, Port safety, Security
	Autonomous / tele-driving	Remote controlled vehicles, Platooning, Self-driving
	Automotive infotainment and telematics	Navigation, Over-the-air updates
	Connected vehicles	Pedestrian and passenger safety
	Smart warehouses	Managing warehouse operations, Automated storage and retrieval
	Traffic safety and flow	Public transport, Smart traffic lights, Parking management
Retail and wholesale	Supply chain management	Last-mile delivery, Inventory management, Quality monitoring, Supply chain visibility, Product traceability
	In-store experience	Holographic mannequins, Self-service, In-store assistance, Immersive retail, Smart mirrors, Endless aisles, Adjusting store layouts
	Administrative tasks	Store security, Immersive training for employees
	Fashion and apparel	Immersive fashion
Properties and buildings facilities management	-	Facility management
Media and ICT	Gaming	Cloud gaming, Immersive games
	Sporting events	In-stadium experience, At-home experience
	Broadcasting	Emergency broadcasts, Live events
	Remote / hybrid work	Enterprise connectivity, Immersive meetings
	Metaverse / extended reality	Immersive experience
	Cinema and television	Transfer of movie files, Immersive experience
	Production	Immersive content
	Digital advertising	Immersive ads, Geo-targeted ads
Accommodation and food services	Guest amenities	Immersive / interactive experience, Concierge robot, Personalized experience, Real-time social media / website updates, Office on demand
	Site operations	Automated equipment, Inventory management / asset tracking, Housekeeping / predictive maintenance, Security / safety
Art, entertainment and recreation	Fine / performing arts	Immersive theatre / concerts, Collaborative music, Immersive art exhibitions, Robotics
	Tourism	Immersive experience, Visitor forecasting / travel planner
	Theme parks	Immersive experience

Source: EY Research

B2. Quantifiable impacts on use cases at industry level

With reference to the list of use cases summarized in section B1 above, quantifiable impacts of 5G technologies at the industry level across various economies are reviewed.

Financial services: Various benefits from 5G in several use cases can be realised, including a use case trial performed in India, which recorded a faster data download by 10-20 times due to 5G

low latency time[106], demonstrating 5G use in banking applications. In Europe, a project was developed to provide customised 5G solutions for the banking industry – the project included use cases such as 5G low latency cloud storage and virtual visit of co-working spaces using VR and edge computing technologies.[107] These uses of 5G allowed for zero-delay communication and increased quality of video conference between bank offices. Due to the international nature of Hong Kong's financial and banking industry, utilisation of 5G's low latency and high speed in communication technology could lead to improved connections with international players, creating valuable business opportunities.

Construction: 5G was incorporated in a use case in Singapore[108] wherein robots with the capability to scan construction site progress were connected by a 5G and edge computing network. The robots utilized 3D scanning, CCTV cameras supplying footage to image recognition software, drones, and AR headsets. This results in 30-40% improvement in productivity on construction projects. Implementing 5G connectivity to update the technology used in Hong Kong's construction could yield similar improvements in productivity and potentially aid in advance warning systems.

Education: Video conference and virtual systems e.g., cloud storage supported by 5G could provide great benefits and improve the productivity and capabilities of the industry. Another use case in Singapore was developed by exploring applications of IoT and 5G in use of drones and patrol robots to improve operational efficiency in management of outdoor campus facilities.[109] This has resulted in a 70% reduction in time needed to inspect building facades through 5G-powered drones and AI.[110] In Hong Kong's education industry, improved video conferencing could provide a boost to the already significant private tutoring industry.

Healthcare: Use cases of 5G include the UK's NHS which has experienced tangible benefits. In a use case as part of the Future Wireless Project Trials, the NHS has deployed a mobile health clinic utilizing 5G networks to connect screening technology on board with doctors to enable remote real-time consultation and diagnosis of diseases such as tuberculosis, Hep B & C, or HIV.[111] The project screens around 10,000 vulnerable people yearly. Additionally, another firm conducted a 'Smart Ambulance' use case trial a with focus on rapid treatment; the project upgraded standard ambulances to allow paramedics to receive guidance on treatment during transport, acting uniquely as remote consultation rooms.[112] Its 5G connectivity research on healthcare estimates that widespread adoption of wearable monitoring devices will save £463m per year in cities in the UK, and decrease overall bed occupancy rates by 6%.[113] In Spain, one of the largest hospital groups utilises 5G networks and AR technology in digestive endoscopy surgeries, allowing 100 doctors from international backgrounds to attend the surgery session live.[114] Hong Kong's healthcare industry can apply 5G to combat the city's unique pain points, such as remote telehealth to support elderly patients with limited mobility.

[106] https://www.airtel.in/press-release/12-2022/5g-in-healthcare-airtel-apollo-hospitals-aws-carry-out-indias-first-5g-driven-artificial-intelligence-guided-colonoscopy-trial

[107] https://www.telefonica.com/en/communication-room/santander-and-telefonica-develop-together-the-first-5g-use-cases-of-the-banking-sector-in-europe/

[108] https://www.gsma.com/5ghub/construction

[109] https://www.zdnet.com/article/singapore-university-to-tap-iot-5g-in-smart-campus-trial/

[110] Ibid.

[111] https://digital.nhs.uk/about-nhs-digital/corporate-information-and-documents/nhs-digital-s-annual-reports-and-accounts/nhs-digital-annual-report-and-accounts-2021-22/it-operations-what-we-did-in-2021-22; https://www.digitalhealth.net/2022/03/find-and-treat-tackling-diseases-london/#:~:text=The%20E2%80%98Find%20and%20Treat%E2%80%99%20van%20is%20part%20of,and%20referrals%20on%20board%20the%20mobile%20health%20unit

[112] https://static-www.o2.co.uk/sites/default/files/2020-03/O2_Business_Smart_Ambulance_5G_0220.046_0.pdf

[113] https://www.cambridgewireless.co.uk/media/uploads/files/Smart-Cities-Report.pdf

[114] https://www.telefonica.com/en/communication-room/quironsalud-malaga-hospital-and-telefonica-present-the-first-system-of-expert-remote-assistance-to-surgeries-based-on-5g-and-the-integration-of-medical-data-through-augmented-reality/

Utilities: The Shenzhen Power Supply Bureau deployed video surveillance for power transmission lines, harnessing 5G's low latency and fast speed to monitor operating sites in real-time with HD video backhaul.[115] There was a 30% reduction in system costs due to real-time alerts with higher accuracy and efficiency.[116] Over 2,000 online video monitoring devices were installed to achieve full coverage of transmission line conditions.[117] In the UK, a water supply company utilized NB-IoT technology for its intelligent water distribution network, analysing the data collected to send alerts in case of any issues, reducing water leakage by 15% in three years.[118] The use cases mentioned above demonstrate potential examples of 5G application in the utility industry. The monitoring and analysis systems in these use cases supported by 5G could equally be applied to the property and building facilities industry in Hong Kong to operate utility assets in their facilities.

Transport and logistics: In UAE, 5G capabilities were delivered to selected warehouses[119], creating significant time and cost savings: 25% increase in warehouse operational efficiency, 20% increase in inventory turnover, 30% reduction in production and shipment time, and 20% reduction in manpower deployed. In South Korea, autonomous self-driving carts were launched utilizing 5G's low latency to analyse operating conditions, reducing employees' travel range for inventory transportation by 50% at the distribution centre of a South Korean telecommunications company.[120] A port operation company in Mainland China implemented 5G-powered navigation system and intelligent driving platform, allowing containers to be transported unmanned.[121] 76 unmanned trucks operate between the port and container yard, resulting in 20% less energy consumed by containers, 20% more efficient cranes due to remote controlled system, and significantly improved operational efficiency.[122]

Retail and wholesale: 5G use cases in the retail and wholesale industry are diversified. A telecommunications company demonstrated 5G-based interactive holograms that offer customers an engaging and entertaining way to learn about products.[123] it developed a holographic human that twirls and poses just like a showroom model, has already been adopted by one of the luxury fashion brands and is currently being rolled out across its flagship stores for the 2023 season's collections.[124] This is a showcase of 5G-empowered solution that enables the brand new shopping experience for customers. Also, 5G makes the self-service store a reality. In Singapore, 5G-enabled unmanned, self-serve pop-up stores enable consumers to check out phones, sign up for phone plans through video-assisted self-service kiosks, pick up their online orders, and pay their bills among other things.[125] In these stores, customers can interact with staff through a roving live robot[126]. Retailers in Hong Kong can also attempt to develop self-serve stores to save labour cost or cope with situations that may limit social distancing.

Properties and buildings facilities management: Announcing in early 2022, the country's first smart green corporate tower in Malaysia will be constructed. The tower will be outfitted with 5G internet-enabled cameras and sensors to monitor the environment, energy consumption, and

[115] https://www.cio.com/article/217663/china-southern-power-grid-energy-supply-gets-smart-with-ai.html
[116] Ibid.
[117] Ibid.
[118] https://www.mobileuk.org/news/5g-set-to-revolutionise-how-we-tackle-the-climate-change-challenge
[119] https://www.thefastmode.com/technology-solutions/28208-du-partners-with-huawei-sinotrans-to-deliver-5g-driven-robot-warehouse-solutions
[120] http://www.businesskorea.co.kr/news/articleView.html?idxno=46333
[121] https://www.euronews.com/next/2022/12/12/huaweis-revolutionary-vision-for-ports-sets-sail-with-ai-powered-hub-utilising-5g-and-gree
[122] Ibid.
[123] https://www.verizon.com/about/news/verizon-business-showcase-national-retail-federations-big-show-2023
[124] https://www.verizon.com/about/news/verizon-business-showcase-national-retail-federations-big-show-2023
[125] https://www.singtel.com/about-us/media-centre/news-releases/singtel-switches-on-5g-at-its-unmaned-pop-up-retail-store
[126] Ibid.

human traffic flow for data collection purposes.[127] This means that resource planning for security and cleanliness can be managed more effectively, since the energy used to power lights, air conditioning, and other electrical equipment can be tuned automatically based on the weather and the number of people inside the building[128]. At one of the teaching hospitals in South Korea, 5G is being used to connect ultra high-definition video streaming for contactless security[129]. 5G-powered facial recognition provides contactless entry for staff onto wards to help reduce the risk of infection potentially associated with card or fingerprint access methods, benefiting both hospital staff and patients[130].

Media and ICT: A cloud gaming service was launched in Malaysia, powered by its 5G network.[131] It offers high quality gaming experience through the cloud to any device, eliminating the need for heavy downloads and hardware upgrades. The cloud gaming service can connect to most major game platforms. The service has provided access to the latest games with over 1,500 on offer already. 5G-enabled cloud gaming service solutions brings better playing experience, which may encourage more potential players to give a try. This is a showcase of the potential growth for the industry.

Accommodation and food services: The industry has adopted 5G widely, such as a smart hotel built by one of the luxury hotels in Shenzhen that is equipped with intelligent connectivity boosted by 5G networking[132], e.g., use of 5G-enabled VR to showcase nearby scenic sights. They aim to improve the connection between back-end data and front-end technology to guarantee security in the guest experience[133]. A use case of 5G supporting advanced technology is the AI robot developed by one of the South Korean telecommunications companies, using 5G to fulfil needs such as downloading large-sized map data[134]. The robot's first generation served a 4-star Hotel in Dongdaemun for six months, servicing their 211 rooms and making the most deliveries between 10pm and 7am to guests for bottled water and other amenities. Currently on its second generation, the delivery capsule is 1.5 times larger to carry deliveries more efficiently, has had a 40% increase in its speed, and a 30% longer battery lifespan.[135]

Arts, entertainment and recreation: An immersive fan experience was created to coincide with the Super Bowl. Two primetime livestreams were created on a livestreaming platform with simulcasting across various social channels. 40 million players visited the stadium in Fortnite, 1.5 million visitors competed and played the games available, and over 5 million fans viewed the livestreams the livestreaming platform.[136] A Hong Kong telecommunications company provided 5G technical support and live streamed concert events in 4K ultra high-definition via its 5G network for music fans worldwide.[137] Similar use cases in art, entertainment and recreation area in Hong Kong are rare at the moment, but as 5G-enabled use cases get mature, the industry operators in Hong Kong will be more willing to upgrade their network to 5G to bring new experience for their customers.

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[127] https://www.nst.com.my/property/2022/01/766275/i-city-and-china-mobile-international-malaysia-build-countrys-first-smart

[128] Ibid.

[129] UK5G, https://uk5g.org/discover/5g-industry/health-social-care/5g-in-healthcare-infrastructure-operations-UK/5g-healthcare-operations-connected-facilities-UK/

[130] Ibid.

[131] https://technave.com/gadget/Yes-5G-launches-NVIDIA-GeForce-NOW-cloud-gaming-service-beta-in-Malaysia-33805.html

[132] https://www.huawei.com/en/news/2019/4/intercontinental-shenzhen-telecom-huawei-smart-hotel

[133] https://carrier.huawei.com/en/success-stories/Industries-5G/5G-Smart-Hotel

[134] https://www.ajudaily.com/view/20190226093449028

[135] https://www.prnewswire.com/news-releases/kts-2nd-generation-ai-hotel-robot-enhances-room-services-301085622.html

[136] https://rga.com/work/verizon-fortnite-stadium

[137] https://web.three.com.hk/5g/video02-en.html

B3. Quantifiable economy wide impacts

According to the research on 5G's impact on the US economy[138] completed by a consulting firm, 5G network implementation is expected to contribute more than US$1.7 trillion to the US economy by 2030, creating 3.8 to 4.6 million job opportunities both direct (30%) and indirect (70%). Direct impact represents around 30% of 5G potential in the US market.[139] The industries standing to benefit the most are information services, construction, and manufacturing, with increasing demand for infrastructure and supporting services. Information services is expected to have US$468 billion of 5G-driven growth through both direct and indirect impact by 2030.

As observed throughout the literature, the industries overall that have the greatest expected benefit in percentage of jobs created are information and communication, public service and defence, and transportation and storage. For example, information and communication in France is expected to have 23% of total 422,000 jobs created due to 5G, and by 2030 public service and defence is expected to be the largest employer in France at 16% of the total workforce.[140] The industries that are expected to have greatest number of 5G-enabled sales in 2030 include manufacturing and wholesale and retail trade.[141] Following closely behind, varying by country, are the information and communication, public service and defence, and transportation and storage industries.

Conducted by Bahia, K., Castells, P. and Pedros, X. in 2020, a GSMA study on global rollouts of 2G, 3G and 4G indicated that significant economic impacts were observed where mobile connectivity is first available.[142] With access to over 20 years of historic data, this study estimated that a GDP impact of 0.08% to 0.2% can be generated for every 10% increase in 4G connectivity from 3G. The result estimated in this study is referenced for a top-down approach under the Economic Model 1 in this Study. Further details on the methodology for the Economic Model 1 are set out in Appendix A, and the economic impact assessment is set out in Chapter 4.3.

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[138] https://www.bcg.com/publications/2021/5g-economic-impact-united-states
[139] Ibid.
[140] https://5glab.orange.com/wp-content/uploads/sites/37/2021/05/5g-impact-2030.pdf
[141] Ibid.
[142] https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=54165922&file=121120-working-paper.pdf

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