香港工業總會
Federation of Hong Kong Industries

5G物聯網應用研究報告
Research Report on 5G Internet of Things Applications

香港工業總會
FHKI Federation of Hong Kong Industries

Hong Kong Electronics Industry 香港電子業總會 Council

香港工業總會轄下 A FHKI Council

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ASTRI 香港應用科技研究院

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序言

5G網絡是實現物聯網潛力的基礎，兩種技術的結合能為企業帶來重大價值。5G帶來極高速、極低延時以及高覆蓋的連結，同時能降低成本。與昔日的無線技術相比，5G將更廣泛地支援嶄新的解決方案，例如人工智能、自動化營運以及區塊鏈技術。5G的出現讓物聯網設備可更快地傳輸數據，並享有更大的覆蓋範圍。

所有業界朋友都應該掌握相關變革性新技術的知識，並從中發掘新商機。因此，香港工業總會（工總）在工業貿易署「工商機構支援基金」的資助下，委託香港應用科技研究院開展《5G物聯網應用研究報告》，探討5G物聯網的應用及其市場潛力，特別是在香港。研究報告亦著墨討論5G發展與香港再工業化的關係。

工總希望這份研究報告能幫助業界、政府和各持份者建立有關5G物聯網應用更全面的觀點。總而言之，全球5G物聯網市場將出現顯著增長，業界應充分發揮5G物聯網發展的巨大潛力，帶領香港成為亞洲領先的5G物聯網發展中心。

莊子雄
香港工業總會常務副主席
香港工業總會第5分組（香港電子業總會）主席

香港電子業總會成立於1988年，一直與電子業界並肩同行，亦見證業界多年來所面對的挑戰。5G技術的應用和創新已成為各大經濟體的重要發展議程之一，例如中國「十四五規劃（2021-2025）」的其中一項目標，是把5G用戶普及率提升至56%（即超過7.8億用戶）。由此可見，5G勢必改變電子行業的生態。

香港早於2020年4月已正式邁進5G網絡時代。根據《行政長官2021年施政報告》，現時5G網絡在香港的覆蓋率已逾九成，核心商業區的覆蓋率更達99%，為各種商業服務和智慧城市應用方案提供極大潛力。政府亦多方位推動5G發展，包括推出更多5G頻譜，在速度、容量和覆蓋等方面滿足各種5G服務需要。政府亦通過「鼓勵及早使用5G技術資助計劃」，資助更多行業採納5G創新應用，包括遙距醫療、遙距維修支援、實時工地安全監測等，以提升效率和生產力。

《5G物聯網應用研究報告》正好趕上5G浪潮。本研究透過收集超過100間企業的意見，全面檢視5G物聯網應用的現狀、挑戰和機遇，為未來的產業政策提供參考依據。工總希望本研究報告能為香港5G未來發展提供所需的數據參考，助政府制訂更全面的政策，為香港電子業開創新時代。

謝鴻強
香港工業總會第5分組（香港電子業總會）榮譽副主席
「5G新時代對香港電子業的挑戰和商機」項目主席

前言

研究介紹

這份研究報告介紹5G如何通過物聯網（IoT）技術為電子行業帶來裨益。5G承諾千兆數據速率、低延遲、超高網絡可靠性和高連接密度，滿足各種垂直物聯網應用的苛刻要求。

本研究亦探討了尤其是在香港的5G物聯網應用及其市場潛力。為了觀察業界對5G物聯網應用的看法，本研究採用問卷調查來收集信息。問卷調查於2022年初進行，問卷已分發給來自電子、電信、科技等行業的所有工總會員和非會員公司，共收到有效問卷105份。此外，本研究還進行了文獻探討以作參考。

從5G物聯網應用收集的數據可以有相當價值，但如果系統應用不當，會增加網絡安全風險。為了將這些數據貨幣化並解決安全問題，本研究探討了如何使用區塊鏈/分散式賬本技術，來實現以連貫、安全、開放和透明的方式發布和分發這些數據的具果效和高效率機制。報告介紹區塊鏈的實際應用，以解決5G物聯網技術可能帶來的網絡安全隱患。

為了讓電子行業更加了解和推廣5G物聯網應用，本研究評估了5G物聯網應用的利弊，並為企業如何準備使用5G物聯網技術提供建議。研究還探討了政府在這一主題上的角色，指出政府可以如何支持香港發展5G物聯網技術。

總體而言，5G物聯網應用正在全球各地廣泛使用，本研究旨在調查它如何能促進香港的新業務、服務、商業活動以及其新研發方向和創新的應用。

Foreword

5G is the foundation for unleashing the full potential of the Internet of Things ("IoT"). Both technologies can create substantial value for enterprises when implemented together. 5G promises lightning-fast speed, incredibly low latency, and the capacity to carry massive numbers of connections simultaneously at a lower cost. In comparison to previous wireless technologies, 5G is expected to support a wide array of new solutions, such as AI, autonomous operations and blockchain. The advent of 5G enbables more IoT devices to transmit data faster, while covering significantly larger areas.

All industry players should equip themselves with knowledge on relevant transformative new technologies and seek new business opportunities. Funded by The Trade and Industrial Organisation Support Fund of the Trade and Industry Department, the Federation of Hong Kong Industries ("FHKI") entrusted Hong Kong Applied Science and Technology ("ASTRI") to conduct a study, Research Report on 5G Internet of Things Applications. In this research study, 5G IoT applications and their market potentials, especially in Hong Kong, were investigated. The report also discussed the relationship between Hong Kong re-industrialization and 5G development.

FHKI hopes that this research report will help the industry, the government and various stakeholders to establish a more holistic view of 5G IoT applications. All in all, the global 5G IoT market is expected to witness significant growth. Industry players should leverage the full potential of 5G IoT development and lead Hong Kong to become a leading 5G IoT center in Asia.

Steve Chuang
Executive Deputy Chairman of the Federation of Hong Kong Industries
Chairman of FHKI Group 5 (Hong Kong Electronics Industry Council)

Established in 1988, the Hong Kong Electronics Industry Council has been a staunch supporter of the electronics industry, and has witnessed the challenges faced by the industry over the years. The application and innovation of 5G technology is one of the most important development agendas of the world's major economies. For example, China aimed to raise the 5G penetration rate to 56% (or over 780 million users) in its 14th Five-Year Plan (2021-2025). Therefore, it is anticipated that 5G will change the dynamics of the electronics industry.

Hong Kong officially entered the 5G era in April 2020. According to *The Chief Executive's 2021 Policy Address*, the network coverage of 5G in Hong Kong is now topping 90%, and even up to 99% in core business districts, bringing vast potential for various commercial services and smart city applications. The government also promotes 5G development on various fronts, including releasing more 5G spectrum to satisfy the needs of numerous 5G services in terms of speed, capacity and coverage. Through the Subsidy Scheme for Encouraging Early Deployment of 5G, the government subsidizes more sectors to enhance efficiency and productivity by adopting innovative 5G applications, such as telemedicine, remote maintenance support and real-time safety monitoring at construction sites.

Jumping on the 5G bandwagon, this research study gathered opinions from more than 100 enterprises on the current development, challenges, and opportunities of 5G IoT applications to provide important references for formulating future industrial policies. FHKI hopes that this research report can provide necessary data to support the Hong Kong government in planning a comprehensive 5G development blueprint and bringing Hong Kong's electronics industry into a new era.

Christopher Tse
Honorary Vice President of FHKI Group 5 (Hong Kong Electronics Industry Council)
Project Chairman of "Challenges & Opportunities for Hong Kong Electronics Industry in the 5G Era"

Preface

Introducing the Study

This research report studied how 5G empowers the electronics industry with Internet of Things (IoT) technology. 5G promises gigabit data rates, low latency, ultra-high network reliability, and high connection density, meeting the demanding requirements of various vertical IoT applications.

It also investigated 5G IoT applications and their market potentials, especially in Hong Kong. Aiming to observe the views from the industry towards 5G IoT applications, this research study has employed a questionnaire survey to collect information. The questionnaire survey was conducted at the beginning of 2022 and was distributed to all FHKI members and non-member companies from electronics, telecommunication, technology industries etc. A total of 105 valid questionnaires were received. A literature review has also been undertaken.

Data collected from applications can be valuable, and the sheer volume of data in 5G IoT applications can increase cybersecurity risks. To monetize this aggregated data and address security concerns, this study investigates the use of blockchain/distributed ledger technology to enable effective and efficient mechanisms for publishing and distributing this data in a coherent, secure, open, and transparent manner. Practical applications of blockchain are introduced to address the security issues that 5G IoT technology may bring.

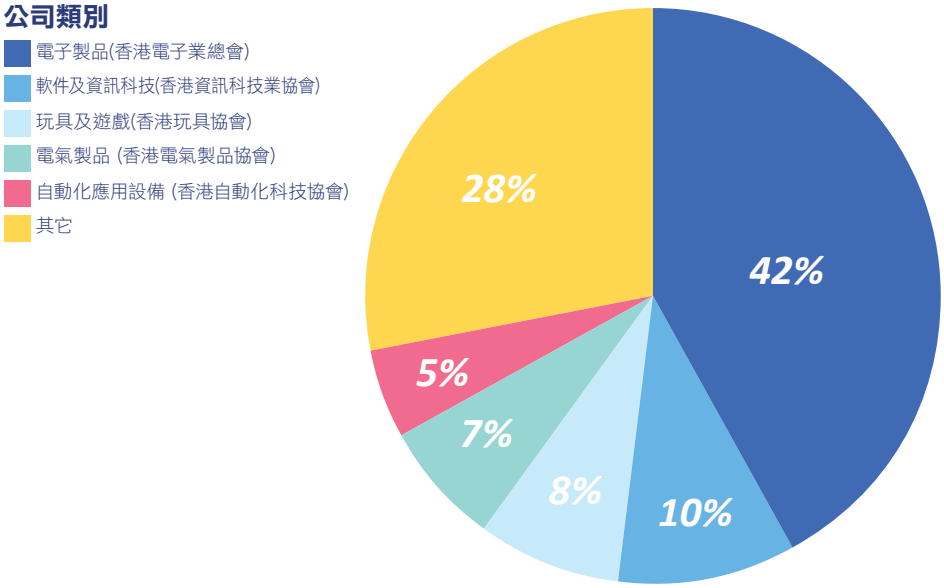
To provide more understanding and promote the adoption of 5G IoT applications for the electronics industry, this report assessed the pros and cons of 5G IoT applications and suggested ways for enterprises to prepare for and make use of 5G IoT technology. This report also included the government's role on this topic, giving information on how the government is supporting the development of 5G IoT technology in Hong Kong.

All in all, 5G IoT applications are being realised in all directions around the world. This study aims to investigate applications that promote new businesses, services, commercial activities, and new R&D directions and innovations in Hong Kong.

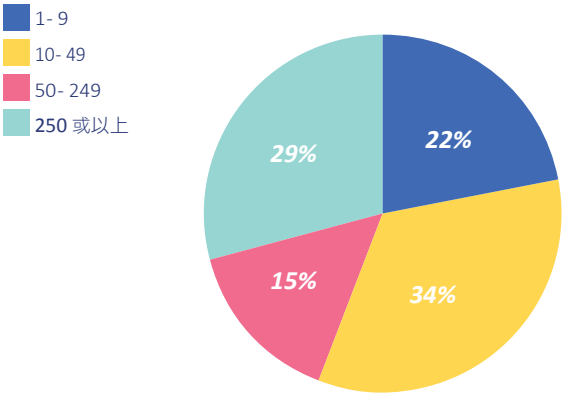
受訪者的背景

大多數受訪者的業務與電子產品有關。他們的公司擁有 10-49 名員工，對5G物聯網技術有一定的了解，成立了超過 16 年，並將公司銷售收入的 10% 以上用於研發和產品開發。

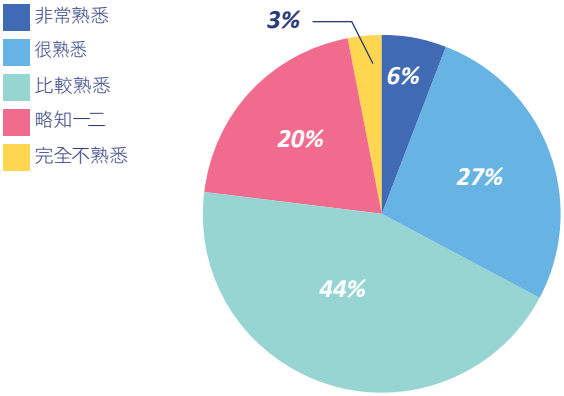
公司類別



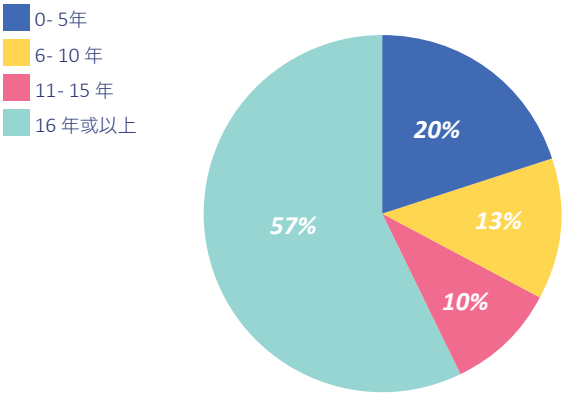
公司規模—以員工人數計算



對5G物聯網技術熟悉程度



公司成立年數



去年用於研發和產品開發的公司銷售收入百分比

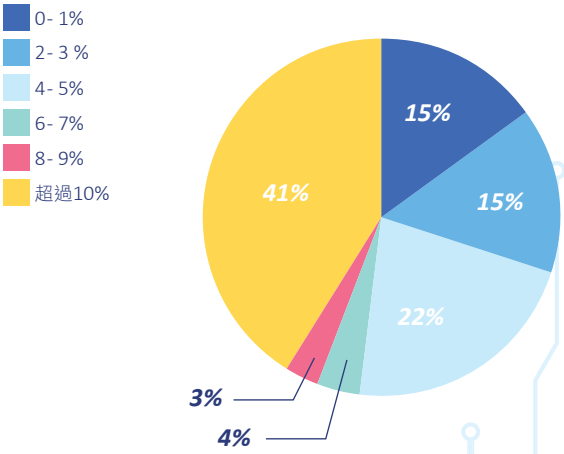
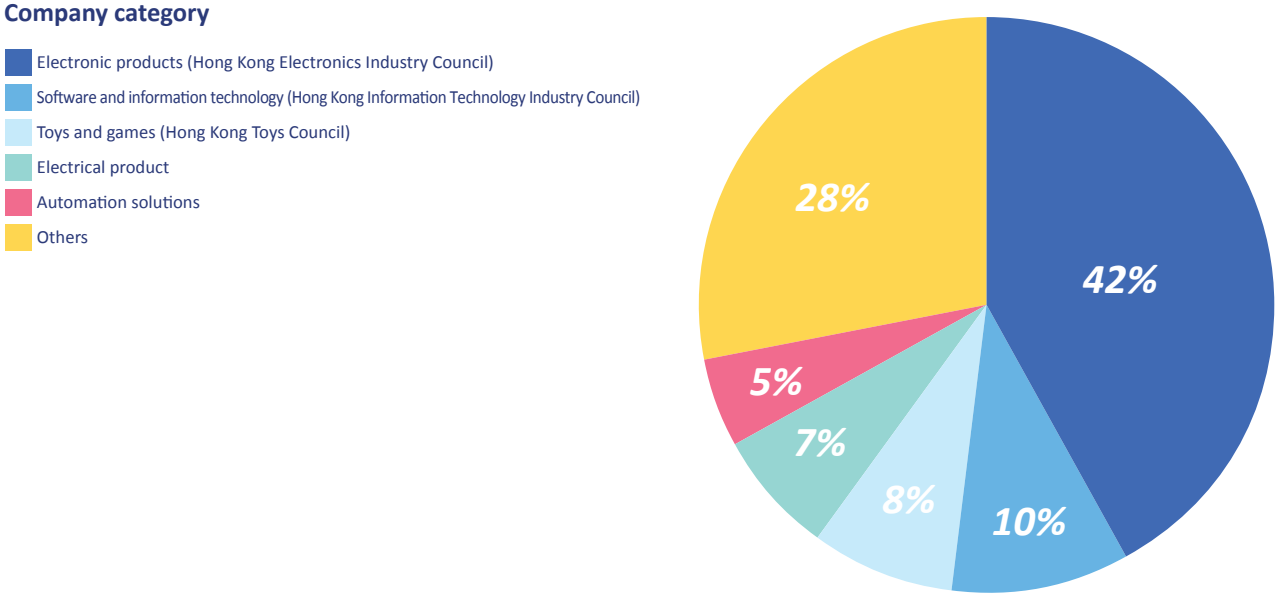


圖 0.1 受訪者的背景信息

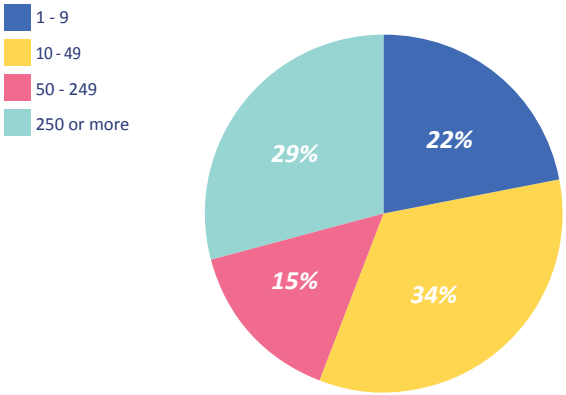
Background of the Respondents

Most respondents have business relating to electronic products. Their companies are employed with 10-49 employees, has a moderate familiarity with 5G IoT technology, has been set up for over 16 years, and put more than 10% of their company sales revenue for R&D and product development purposes.

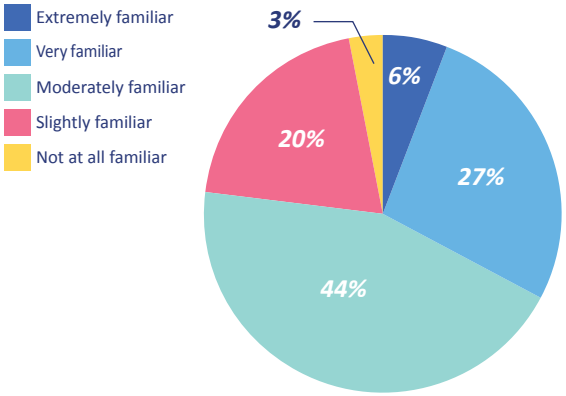
Company category



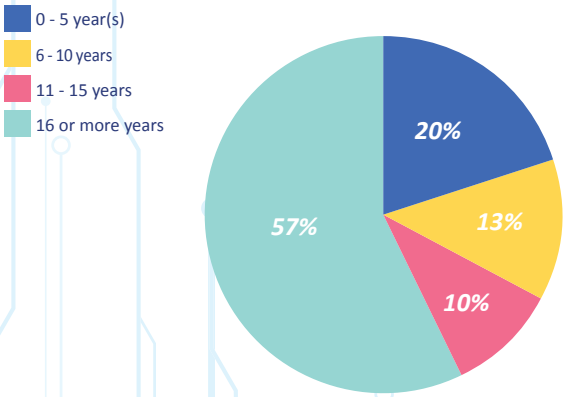
Company size in term of number of employees



Familiarity with 5G IoT technology



Company setup years



Percentage of company sales revenue used for R&D and product development purposes in last year

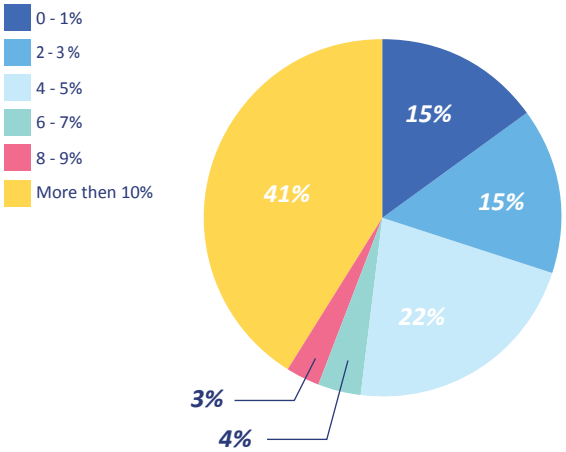


Figure 1 Background Information about the Respondents

1 5G 物聯網（IoT）

1.1 移動通訊技術的演進

在5G出現之前，移動通訊網絡經歷了1G、2G、3G和4G。「G」代表通訊技術發展的世代。每一代都在數據承載能力和減少傳輸時延方面取得了顯著的進步。

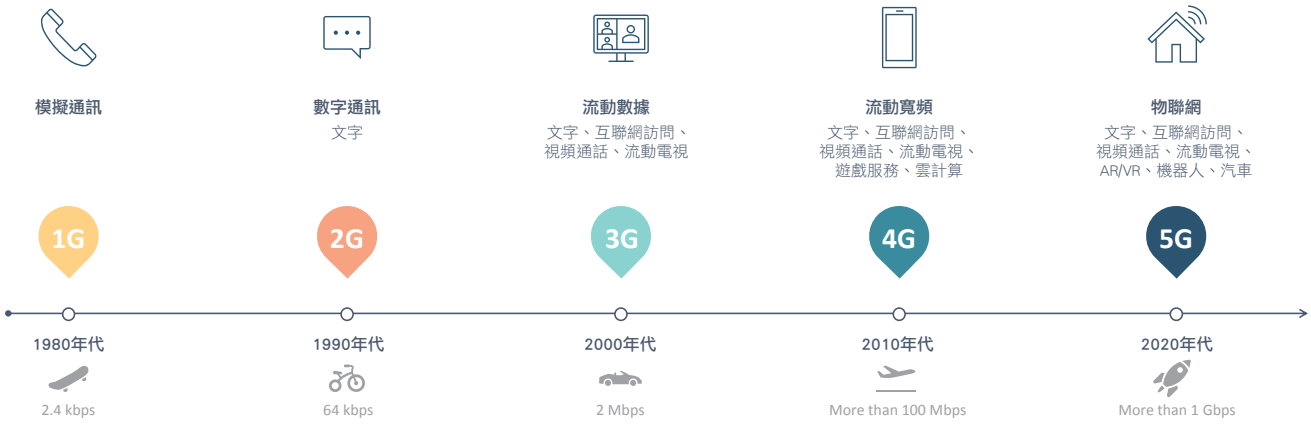


圖1.1 移動通訊技術從1G到5G的演進

1G 始於 1980 年代，是一種基於模擬通訊技術的蜂窩無線電話系統。它存在音質差、覆蓋範圍有限、無線電頻譜使用效率低、營運商之間不支持漫遊、不支持加密等問題，亦無法發送短信。

2G 始於 1990 年代，使用數字調製。1G話音質素低、訊號不穩定，2G開始支持文字和圖像信息傳輸功能。相比之下，2G的保密性高，系統容量增加，和容許移動互聯網接入。

3G始於2000年代，提供高速數據傳輸和支持多媒體通訊。由於網絡速度和用戶容量大幅提升，帶來高達2 Mbps的新多媒體服務，從而推動了智能手機的發展。

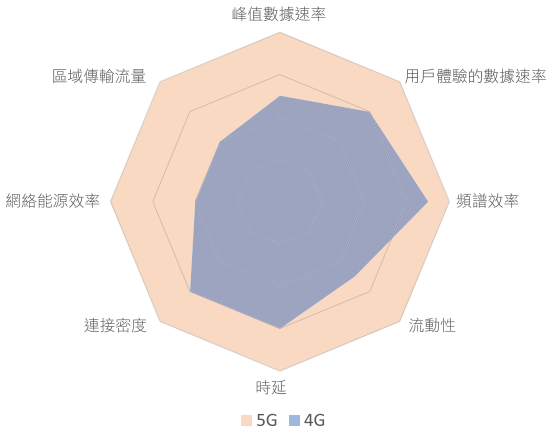


圖1.2 從 4G 到 5G 的性能提升

4G 始於 2010 年代。可以應付更多的數據傳輸，帶來了更快的速度。 網絡下載速度可以達到100 Mbps以上，有助於提升視頻質量並使串流媒體更流暢。

4G 讓移動通訊設備的使用更加普遍。在4G後期，物聯網技術發展迅速。物聯網設備需要更高的反應能力，並允許多個設備同時連接到互聯網。因此，5G低時延和多連接的特性應運而生。

2020年代開始的5G時代，網速可達1 Gbps以上，瞬間便可完成下載。5G的時延只有一毫秒，大大改善機器之間的無線通訊。1G實現了人與人之間的連接，5G實現了萬物之間的連接。

2G實現了從1G模擬時代走向數碼時代，3G實現了從2G語音時代走向數據時代，4G實現了IP化，數據速率大幅提升。從4G到5G代表的不僅是更快的互聯網接入，更是一場改變社會的信息革命。

5G最大的變化是從人與人之間的通訊走向人與物、物與物之間的通訊，實現萬物互聯，推動社會發展。端到端的生態系統將創建一個完全移動和完全連接的社會。通過現有和新的使用實例，5G將進一步改變我們的生活和社會，推動高速和實踐物聯網技術的智能時代。

1 5G Internet of Things (IoT)

1.1 Evolution of Mobile Communication Technologies

Before the emergence of 5G, mobile communication networks experienced 1G, 2G, 3G, and 4G. “G” stands for a mobile generation. Each generation has made great strides in data-carrying capacity and latency reduction.

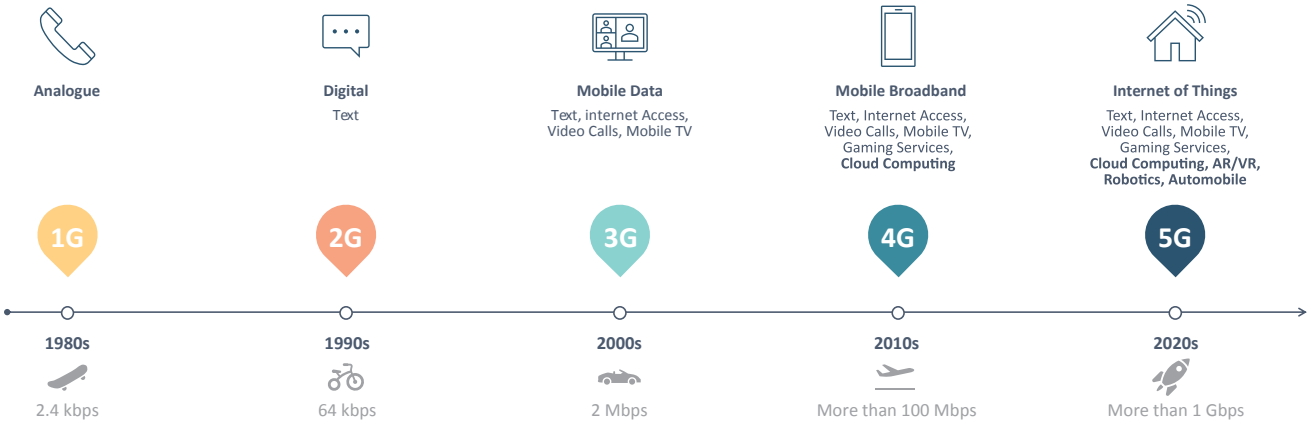


Figure 1.1 Evolution of Mobile Communication Technologies from 1G to 5G

1G started in the 1980s and is a cellular wireless telephone system based on an analogue voice communication technology. It suffered from poor sound quality, limited coverage, inefficient use of radio spectrum, no roaming support between operators, and no support for encryption. Text messages cannot be transmitted.

2G started in the 1990s and uses digital modulation. 1G voice quality is low and the signal is not stable, 2G begins to support text and multimedia transmission functions such as text and pictures messages. In comparison, 2G has a high degree of confidentiality, increases the system capacity, and enables mobile Internet access.

3G started in the 2000s and supports high-speed data transmission and combines wireless communication with multimedia communication. There is a huge increase in network speed and user capacity, bringing new multimedia services at a high speed of up to 2 Mbps. It drives the trend of smartphones.

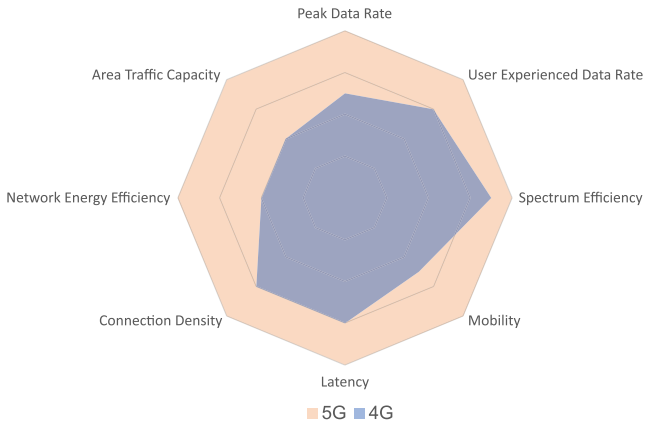


Figure 1.2 Performance Enhancement from 4G to 5G

4G started in the 2010s. The advent of 4G can cope with greater data transmission. 4G brings a much faster speed. Network download speeds can reach more than 100 Mbps, allowing video caching hard to detect. It helps upgrade video quality and makes streaming smoother.

4G makes the use of mobile communication devices more prevalent. In the late 4G period, IoT technology developed rapidly, and wearable devices emerged. IoT devices need more responsiveness and allow multiple devices to be connected to the Internet at the same time. Therefore, 5G with low latency and multi-connection characteristics came into being.

In the 5G era, started in the 2020s, network speeds can reach more than 1 Gbps, which allows all downloading behaviours to be completed in an instant. The low latency of 5G with only a millisecond delay will also improve the wireless communication between machines. 1G realizes the connection between people, 5G realizes the connection between everything.

2G realizes the transition from the analogue era of 1G to the digital era, 3G realizes the transition from the 2G voice era to the data era, and 4G realizes IP and greatly increases the data rate. From 4G to 5G, it is not only faster Internet access, but also an information revolution that changes society.

The biggest change in 5G is to move from communication between people to communication between people and things, and between things and things, realize the interconnection of all things, and promote society development. An end-to-end ecosystem will create a fully mobile and fully connected society. Through existing and new use cases, 5G will further change our lives and society, and promote an intelligent era with high speed and IoT.

1.2 5G：智能時代

5G 以其獨特的全新網絡和服務能力開啟了各種機遇。5G的超高速、超低時延、超廣泛連接特性，以及可以通過智能電源管理和大規模物聯網傳感器部署而節省電力和成本，是發展智慧城市的必要條件。

1.2.1 5G 標準進展

5G 技術規格由第三代合作夥伴計劃（3GPP）制定，為移動通訊提供完整的系統描述。3GPP在標準化的制定是按「版本」計劃的。5G第一和第二階段的全套技術標準分別於2018年和2019年發布，分別為第15版（R15）和第16版（R16）。第 17 版（R17）預計將於 2022 年完成。

圖1.3 R15-R17的發展

1.2.2 5G三大目標

國際電信聯盟（ITU）通過各種5G標準技術的制定和使用，為5G制定了三大目標，「高速度」、「低時延」和「多連接」。

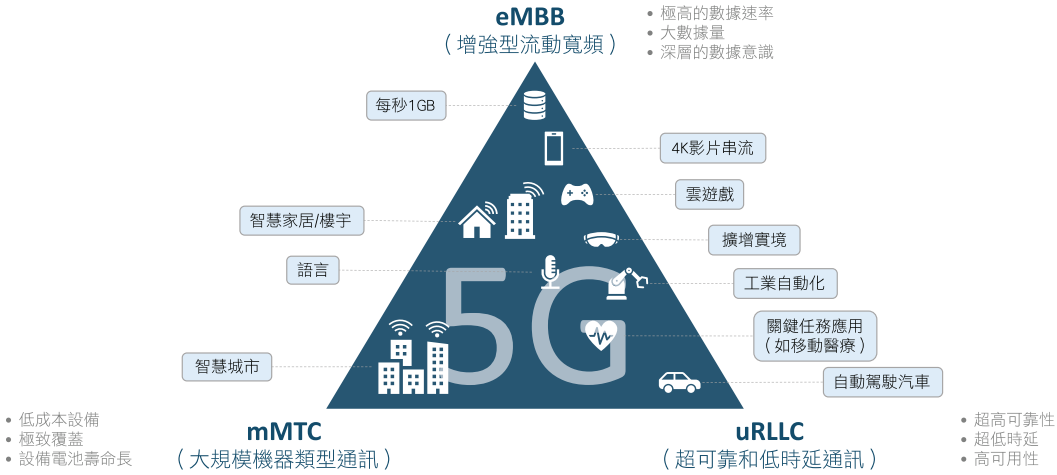


圖 1.4 5G 應用場景

增強型流動寬頻（eMBB）

5G在理想條件，數據下載速度可以高達20 Gbps，從而提供更快、更穩定的流動寬頻，為用戶在不同應用領域帶來更豐富、更多樣化的體驗。

超可靠和低時延通訊（uRLLC）

5G網絡的低時延特性，提供近乎實時和高度可靠的通訊。可以支援關鍵任務需要超低時延（低至1毫秒）通訊的應用。

大規模機器類型通訊（mMTC）

5G可以通過互聯網在每平方公里內同時連接多達100萬台的海量設備，為物聯網提供技術基礎。

1.2 5G: Intelligent Era

5G opens various of opportunity with its new and unique network and service capabilities. The ultra-high speed, ultra-low latency, and ultra-wide connection characteristics of 5G, as are the intelligent power management to extend battery life, and the cost savings from large-scale IoT sensors deployment, are necessary conditions for the development of a smart city.

1.2.1 Progress of 5G Standards

5G technology specifications are defined by the 3rd Generation Partnership Project (3GPP) to provide a complete system description for mobile telecommunications. 3GPP standards are structured as “Releases”. The first and second full sets of 5G technical standards were released in 2018 and 2019, namely Release 15 (R15) and Release 16 (R16) respectively. Release 17 (R17) is expected to be completed in 2022.

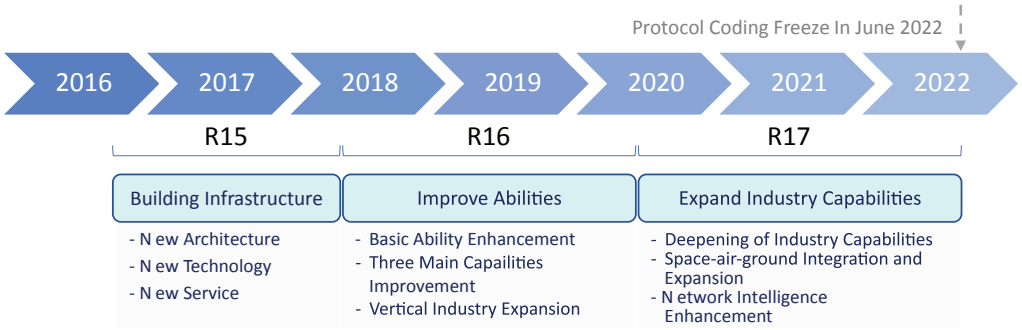


Figure 1.3 Development of R15 - R17

1.2.2 5G Main Dimensions

The formulation and use of various 5G standard technologies are aimed at achieving the three major goals set by the International Telecommunication Union (ITU) for 5G, highlighting “high speed”, “low latency” and “multiple connections”.

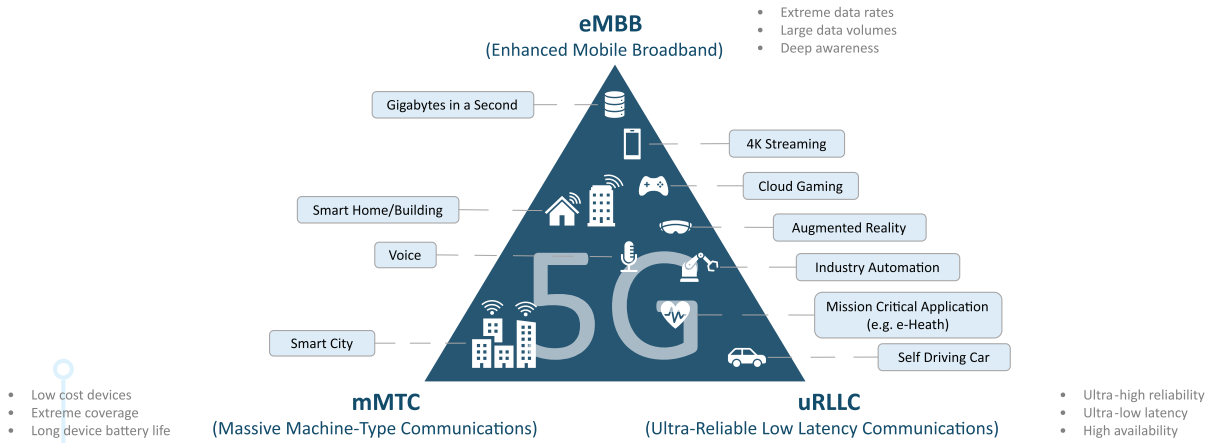


Figure 1.4 5G Usage Scenarios

Enhanced Mobile Broadband (eMBB)
5G supports extremely high-speed data download transmission speeds of up to 20 Gbps under ideal conditions. It is expected to provide significantly faster and more stable mobile broadband, bringing users a richer and more diverse experience in different application areas.

Ultra-Reliability and Low Latency Communications (uRLLC)
The low latency 5G network is expected to provide near real-time and highly reliable communications. It supports mission-critical smart applications and applications that require ultra-low latency communications with a delay time as low as 1 millisecond.

Massive Machine Type Communications (mMTC)
5G can connect a massive number of devices up to 1 million within one square kilometre at the same time through the Internet, providing the backbone technology for the IoT.

1.2.3 5G端到端系統

5G端到端系統由終端、無線基站、核心網和應用組成。整個網絡被劃分為不同的區域，這些區域配備了具有各種相關設備和系統的微型或大型基站。用戶可以使用移動設備連接到互聯網。當基站接收到來自終端（用戶設備）的訊號時，該訊號將通過回程鏈路傳輸數據。數據將傳輸到5G核心網，最終連接到互聯網。5G核心網就像人的大腦，它收集每個基站傳輸的數據並控制整個網絡的運行。

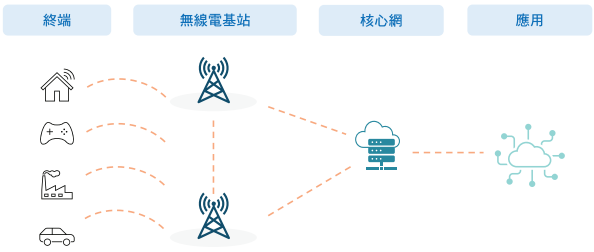


圖 1.5 5G端到端系統

1.2.3.1 5G傳輸技術

移動設備與基站之間的無線網絡使用不同頻段和波長的電磁波技術來傳輸數據。 根據3GPP制定的規範，5G分為兩大頻率範圍，以6 GHz頻帶為界：

6 GHz以下的頻率範圍（Sub-6）

範圍在450 MHz和 6 GHz之間，頻寬小，速度高。它的覆蓋範圍很大，適合廣域部署，並且可以穿透大多數牆壁和障礙物。

6 GHz以上的頻率範圍（毫米波/mmWave）

屬於高頻段，範圍在24 GHz和52 GHz之間。頻寬大，速度非常高，最高可達20 Gbps，通常在100 Mbps左右。它的覆蓋範圍小，與使用Sub-6相比，需要更多的基站才能達到相同的無線電覆蓋範圍，並且無法穿透建築物。

圖1.6 5G的頻率範圍

在香港，通訊事務管理局辦公室（通訊辦）已指配700 MHz、3.3 GHz、3.5 GHz、4.9 GHz、26 GHz和28 GHz頻帶內的頻譜，以提供公共 5G 服務[1]。

1.2.3.2 非獨立組網及獨立組網

5G有兩種組網類型，即非獨立組網（NSA）和獨立組網（SA）。前者基於現有4G網絡，部署5G網絡。用戶可以同時使用5G頻譜和4G頻譜，速度比4G更快；後者是純5G網絡建設，包括基站、回程鏈路、核心網，與4G網絡分離。

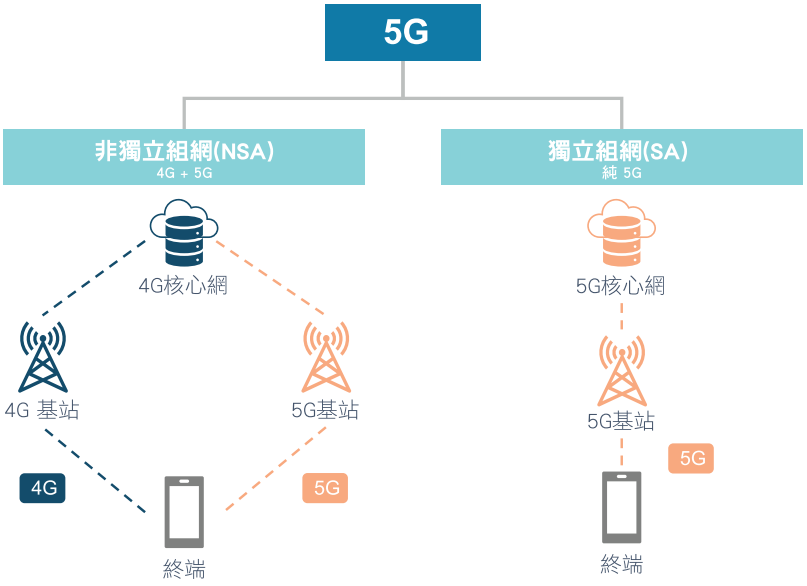


圖1.7 5G NSA 和 SA 的區別

[1] 通訊事務管理局。什麼是5G？。取自迎接5G新世代網址：https://www.5g.gov.hk/tc/what-is-5g/introduction.html

1.2.3 5G End-to-end System

A 5G end-to-end system consists of terminals, radio base stations, core network, and applications. The entire network is divided into different areas that are equipped with micro or large base stations with various related equipment and systems. Users can use mobile devices to connect to the Internet. When the base station receives the signal from the terminal (the user device), the signal will transmit data through the backhaul. The data will be transmitted to the 5G core network, ultimately connected to the Internet. 5G core network is like a human brain. It gathers data transmitted by each base station and controls the operations of the entire network.

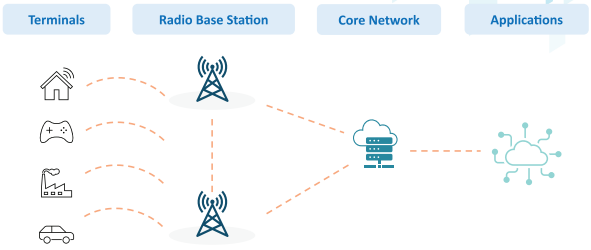


Figure 1.5 5G End-To-End System

1.2.3.1 5G transmission technology

The wireless network between the mobile device and the base station uses electromagnetic wave technologies of different frequency bands and wavelengths to transmit data. According to the specifications defined by 3GPP, 5G is divided into 2 large frequency ranges, with the 6 GHz frequency band as the boundary:

Frequency range below 6 GHz (Sub-6)

The range is between 450 MHz and 6 GHz. The bandwidth is small, and the speed is high. Its coverage is large that it is good for wide-area deployments and penetrates most walls and obstructions.

Frequency range above 6 GHz (millimetre wave/mmWave)

It belongs to the high-frequency band, ranging from 24 GHz to 52 GHz. The bandwidth is large, and the data rate is very high, with up to 20 Gbps, and typically around 100 Mbps. Its coverage is small, and it needs more base stations to achieve the same size of radio coverage than using Sub-6 and cannot penetrate the building.

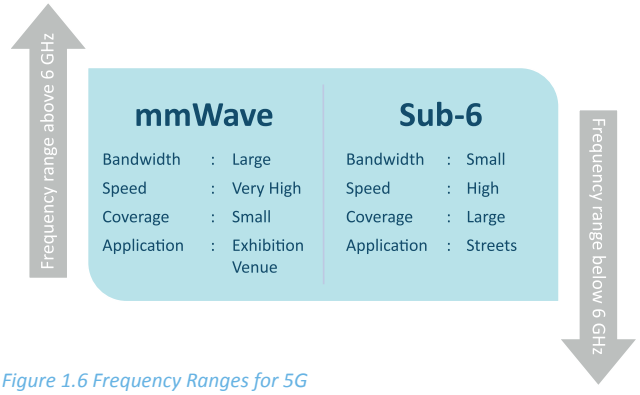


Figure 1.6 Frequency Ranges for 5G

In Hong Kong, the Office of the Communications Authority (OFCA) has assigned spectrums in the 700MHz, 3.3GHz, 3.5GHz, 4.9GHz, 26GHz, and 28GHz bands for the provision of public 5G services. [1]

1.2.3.2 Non-Standalone and Standalone 5G

There are two types of 5G, namely non-standalone (NSA) and standalone (SA). The former is based on the existing 4G network and deploys a 5G network. Users can use the 5G spectrum and 4G spectrum at the same time, and the speed is faster than 4G; the latter is a pure 5G network construction, including base stations, backhaul links, and core network, which are separated from 4G network.

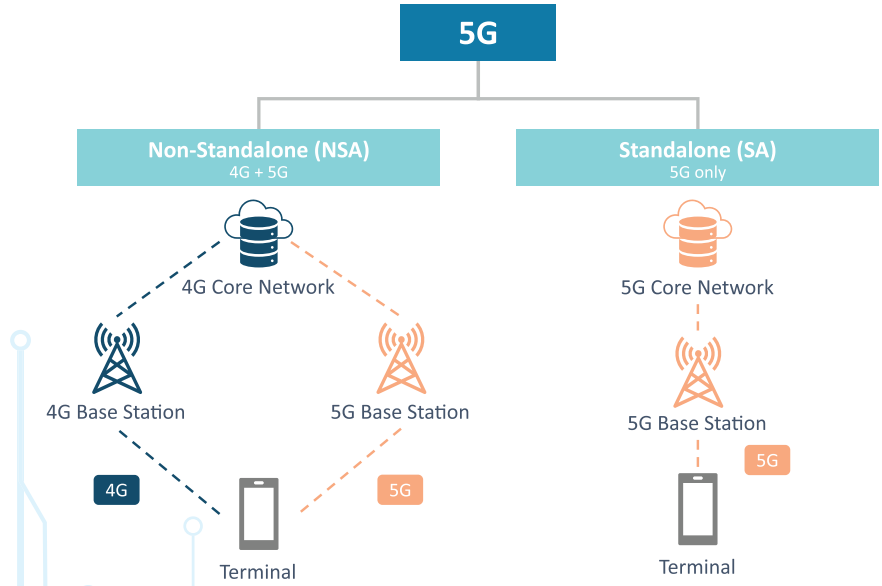


Figure 1.7 Difference between 5G NSA and SA

[1] Communication Authority. What is 5G?. Retrieved from Embracing the New 5G Era Website: https://www.5g.gov.hk/en/what-is-5g/introduction.html

1.2.4 網絡切片

5G SA支持網絡切片技術，是物聯網發展的重要組成部分，主要用作商業應用。沒有網絡切片的網絡就像普通的商業寬頻服務。當大量用戶同時使用網絡資源時，質量無法得到保證。

相反，支持網絡切片的網絡就像是獨立的商業專線業務。由於切片後的網絡資源只會提供給一組用戶，其速度、時延、可靠性和安全性更有保障。網絡切片是將一個物理網絡切割成多個虛擬的端到端網絡。每個虛擬網絡包括網絡中的設備、接入、傳輸、核心網都是獨立的，任何一個虛擬網絡出現故障都不會影響其他虛擬網絡。每個虛擬網絡包含不同的功能和特性，針對不同的需求和服務。

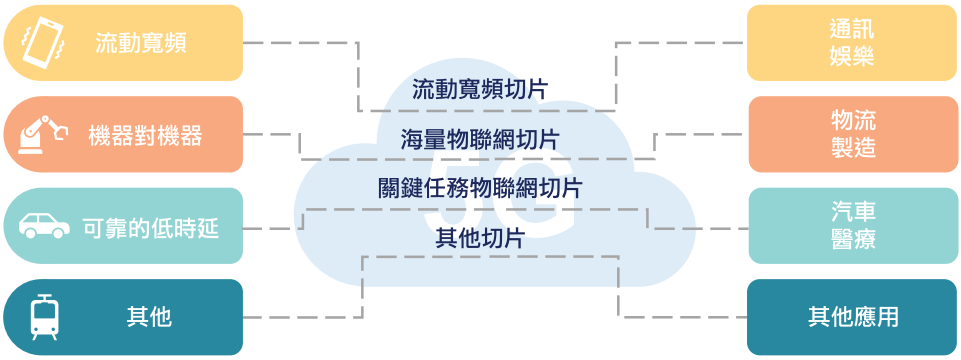


圖1.8 網絡切片——根據應用需求定制的虛擬端到端網絡

1.2.5 移動邊緣計算

移動邊緣計算（MEC），也稱為多接入邊緣計算，為靠近終端用戶網絡的應用提供執行資源（計算和儲存），通常在營運商網絡內部或邊界，而不是在一些遙遠的數據中心或雲端。邊緣計算還可以放置在企業場所，例如廠房、住宅和車輛，包括火車、飛機和私家車。邊緣基礎設施可以由通訊服務提供商或其他的服務提供商管理或託管。

邊緣計算解決方案的主要優勢包括低時延、高頻寬、設備處理和數據卸載以及可靠的計算和儲存。它支持實時物聯網在行業中使用，它的分散式特性為架構帶來更大的靈活性和可擴展性。

1.2.5.1 5G 對大數據的影響

大數據的應用產生了海量的數據，也對數據的時效性和傳輸速率有更高的要求。設備連接數量的顯著增加，又會產生海量的數據，這令到數據量極大幅地增長。

5G支持更多數據類型，亦增加了數據的收集，例如視頻和其他非結構化數據。由於它們可以通過5G在雲端上執行，從而推動數據處理和分析的技術。

1.2.5.2 5G邊緣智能

為了實現更多場景的需求，企業還可以在更靠近數據源的地方部署人工智能（AI），讓計算能力移向邊緣。支持 MEC 的應用程序包括擴增實境（AR）、虛擬實境（VR）和 物聯網。

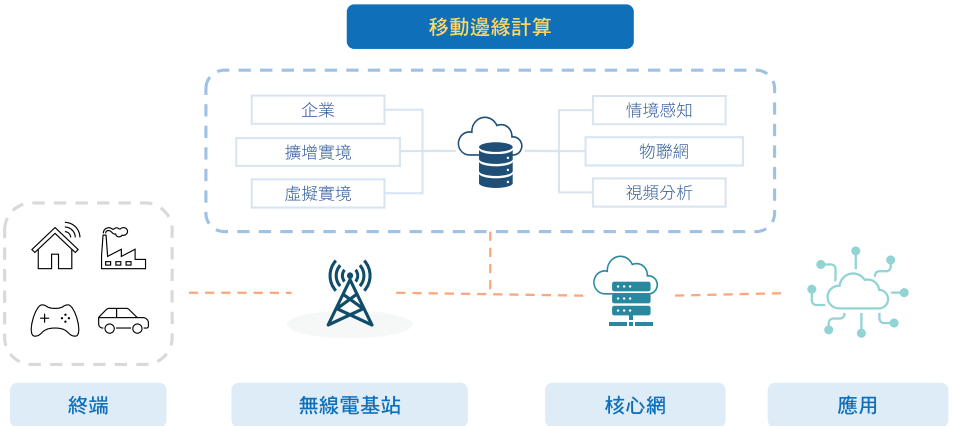


圖1.9支持MEC的分散式資料中心

1.2.4 Network Slicing

5G SA supports network slicing technology, which is mainly used commercially and is a major part of the development of IoT. A network without network slicing is like a normal commercial broadband service. Multi-users share network resources at the same time, so their quality cannot be well guaranteed.

On the contrary, a network that supports network slicing is like a commercial independent dedicated line service. Due to the sliced network resources will only be provided for a group of users, its speed, delay, reliability, and safety are more guaranteed. Network slicing is to cut a physical network into multiple virtual end-to-end networks. Each virtual network, including the equipment, access, transmission, and core network in the network, is independent, and any failed virtual network will not affect other virtual networks. Each virtual network contains different functions and features, and it is oriented to different needs and services.

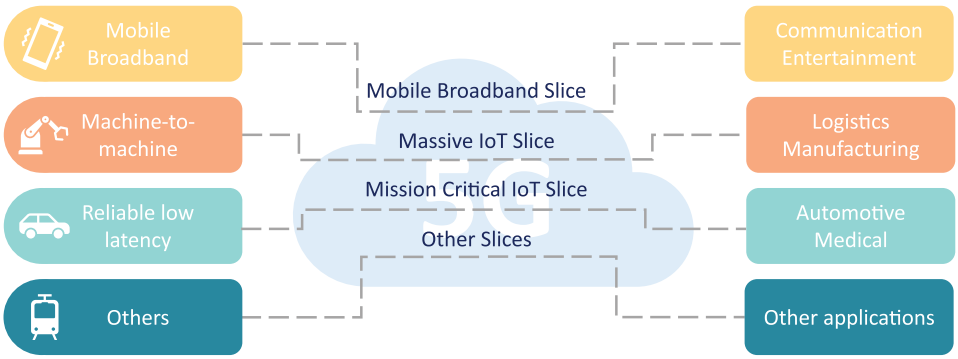


Figure 1.8 Network Slicing - Virtual End-To-End Networks Tailored to Application Requirements

1.2.5 Mobile Edge Computing

Mobile edge computing (MEC), also known as multi-access edge computing, provides execution resources (compute and storage) for applications on the network close to the end-user, usually inside or at the boundary of the carrier network, rather than in some distant data centre or cloud. Edge computing can also be placed in enterprise locations, such as factory buildings, homes, and vehicles, including trains, planes, and private cars. Edge infrastructure can be managed or hosted by a communications service provider or other types of service provider.

Key benefits offered by edge solutions include low latency, high bandwidth, device processing and data offloading, and trusted computing and storage. It supports real-time IoT applications for industries. Its distributed nature brings greater flexibility to the architecture and solves scalability issues.

1.2.5.1 The Impact of 5G on Big Data

Applications of big data have generated huge amounts of data, and it has also put forward higher requirements for data timeliness and transmission rate. The number of connected devices will increase significantly, and they will generate massive data, which will greatly drive the growth of the data volume.

5G enriches the types of data generated and increases data collection, such as videos and other unstructured data. Data processing and analysis technologies will be advanced, as they can be performed in clouds with 5G.

1.2.5.2 5G Edge Intelligence

To achieve the requirements of more scenarios, enterprises can also deploy artificial intelligence (AI) capabilities closer to the sources of data, making computing power move to the edge. Some MEC-enabled applications are Augmented Reality (AR), Virtual Reality (VR), and IoT.

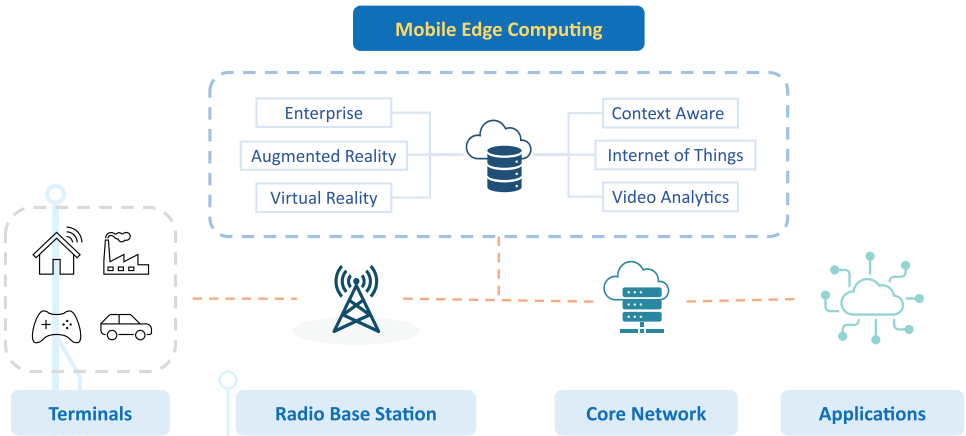


Figure 1.9 A Distributed Data Centre Enabled by MEC

5G的高頻寬、低時延、高連接性使其與邊緣計算有更強的兼容性。它為邊緣計算和AI技術的進一步融合，即邊緣智能，提供了網絡基礎。它允許用戶運行AI程式而無需擔心私隱或數據傳輸緩慢的問題，智能設備無需訪問雲端平台即可對輸入作出快速的反應。

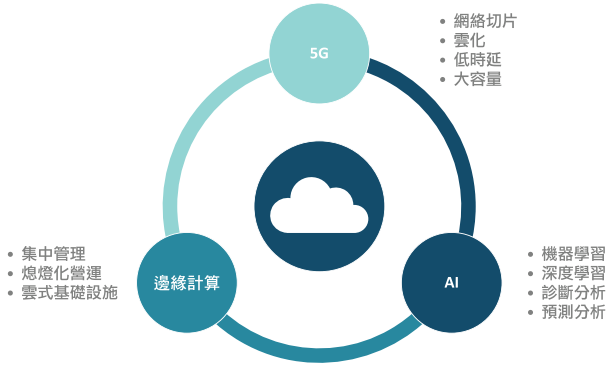


圖1.10 5G、邊緣計算和AI的結合

1.3 5G發展

世界各國都期待5G所帶來的機遇可以帶動未來經濟增長。於2019年4月，美國和韓國率先推出商用5G服務。截至 2021 年 11 月， 140 個國家/地區的 469 家營運商已經投資 5G。73個國家/地區的182家營運商推出了一項或多項5G服務[2]。在香港，移動網絡營運商於 2020 年 4 月 1 日正式推出商用 5G 服務。截至2021年5 月，香港的5G 網絡已覆蓋超過 90% 的人口，包括大型商場和地鐵沿線的所有車站。部分核心商業區或人口密集區的覆蓋率已高達99%[3]。為保障5G業務的可持續發展，政府從多方面推動5G的發展。以下是一些促進香港部署 5G 的措施：

開放政府場所

政府已於2019年3月主動開放1,000多個合適的室外或室內政府場所，供移動網絡營運商安裝基站。該計劃將通過「需求主導」的方式逐步擴展到其他政府場所，研究在公眾收費電話亭和巴士站上蓋等公共設施安裝基站[4]。

推出鼓勵及早使用5G技術資助計劃

通訊辦於 2020 年 5 月 5 日推出鼓勵及早使用5G技術資助計劃[5]，通過提供財政誘因，鼓勵各界盡快使用5G技術，推動創新和智慧城市的應用。政府將資助獲批項目中，與使用5G技術直接相關的50%[6]實際開支。為推動持續創新，政府透過防疫抗疫基金增加撥款，將總資助額由5,000萬港元增加至1億港元，預計可惠及額外約100個合資格項目[7]。

簡化電訊設施的審批程序

通訊辦和屋宇署已於 2021 年初為安裝於建築物外牆的小型5G基站天線和收發器等電訊設施推出簡化審批程序。此外，當局計劃於2021年 9 月推出簡易網上平台，以方便自助登記低功率室內基站。

解決大埔「3.5 GHz限制區」的問題

現時大埔及赤柱的衛星通訊站使用 3.5 GHz頻帶。該頻帶被認為是 5G 服務中最廣為使用的頻帶。為避免信號干擾，通訊辦在大埔及赤柱設立限制區，限制在區內設置使用 3.5 GHz頻帶的流動基站[8]。政府一直積極與兩家衛星營運商[9]商討，將位於大埔使用 3.5 GHz頻帶的衛星測控站遷往春坎角電訊港，預計於2024年底前完成[10]。

[2] Global mobile Suppliers Association（GSA）（2021）。5G Market Snapshot - Member Report - November 2021。
[3] 吳珈毅（2020，4月14日）。5G技術。取自香港特別行政區立法會網址：https://www.legco.gov.hk/research-publications/chinese/essentials-1920ise06-5g-technology.htm
[4] 卓聖德（2020，9月29日）。香港的5G發展概況與工商業的應用。取自通訊管理事務局辦公室網址：https://www.ofca.gov.hk/filemanager/ofca/listarticle/tc/upload/2173/Presentation_notes_at_HKLF.pdf
[5] 自計劃推出以來，通訊辦共接獲415宗申請，已批出103宗。 獲批項目的平均資助金額約為 44萬港元。 - 香港特別行政區政府（2021，7月14日）。立法會二十一題：第五代流動通訊服務。取自香港特別行政區政府新聞公報網址：https://www.info.gov.hk/gia/general/202107/14/P2021071400227.htm
[6] 通訊事務管理局辦公室（無日期）。鼓勵及早使用5G技術資助計劃。取自通訊事務管理局辦公室網址：https://www.ofca.gov.hk/tc/industry_focus/industry_focus/5g_subsidy/index.html
[7] 香港特別行政區政府（2021，7月4日）。政府增加「鼓勵及早使用5G技術資助計劃」總資助額並延長申請期。取自香港特別行政區政府新聞公報網址：https://www.info.gov.hk/gia/general/202107/04/P2021070200592.htm?fontSize=1
[8] 吳珈毅（2020，4月14日）。5G技術。取自香港特別行政區立法會網址：https://www.legco.gov.hk/research-publications/chinese/essentials-1920ise06-5g-technology.htm
[9] 其中一家營辦商已獲地政總署批出土地。 另一家營辦商也在與各部門商討批地細節方面取得良好進展。
[10] 香港特別行政區政府（2021，7月14日）。立法會二十一題：第五代流動通訊服務。取自香港特別行政區政府新聞公報網址：https://www.info.gov.hk/gia/general/202107/14/P2021071400227.htm?fontSize=1

The large bandwidth, low latency, and high connectivity of 5G make it more compatible with edge computing. It provides a network foundation for the further integration of edge computing and AI technology, namely edge intelligence. It allows users to run AI processes without worrying about the impact of privacy or slow data transmission and smart devices can quickly respond to input without accessing the cloud platform.

1.3 5G Development

In response to the opportunities brought, countries around the world expect 5G to help drive future economic growth. In April 2019, the United States and South Korea took the lead in launching commercial 5G services. As of November 2021, 469 operators in 140 countries/territories were investing in 5G. 182 operators in 73 countries/territories had launched one or more 5G services[2].

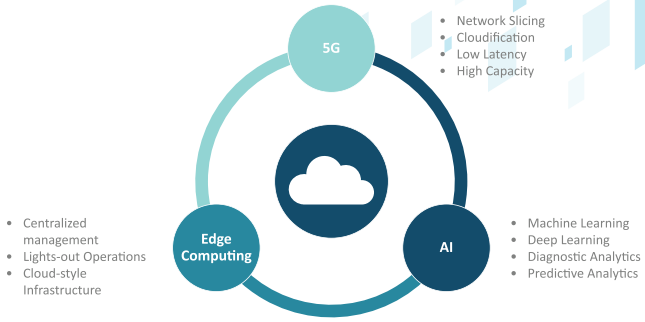


Figure 1.10 Combination of 5G, Edge Computing and AI

In Hong Kong, mobile network operators officially launched the 5G service commercially on April 1, 2020. As of May 2021, Hong Kong's 5G network has covered more than 90% of the population, including large shopping malls and all stations on the main MTR lines. Some core commercial areas or densely populated areas have a coverage rate of 99%[3].

To ensure the sustainable development of 5G services, the government promotes the development of 5G in many aspects. Below are some measures to facilitate 5G deployment in Hong Kong:

Open Government Premises

The government was proactively opening more than 1,000 suitable outdoor or indoor government premises for mobile network operators to install base stations in March 2019. The scheme will be gradually extended to other government premises through a "demand-oriented" approach. The installation of base stations in public facilities, such as public telephone booths and bus shelters, is also under study[4].

Launch Subsidy Scheme for Encouraging Early Deployment of 5G

OFCA launched the Subsidy Scheme for Encouraging Early Deployment of 5G on 5 May 2020[5]. By providing financial incentives, various industries are encouraged to deploy 5G technology as soon as possible to promote innovation and smart city applications. The government will subsidize 50% of the actual costs directly related to deploying 5G technology in approved projects[6]. To promote continuous innovation, the government has increased funding for the scheme through the Anti-epidemic Fund to increase the total funding from HK$50 million to HK$100 million. It is expected that about 100 additional eligible projects will be benefited[7].

Simplify Approval Procedures for Telecommunication Facilities

OFCA and the Buildings Department have already introduced simplified approval procedures for telecommunications facilities such as small 5G base station antennas and transceivers installed on the outer walls of buildings at the beginning of 2021. In addition, the authorities plan to launch a simple online platform in September 2021 to facilitate the self-registration of low-power indoor base stations.

Solve "3.5 GHz Restricted Zone" Problem in Tai Po

Satellite communication stations in Tai Po and Stanley currently use the 3.5 GHz frequency band. This frequency band is considered to be the most widely used frequency band in 5G services. To avoid signal interference, OFCA has established restricted zones in Tai Po and Stanley to restrict the installation of mobile base stations in the 3.5 GHz frequency band[8]. The government has been actively discussing with the two satellite operators[9] to move the stations in Tai Po that uses the 3.5 GHz frequency band to Chung Hom Kok Telecommunications Port. It is expected to be finished before the end of 2024[10].

[2] Global mobile Suppliers Association (GSA). (2021). 5G Market Snapshot - Member Report - November 2021.
[3] Ng, G. (2020, April 14). 5G Technology. Retrieved from Legislative Council of the Hong Kong Special Administrative Region Website: https://www.legco.gov.hk/research-publications/english/essentials-1920ise06-5g-technology.htm
[4] Cheuk, S. (2020, September 29). Overview of 5G Development and Industry. Retrieved from Office of the Communication Authority Website: https://www.ofca.gov.hk/filemanager/ofca/listarticle/en/upload/2173/Presentation_notes_at_HKLF.pdf
[5] Since the launch of the scheme, OFCA has received a total of 415 applications, and 103 applications have been approved. The average funding amount for approved projects is about HK$440 thousands. - The Government of the Hong Kong Special Administrative Region. (2021, July 14). LCQ21: The fifth generation mobile communications services.
Retrieved from The Government of the Hong Kong Special Administrative Region Press Releases Website: https://www.info.gov.hk/gia/general/202107/14/P2021071400234.htm?fontSize=1
[6] Office of the Communication Authority. (n.d.). Subsidy Scheme for Encouraging Early Deployment of 5G. Retrieved from Office of the Communication Authority Website: https://www.ofca.gov.hk/en/industry_focus/industry_focus/5g_subsidy/index.html
[7] The Government of the Hong Kong Special Administrative Region. (2021, July 4). Government increases funding and extends application period for Subsidy Scheme for Encouraging Early Deployment of 5G. Retrieved from The Government of the Hong Kong Special Administrative Region Press Releases Website: https://www.info.gov.hk/gia/general/202107/04/P2021070200587.htm?fontSize=1
[8] Ng, G. (2020, April 14). 5G Technology. Retrieved from Legislative Council of the Hong Kong Special Administrative Region Website: https://www.legco.gov.hk/research-publications/english/essentials-1920ise06-5g-technology.htm
[9] One of the operators has been granted land by the Lands Department. The other operator is also making good progress in discussing the details of the land grant with various departments.
[10] The Government of the Hong Kong Special Administrative Region. (2021, July 14). LCQ21: The fifth generation mobile communications services.
Retrieved from The Government of the Hong Kong Special Administrative Region Press Releases: https://www.info.gov.hk/gia/general/202107/14/P2021071400234.htm?fontSize=1

1.4 5G與物聯網的融合

雖然現時的電訊基礎設施可以實現物聯網帶來的部分好處，但前幾代的移動通訊技術無法配合自動機械人等先進技術。 5G 的超低時延特性可以支持至關重要和其他需要精確度且延遲時間僅為一毫秒的應用。涉及生死攸關情況的應用更需要同時具有低時延和超可靠性。任何網絡故障或滯後都會導致災難性後果。

4G網絡的設備容量限制了物聯網技術。與4G相比，5G每平方公里最多可支持一百萬台設備，是4G的十倍。5G讓連接的設備既能低功耗又能低數據消耗。設備的連接性是很重要，因為如果設備消耗大量能源和需要傳送大量數據，系統可能會在瞬間崩潰。5G 不僅可以處理更多設備，還可以提供更高的速度。設備變得越來越複雜，以及收集和發送的信息越來越多，會積累了大量數據。這些設備的通訊速度，將決定其實際用途。

1.4.1 物聯網介紹

物聯網包括各種可以連接到互聯網的物件或設備，例如工廠設備、車輛和移動設備。物聯網設備可以通過可用的網絡連接，從其環境中收集數據以執行操作。分析物聯網網絡中的數據後得出的結果可以幫助業界作出更多的業務決策。

物聯網可以收集大數據，協助分析和制定策略。公司可以更自由地追蹤和了解用戶或目標客戶的行為模式和偏好，以進一步改善產品、服務和營運。它為企業節省了資源、成本和時間。

1.4.2 5G物聯網應用在香港的市場潛力

5G和物聯網的融合將在我們生活的各個方面創造前所未有的應用和服務。一些重要的應用領域包括：

車聯網（C-V2X）

C-V2X技術是一種通訊系統，可將車輛與一切事物連接起來，包括其他車輛、行人、道路基礎設施和網絡。例如，它使道路使用者能夠實時接收警示，以增強道路安全並提高交通效率。

工業自動化

工業自動化是使用技術和自動控制設備，使機器和工業設備在沒有人為干預的情況下運行，以降低成本、提高產品質量和安全性，並提升流程效率。

智慧物流

智慧物流是將交通管理結構與交通導航相結合，優化交通系統和物流管理。其目標是改善運輸和倉儲管理，使物流流程更快、更安全、更可靠。

自動駕駛汽車（AV）

AV也被稱為無人駕駛汽車，通過感知周圍環境的能力，可以在沒有任何人為干預的情況下自行運作，從而提高道路安全、駕駛員生產力和交通效率，並降低能源消耗。

電動車（EV）

EV是一種使用一個或多個電動機來推動的環保車輛。它使用可再生電力來降低燃料成本。物聯網設備可用於監控和提醒用戶有關車輛的電池效率，以實現最佳充電模式。

圖1.11 5G應用領域

智能家居/樓宇

智能家居/樓宇可以高效、經濟地使用資源。它使用具有自動化、實時監控或遠程控制功能的基本家庭/辦公設備來提高安保水平、安全性、能源效率和用戶的生活質素，並降低成本。

智慧城市

智慧城市是利用數字化方法改善資產管理、提供高效社區服務、解決城市問題等的現代市區，為市民提供更可持續、更高效的生活。

智慧醫療

智慧醫療系統使患者和醫務人員能夠通過交換分析的數據來進行交流。例如，它增強了醫療保健觀察、治療、健康問題檢測和診斷能力，以提高運營效率、患者護理、患者滿意度和降低成本。

1.4 Convergence of 5G and IoT

Although part of the benefits brought by IoT can be realized in the existing telecommunications infrastructure, the previous generations of mobile communication technology cannot integrate automated robots and other advanced technologies. The ultra-low latency feature of 5G supports mission-critical applications and other applications that demand precision with only a millisecond delay. Applications in life-or-death situations require to be low latency and ultra-reliable at the same time. Any network failure or lags would lead to catastrophic consequences.

The capacities of 4G networks limit the IoT technology. Compared with 4G, 5G can support up to a million devices per square kilometre, which is ten times more than 4G. 5G network ensures the devices connected to the network can have both low power and data consumption. The connectivity to the devices is important because if the equipment consumes a lot of power and requires sending a lot of data, everything will fall into pieces in a moment.

5G can not only handle more devices, but it also provides much higher speeds. As devices become more complex, the devices collect and send more information, accumulating a large amount of data. The communication speed of all these devices determines their practical use.

1.4.1 IoT Introduction

IoT includes all kinds of objects or devices that can be connected to the Internet, such as factory equipment, vehicles, and mobile devices. IoT devices can retrieve data from their environment through available network connections to perform operations. After analysing data in the IoT network, insights derived can help make more business decisions.

IoT can collect big data, assist in the analysis, and formulate strategies. Companies can have greater freedom to track and learn the behaviour patterns and preferences of users or target customers to further improve products, services, and operations. It saves resources, costs, and time for enterprises.

1.4.2 Market Potential of 5G IoT Applications in Hong Kong

The convergence between 5G and IoT will create applications and services in all aspects of our lives that have never seen before. Some important application areas are:

Cellular Vehicle-to-Everything (C-V2X)

C-V2X technology is a communication system that connects vehicles to everything, including other vehicles, pedestrians, roadside infrastructure, and networks. For example, it enables road users to receive warnings in real-time to enhance road safety and improve traffic efficiency.

Industry Automation

Industry automation is the use of technologies and automatic control devices that results in operating machines and industrial equipment without human intervention to reduce cost, improve product quality and safety, and also increase process efficiency.

Smart Logistics

Smart logistics is the combination of traffic management structure and traffic navigation to optimize traffic systems and logistics management. The goal is to improve management for transportation and warehousing to make logistics processes faster, safer, and more reliable.

Autonomous Vehicles

An autonomous vehicle (AV), also known as a self-driving car, can operate itself without any human intervention through the ability to sense the surrounding environment, to increase road safety, drivers' productivity, and traffic efficiency, and reduce energy consumption.

Electric Vehicles

An electric vehicle (EV) is an eco-friendly vehicle that uses one or more electric motors for propulsion. It uses renewable electricity to reduce fuel costs. IoT devices can be used in it to monitor and alert battery efficiency for best charging practices.

Smart Home/Buildings

A smart home/building enables efficient and economical use of resources. It uses basic home/office amenities with automation, real-time monitoring, or remote-control functions to improve security, safety, energy efficiency and users' quality of life, and reduce costs.

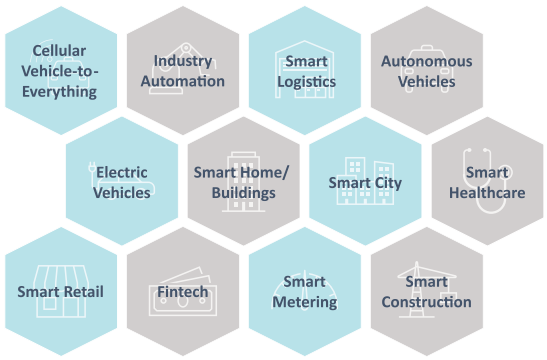


Figure 1.11 5G Application Areas

Smart City

A smart city is a modern urban area that uses digital methods to improve asset management, provide efficient community services, solve city problems, etc. It enables a more sustainable and efficient living for the citizens.

Smart Healthcare

A smart healthcare system enables patients and medical staff to communicate by exchanging analysed data. For example, it enhances healthcare observation, treatment, health issues detection, and diagnosis for operational efficiency, patient care, patient satisfaction improvement, and cost reduction.

Smart Retail

Smart retail allows a business to respond quickly to customer needs and market trends by using data analytics to optimize operations, boost sales performance, improve customer experience, and more.

Fintech

Fintech means financial technologies that can improve and automate the delivery of financial services. For instance, it provides personalized customer service and streamlines internal operations to enhance customers' experience.

智慧零售

智慧零售允許企業通過數據分析來優化營運、提高銷售業績、改善客戶體驗等，從而快速回應客戶需求和市場趨勢。

金融科技

金融科技是指可以改進和自動化金融服務的金融技術。例如，它提供個性化的客戶服務並簡化內部營運以增強客戶體驗。

智能報錶

智能報錶追蹤能源消耗，能讓用戶遠程監控能源消耗數據。它提高了消費者的意識，節省能源，降低開支等。

智慧建築

智慧建築充分利用數碼技術進行建築設計、施工和營運，通過在建築現場安裝傳感器和攝像鏡頭或使用可穿戴設備來提升工作效率和提高安全性。

根據調查（圖1.12），大多數受訪者稱5G物聯網應用的潛力很大，都高於平均水平。

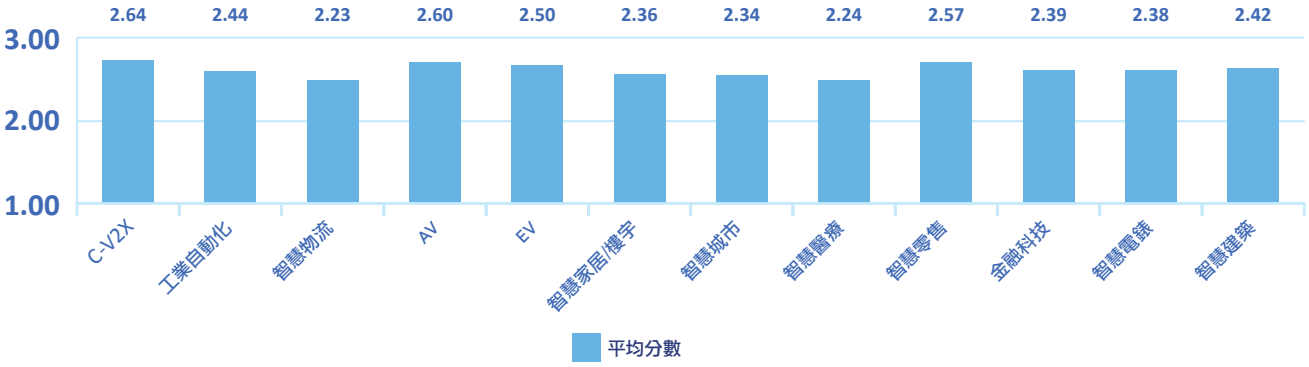


圖1.12 香港 5G物聯網應用的市場潛力評級（1 = 高潛力；5 = 低潛力）

根據調查（圖1.13），超過一半的受訪者認為在整體上5G物聯網應用在香港具有中/高潛力，這意味著市場對在香港應用5G物聯網持積極態度。

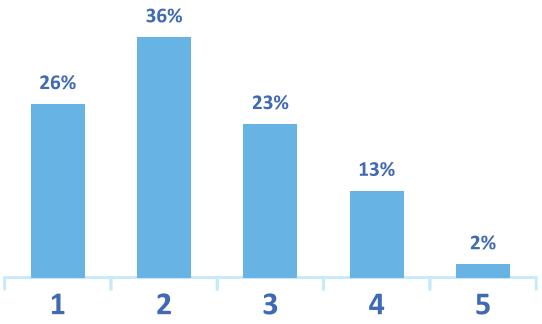


圖1.13 在整體上5G物聯網技術在香港的市場潛力評級（1 = 高潛力；5 = 低潛力）

此外，大多數受訪者（圖 1.14）願意在未來 2-3 年內於5G物聯網上增加 1-29% 的投資。這表明他們認為5G物聯網技術可以為他們的公司帶來新的商機。

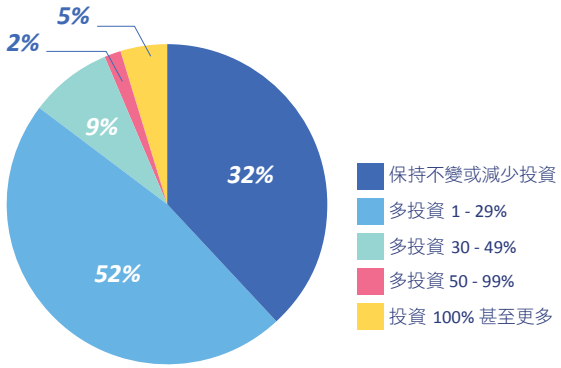


圖1.14 企業在未來 2-3 年內於5G物聯網上的投資意向

Smart Metering

A smart meter keeps track of energy consumption. Smart metering refers to remotely monitoring energy consumption data by using smart meters. It improves consumer awareness, saves energy, lowers expenses, etc.

Smart Construction

Smart construction makes full use of digital technologies for building design, construction, and operations to optimize working efficiency and improve safety by installing sensors and cameras on-site or using wearables.

According to the survey (figure 1.12), most of the respondents claim that there is a high potential to use 5G IoT applications, and all of them have above average potential.

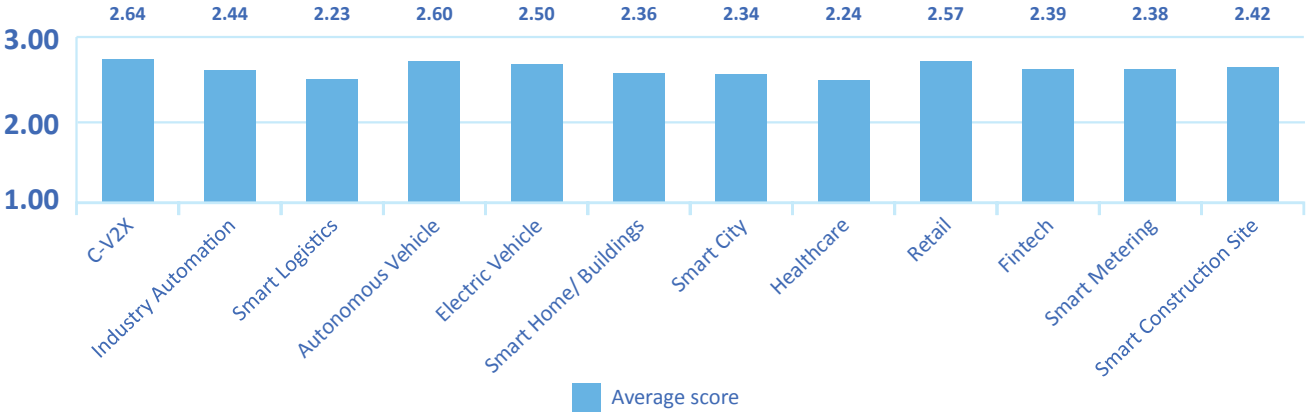


Figure 1.12 The Rating of the Market Potential of the 5G IoT Applications in Hong Kong (1 = High Potential; 5 = Low Potential)

From the survey (figure 1.13), over half of the respondents see there is a medium/high potential of 5G IoT applications as a whole in Hong Kong, meaning the market is having a positive attitude towards applying 5G IoT applications in Hong Kong.

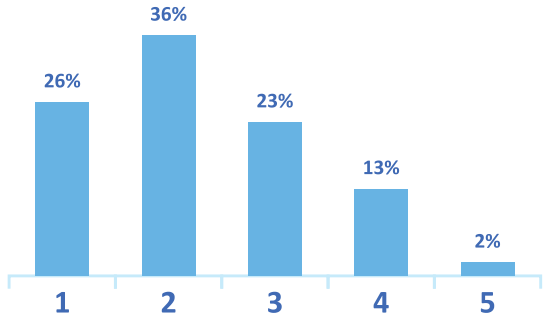


Figure 1.13 The Rating of the Market Potential of 5G IoT Technology as a whole in HK (1 = High Potential; 5 = Low Potential)

Besides, most of the respondents (figure 1.14) are willing to invest 1-29% more in 5G IoT in the coming 2-3 years. It shows that they consider 5G IoT technology can bring new business opportunities for their companies.

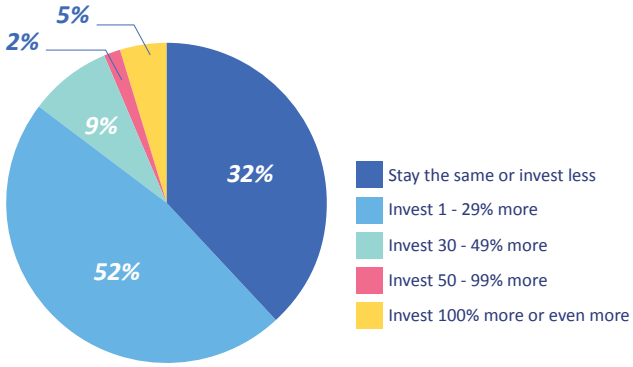


Figure 1.14 View in Changing Companies' 5G IoT Investment in the Coming 2-3 Years

1.4.3 業界在5G物聯網的發展狀況

超過一半的受訪者擁有一個或多個使用物聯網應用的項目，其中大多數是使用 5G 而不是其他通訊技術。超過三分之一涉及5G物聯網的項目正處於研究階段。

大約一半的受訪者擁有一個或多個創建物聯網應用的項目，其中大多數涉及 5G。涉及5G物聯網的項目中有三分之一正處於規劃階段。

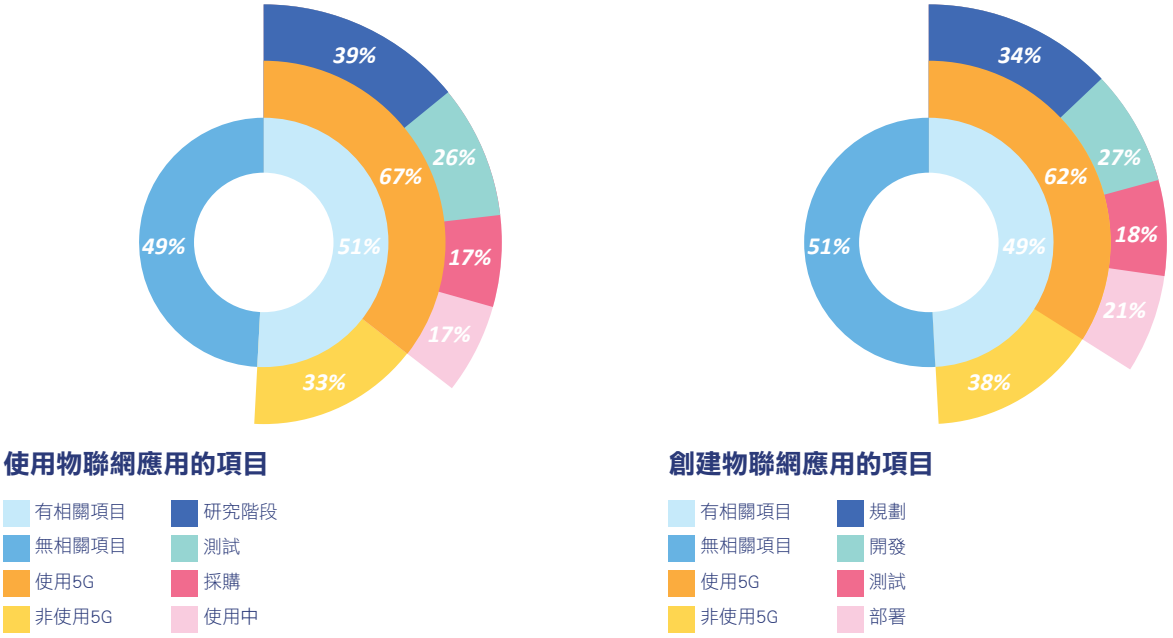


圖1.15 使用/創建物聯網應用的項目

據觀察所得，約有一半的香港企業在本地擁有物聯網項目。此外，對於大多數從事物聯網應用的企業來說，他們正在將物聯網與 5G 技術相結合。大多數用戶都在學習中，而創作者則在規劃5G物聯網的應用，這顯示了市場在不斷增長。

1.5 按行業劃分的5G物聯網應用

5G物聯網技術能幫助行業創造新產品和服務以擴大市場，亦能提高生產力和效率以降低成本，或提高安全性以降低風險。以下部分探討了 13 個不同垂直行業如何使用5G物聯網技術以及企業對不同應用的態度。

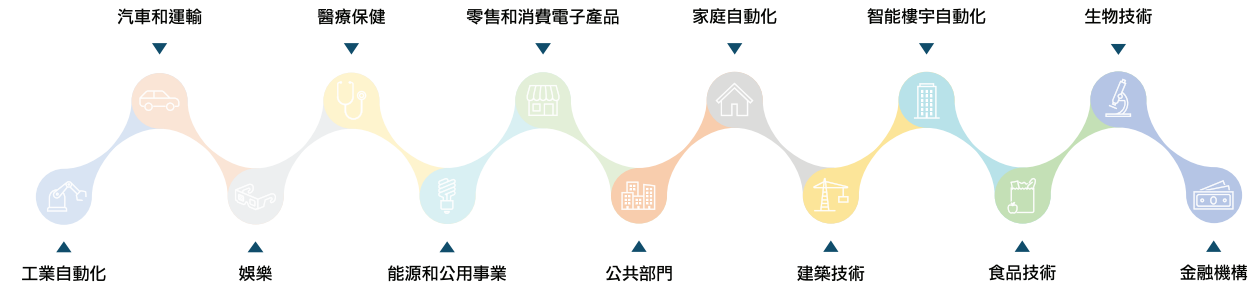


圖1.16 介紹 13 個使用5G物聯網技術的垂直行業

1.5.1 工業自動化應用

AR和遠程專家

企業從國外聘請專家解決他們從未遇到過的問題既費錢又浪費時間。AR技術讓專家和工人之間能夠實時互動。專家可以向沒有經驗的工人遠程地展示如何快速修復故障機器。這把維護成本降到最低，促進了在故障排除上的溝通，節省了時間，並提高首次修復率。

實時監控

監控生產現場大大改善工廠管理並確保員工的安全。企業可以通過實時監控系統了解員工的工作狀態，加強員工考勤管理，提高工廠效率等。此外，實時生產狀態和環境監測可以優化生產線運作。

1.4.3 5G IoT Development Status in the Industries

Over half the respondents has one or more project(s) in using IoT applications, and most of them are using 5G instead of other communication technologies. More than one-third of the projects involving 5G IoT are in the stage of studying.

About half the respondents have one or more project(s) in creating IoT applications, and most of them involve 5G. One-third of the projects involving 5G IoT are in the stage of planning.

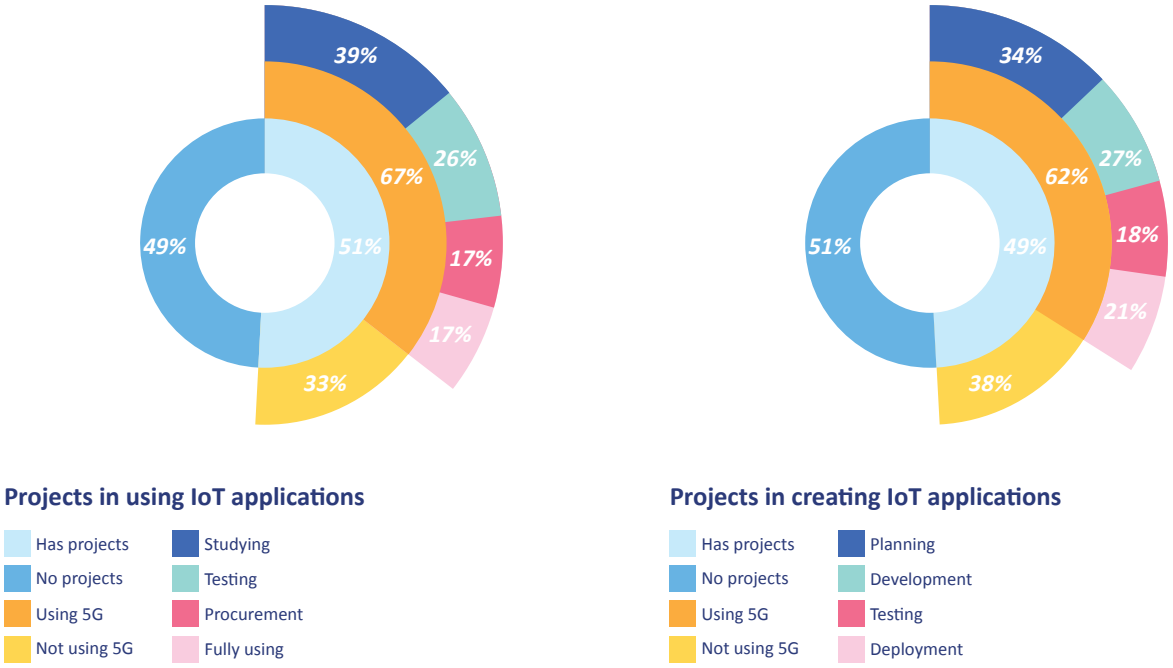


Figure 1.15 Projects in Using/Creating IoT Applications

As observed, about half of the enterprises in Hong Kong have IoT projects locally. Moreover, for most of the enterprises working on IoT applications, they are integrating IoT with 5G technology. Many users are studying, and many innovators are planning for 5G IoT applications. It shows the market keeps on growing.

1.5 5G IoT Applications by Industry Verticals

5G IoT technology helps industries create new products and services to expand the market, increase productivity and efficiency to reduce costs or improve safety to reduce risks. The following sections explore how 5G IoT technology is being used across 13 different industry verticals and the attitude of enterprises towards different applications.

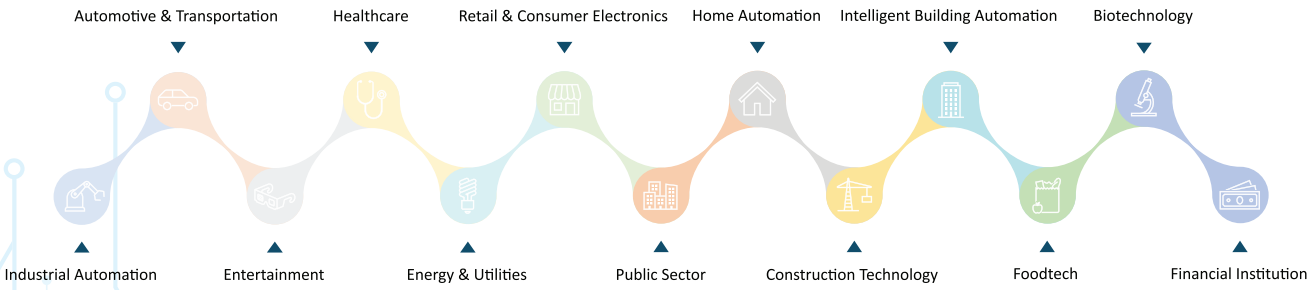


Figure 1.16 Introducing 13 Industry Verticals Using 5G IoT Technology

1.5.1 Industrial Automation Applications

AR and Remote Expert

It is costly and wastes time for enterprises to hire experts from abroad to solve problems they have never encountered before. AR technology allows real-time interaction between experts and workers. Experts can show inexperienced workers how to quickly fix a malfunctioning machine remotely. It minimizes maintenance costs, facilitates troubleshooting communication, saves time, and improves first-time fix rates.

Real-time Monitoring

On-site and production monitoring greatly improves factory management and ensures employees' safety. A real-time surveillance system allows enterprises to understand the working status of the employees, strengthen the management of employee attendance, improve factory efficiency, etc. Besides, real-time production status and environmental monitoring can optimize production line operations.

遠程管理

許多生產線已轉移到內地和東南亞國家。在這種情況下，遠程管理是提高業務營運效率的關鍵。企業不單可以完全掌握生產過程，而且審批程序亦能隨時隨地在遠程終端上進行。此外，通過實時庫存和業務數據分析，企業可以實時掌握分支機構的庫存狀態，並進行調整以降低成本。

協作機械人

協作機械人（cobot）是一種在工作空間中與人類一起工作但不是自主的機械人。它們為工人執行骯髒、危險或重複性的任務，例如拾取和放置物品。讓工人可以處理需要更多人類決策的任務，使用協作機械人可以取得一致的產品質量和處理。公司可以輕鬆地在質量控制問題和員工培訓方面節省成本和時間。

高級預測性維護

生產線突然停機、故障排除延遲、人為操作錯誤以及重複的設備維護都會導致額外的成本。預測性維護能透過分析和檢測故障前的機械狀態來預測停機時間，提前告知哪些設備需要維護或更換。預警可以避免突然停機和維護的高昂成本，提高工廠效率。

供應鏈資產管理和跟蹤

為了防止生產瓶頸和延誤的高昂代價，跟蹤所有材料的流動可以快速準確地了解問題並在造成延誤之前進行必要的調整以解決問題。資產跟蹤使公司能夠收集、報告和可視化實時信息，以衡量資產利用率來進行分析。它可以提高運營效率、節省時間和降低成本。

數字孿生

數字孿生幫助公司預測設備和系統在不同環境條件下的反應。公司可以積極規劃製造流程以提高運營效率，亦可隨時進行持續分析、測試、維護和在異常情況下的恢復，從而縮短試錯過程，保持產品質量和穩定性。

供工人使用的智能可穿戴設備

智能可穿戴設備可以為工人提供安全和環境信息，幫助他們了解周邊環境。公司可以向工人發出具體指示，並引導他們前往工作區域。它們也可以通知工人有關工廠的任何變化。此外，可穿戴設備可以跟蹤工人的活動，並進行身份驗證。

根據問卷調查，大部分受訪者在未來投資實時監控和遠程管理的可能性很大。相信隨著大部分企業的生產線轉移到不同的國家，遠程管理和實時監控對於它們管理和了解生產線是有效的。其他更受關注的應用包括了供應鏈資產管理和跟蹤、供工人使用的智能可穿戴設備和高級預測性維護。

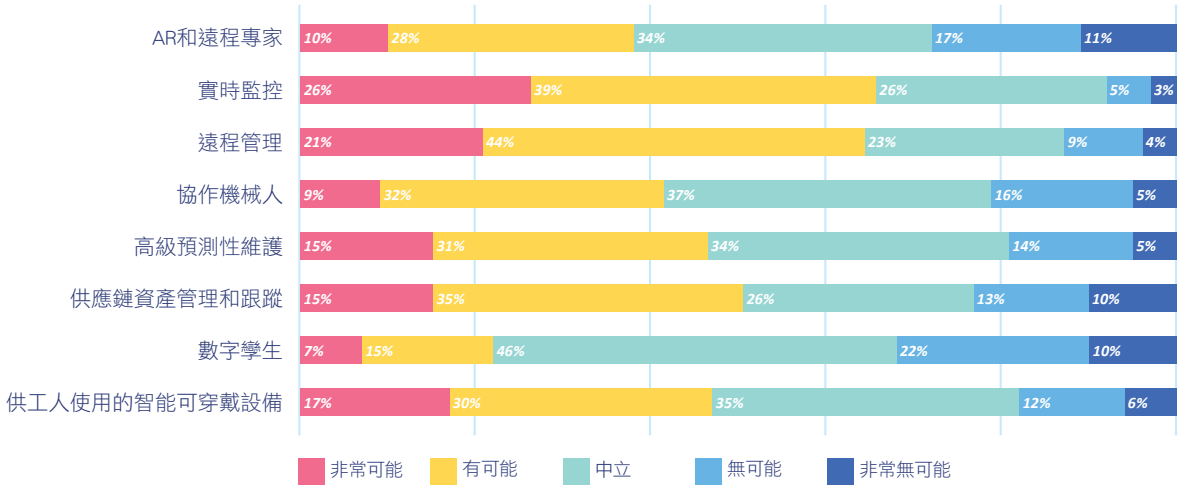


圖1.17 工業自動化應用

1.5.2 汽車和運輸應用

自動駕駛

AV 也被稱為無人駕駛汽車，為一種需要或完全不需要駕駛員輔助的車輛。它們無需人工操作即可感知環境並導航。它們還可以與智能道路基礎設施和車輛互動，形成智能交通系統，改善交通安全、提高生產力和效率，並增強舒適性和便利性。

車載信息娛樂系統

車載信息娛樂系統為駕駛員和乘客提供信息和娛樂。傳感器和攝像鏡頭能跟蹤車輛的狀況並將數據發送到流動應用程式上。如果有人試圖在未經授權的情況下進入車輛，系統會向車主發出警報。車主亦可以遠程控制汽車。該系統還可提供汽車導航和附近加油站和其他景點的信息。

Remote Management

Many production lines have moved to the mainland and Southeast Asian countries. In this case, remote management is a key to efficient business operations. The production process can be visible, and the approval process can be operated on remote terminals anytime and anywhere. Also, with real-time inventory and business data analysis, companies can keep track of the inventory flow status of branches and adjust to reduce inventory costs.

Collaborative Robotics

A collaborative robot (cobot) is a robot designed to work with humans in a workspace but is not autonomous. They help human workers perform dirty, dangerous, or repetitive tasks, such as pick and place. Workers can then handle tasks that require more manual input. Cobots can obtain consistent product quality and surface finishes. Companies can easily save costs and time in quality control issues, and employee training.

Advanced Predictive Maintenance

Sudden shutdown of the production line, delays in troubleshooting, human operating errors, and repeated equipment maintenance lead to additional costs. Predictive maintenance analyses and detect mechanical states before failure and predict downtime to tell in advance which equipment needs to be maintained or replaced. Early warnings can avoid a high cost of sudden shutdown and maintenance, improving factory efficiency.

Supply Chain Asset Management and Tracking

To prevent production bottlenecks and costly delays, tracking the flow of all materials can quickly and accurately understand the problem and make necessary adjustments to resolve it before causing delays. Asset tracking enables companies to collect, report, and visualise real-time information to measure asset utilization for analysis. It leads to higher operational efficiency, time savings, and cost reduction.

Digital Twins

Digital twins help companies to predict how devices and systems react under different environmental conditions. Companies can actively plan manufacturing processes to improve operational efficiency. Continuous analysis, testing, maintenance, and recovery of abnormal conditions can be carried out at any time, thereby shortening the trial-and-error process to maintain product quality and stability.

Smart Wearables for Workers

Smart wearables can provide workers with safety and environmental information to help them understand their environment. Companies can give specific instructions to workers and direct them to their working areas. Workers can also be notified of any changes in factories. Besides, wearable devices can track the activities of workers, and perform Identity authentication.

According to the questionnaire survey, most of the respondents have a high likelihood to invest in real-time monitoring and remote management in the future. It is believed that as the production lines of most companies are moved to different countries, remote management and real-time monitoring are effective for them to manage and understand production lines. Other applications that are more likely to be of interest include supply chain asset management and tracking, smart wearables for workers, and advanced predictive maintenance.

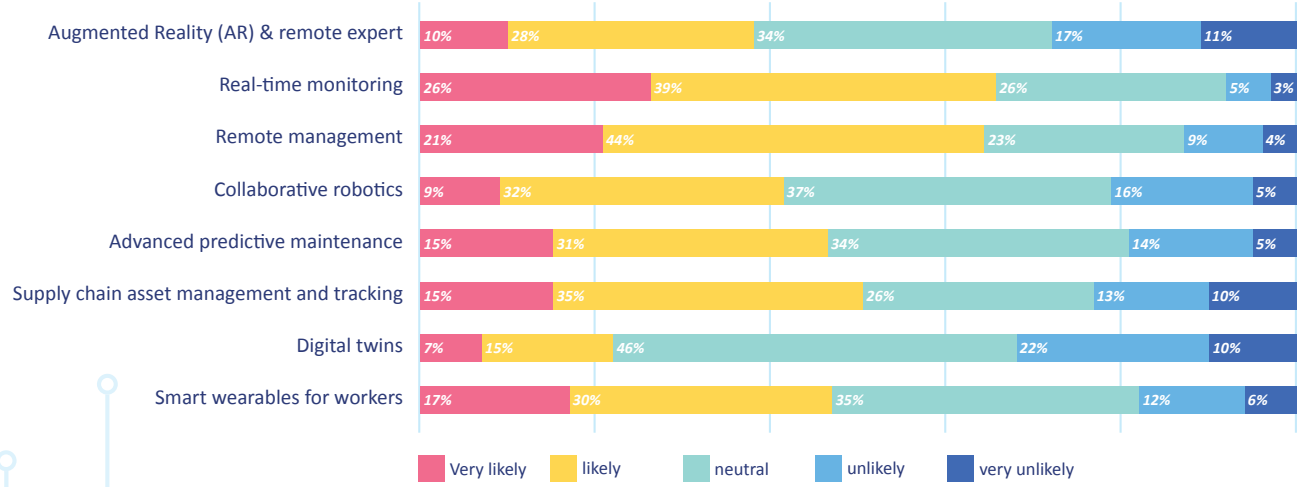


Figure 1.17 Industrial Automation Applications

1.5.2 Automotive and Transportation Applications

Autonomous Driving

AVs are also known as unmanned vehicles that require or do not require driver assistance at all. They can sense their environment and navigate without human operations. AVs can also interact with smart road infrastructure and vehicles to form an intelligent transportation system. They can improve traffic safety, increase productivity and efficiency, and enhance comfort and convenience.

Car Infotainment

In-vehicle infotainment is used to provide information and entertainment for drivers and passengers. Sensors and cameras track the condition of the vehicle and send the data to a mobile application. If someone tries to enter the vehicle without authorization, the system will alert car owners. Users can control the car remotely. The system also offers car navigation and information about nearby gas stations, and other points of interest.

車隊管理

從集合了重量測量器、位置跟蹤器和其他傳感器的貨車車隊上收集的傳感器數據，經過分析後可以幫助日常營運管理。公司可以優化路線、監控效率並把路線延誤減到最低，以保持交通暢通。它提供實時位置監控、貨物重量/體積跟蹤、性能統計、交通狀況跟蹤和駕駛員管理的功能。

電動車充電站和管理

公司可以輕鬆監控和訪問已連接的EV充電站，以進行遠程支持和維護。透過流動應用程式，駕駛者可以輕鬆找到附近的充電站並安排充電時間。若有可用的充電站，應用程式將自動通知司機。用戶亦可以訪問有關充電過程的所有實時信息。

庫存跟蹤

庫存跟蹤能檢查店中的用品或商品的數量。公司能夠使用智能標籤和傳感器跟蹤庫存的狀態和位置。可以防止公司損失，確保貨物存放安全，並提供貨物位置。它還可以幫助企業改善倉儲營運，從而減少人工處理錯誤，降低人工成本，提高效率。

庫存溫度監控

配備了溫度監控系統的特殊貨櫃可以保持產品從一個位置運輸到另一個位置時能處於適宜的環境。通過使用溫度監測傳感器，公司甚至可以跟蹤運送途中的環境參數。它使運輸過程變得透明，並使公司能夠保持其產品的質量。

C-V2X

透過C-V2X，人、車輛和道路基礎設施能相互連接，它亦可以對潛在危險進行實時預警並報告給道路使用者，以增強道路安全和輔助駕駛。它可以應用於實時交通監控、事件管理和路線規劃，以提高交通效率。長遠來看，它可以配合自動駕駛，輔助判斷隱患，提高道路安全。

預測性維護

公司可以確認車輛的性能並在損壞之前修復汽車零件。從不同組件中的傳感器所收集的數據隨後通過算法，根據其組件的性能分析及預測結果。在問題發生之前發送可能的故障警報可以讓公司能夠採取必要的措施來節省成本。

數字孿生

例如，公司可以透過嵌入物聯網傳感器的貨櫃監控貨櫃位置、氣候條件、振幅、坡度和噪音水平及空氣污染水平。結合庫存和營運數據，該系統可以提供機器狀態和產品可用性的概覽。它還可以對運輸過程做出預測和自主決策。同樣的原則也適用於物流樞紐或全球物流網絡。

從調查來看，大部分受訪者未來可能會投資與庫存跟蹤相關的物聯網應用。庫存對企業來說很重要，因為庫存是公司的資產。跟蹤庫存可以確保手頭有足夠的供應。公司可以跟蹤庫存的狀態和位置，提高營運透明度，以確保效率並計劃未來的行動。這還可以提高香港物流服務的效率和可靠性。此外，一些受訪者還傾向投資於預測性維護、庫存溫度監控系統以及電動車充電站和管理。其中一位受訪者亦有興趣投資於智能鎖和汽車跟蹤。

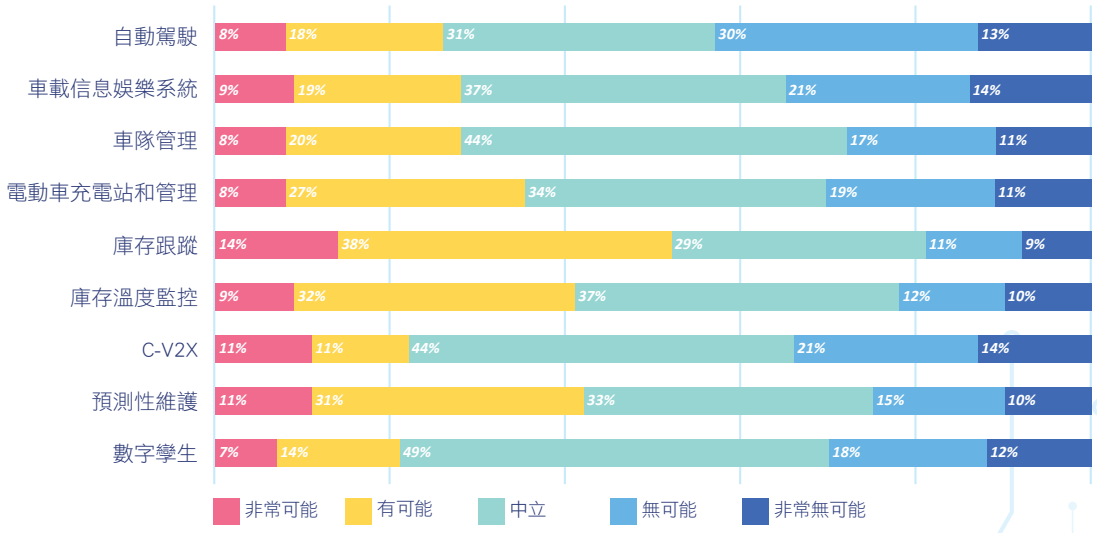


圖1.18 汽車和運輸應用

Fleet Management

Sensor data gathered from a fleet of trucks integrate weight measurers, location trackers, and several other sensors is analysed to help daily operation management. Companies can optimize the route, monitor efficiency, and minimize route delays to keep traffic flow smooth. It offers real-time location monitoring, weight/volume tracking of cargo, performance statistics, traffic conditions tracking, and driver management.

EV Charging Station and Management

Connected EV charging stations can be easily monitored and accessed for remote support and maintenance. With mobile applications, drivers can easily find a nearby charging station and schedule a time to fill up. The application will automatically notify the driver if the station is available. Users can access all real-time information about the charging process.

Track-and-trace Inventory

Inventory tracking is to check the number of supplies or merchandise in the store. Smart tags and sensors enable companies to track inventory items with their status and location. Companies can prevent losses, ensure safe storage of goods, and locate needed items. It can also help companies improve their warehousing operations, thereby reducing manual processing errors, reducing labour costs, and increasing efficiency.

Inventory Temperature-control Monitoring

Companies use special containers integrated with the temperature monitoring system to maintain a suitable environment when transporting the products from one location to another. Using temperature monitoring sensors, the company can even track environmental parameters on the way to the destination. It establishes transparency in the transportation process and enables companies to maintain the quality of their products.

C-V2X

People, vehicles, and road infrastructure are connected. Potential dangers are warned and reported to road users in real-time to enhance road safety and assist driving. It can be applied to real-time traffic monitoring, incident management, and route planning to improve traffic efficiency. In the long run, it can cooperate with autonomous driving, assist in judging hidden dangers, and improve road safety.

Predictive Maintenance

Companies can confirm the performance of the vehicles and repair the car parts before they are damaged. Data collected by sensors embedded in different components is then processed by an algorithm to analyse the future outcomes of the components based on the performance. Alerts of possible malfunctions are sent way before the problem occurs, allowing companies to take necessary measures to save costs.

Digital Twins

For example, a shipping container embedded with IoT sensors can monitor its location, climate conditions, vibration, slope and sound, and air pollution levels. Combining with inventory and operational data, the system can provide an overview of machine status and product availability. It can also make predictions and autonomous decisions on delivery. The same principle applies to logistics hubs or global logistics networks.

From the survey, most of the respondents will probably invest in IoT applications relating to track-and-trace inventory in the future. Inventory is important to enterprises as it is an asset. Tracking inventory can ensure there is enough supply on hand. They can track their status and location, improving operational transparency to ensure efficiency and plan future actions. It can also improve the efficiency and reliability of logistics services in Hong Kong. Besides, some of the respondents also like to invest in predictive maintenance, inventory temperature-control monitoring, and electric vehicle charging station & management.

One of them also likes to invest in smart locks, and automobile tracking.

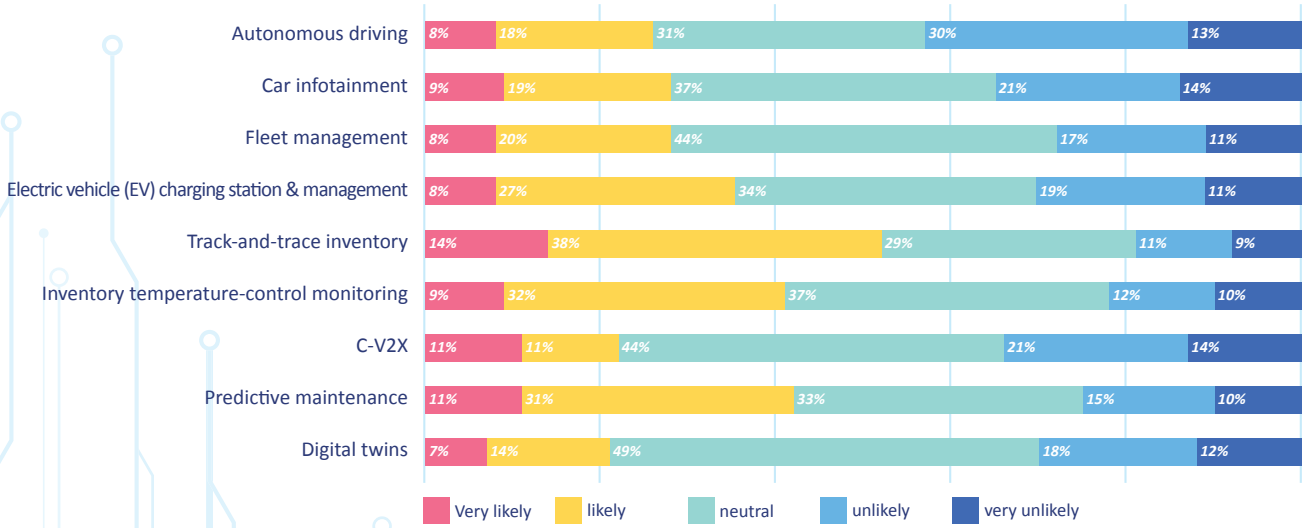


Figure 1.18 Automotive and Transportation Applications

1.5.3 娛樂應用

AR/VR 智能健身

個人信息，例如心率，可以顯示在AR眼鏡或智能手機上。AR讓用戶與虛擬的對象進行互動，帶來更加刺激的健身體驗。而VR技術可以為用戶提供身臨其境的體驗。即使所有用戶不能聚集在一個空間，VR能讓用戶與其他用戶一起訓練。它還能夠分析用戶的運動表現和技術，以提升用戶的表現。

3D通話/全息圖

3D全息圖根據觀看者的位置提供不同的視角。觀看者的眼睛會調整焦深以交替地聚焦前景和背景。3D全息圖對每個光波的亮度和相位進行編碼，這種組合可以更真實地描述場景的視差和深度，因此全息圖可以讓場景變得栩栩如生，讓觀看者沉浸在更逼真的畫面中。

智能可穿戴設備

智能可穿戴設備包括智能手錶、衣服、鞋子和不同的智能配件。衣服可能包含收集信息的電子部件，與織物接觸的皮膚或汗液產生的信息可能包括穿著者的脈搏、血糖水平、體溫、血壓和血氧水平。教練可以利用這些指標來制定未來的訓練計劃和比賽策略。

無人機

在第一人稱視角（FPV）無人機競賽中，無人機駕駛員佩戴可顯示來自車載攝像鏡頭影像的FPV眼鏡，以控制無人機儘快完成指定的賽道。另一例子是由發光、同步和精心編排的無人機機群進行的無人機燈光秀。在表演中，無人機機群能在夜空中拼湊出多變的形狀。

智能自行車

已安裝速度與踏頻傳感器的智能自行車可實現直接的用戶互動。企業可以通過分析騎行、消費、用戶行為數據來規劃市場策略，滿足用戶服務需求。他們也可以通過大數據分析進行精確的業務決策並改善客戶服務。而用戶則可以使用智能手機中的流動應用程式來跟蹤自行車和搜索附近商店。

體感遊戲

體感遊戲增加了玩家對遊戲的投入程度。通過動作感應器檢測用戶活動和身體姿勢，可改善玩家的遊戲體驗，讓他們的虛擬角色能夠以與現實世界相同的方式行動。遊戲還可以透過攝像鏡頭進行人臉識別和語音識別，以識別用戶並創建玩家的骨架圖像。

AR/VR遊戲

AR遊戲將游戲的視聽內容整合到用戶的環境中。玩家可以透過遊戲來探索一個新的城市，甚至是一個他們從未去過的城市的某一部分。VR遊戲使用VR眼鏡形成 3D 環境，讓玩家與遊戲世界互動。玩家還可以通過其他VR遊戲設備（例如帶有傳感器的手套）體驗和影響遊戲環境。

互動表演

延展實境（XR）涵蓋AR、VR和混合實境（MR），讓用戶沉浸在多感官的音樂體驗中。VR眼鏡讓觀眾能夠在家中體驗坐在音樂會前排的感覺。AR眼鏡則可以用於顯示互動元素，例如表演燈光秀和實時顯示歌詞。而借助MR，用戶可以在真實環境中演奏多種虛擬樂器。

從調查來看，大部分受訪者未來很有可能會投資智能可穿戴設備。如今，智能手錶等智能可穿戴設備變得越來越流行。它們為用戶提供更多個人信息，以便更好地了解他們在運動鍛煉中的健康狀況。此外，智能健身、遊戲、3D通話/全息圖等AR/VR相關應用在市場上越來越突出，這可能與新興的流行語「元宇宙」有關。此外，一些受訪者亦傾向投資於互動表演。

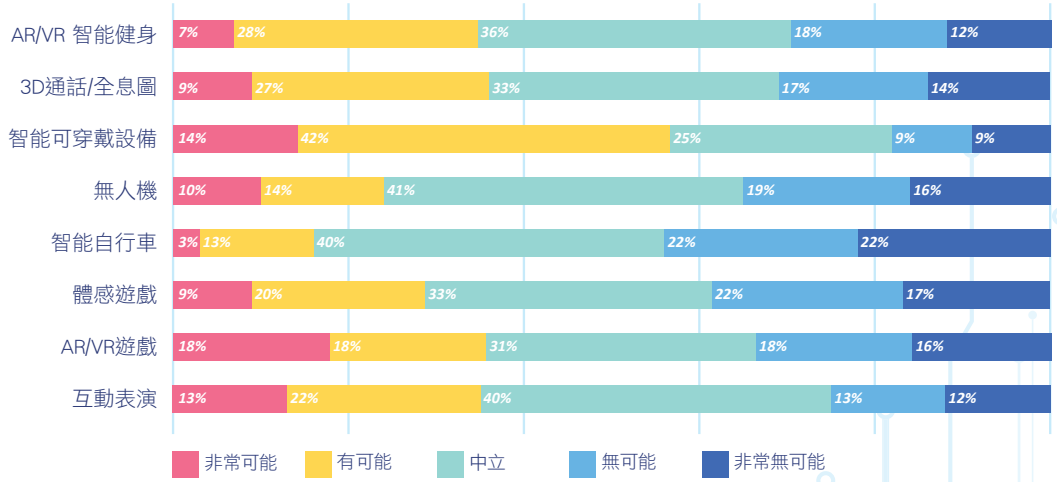


圖1.19 娛樂應用

1.5.3 Entertainment Applications

Smart Fitness with AR/VR

Personal information, such as heart rate, can be displayed on AR glasses or smartphones. AR also allows users to interact with objects that are not existed, making their workout more stimulating. VR technology can provide an immersive experience. Even if everyone cannot gather in one space, VR allows training with others. It is also able to analyse sports performance and technique, improving users' performance.

3D Calls/Holograms

3D holograms provide varying perspectives based on the viewer's position. They allow the eye to adjust the depth of focus to focus on the foreground and background alternately. They encode the brightness and phase of each light wave. This combination can describe the parallax and depth of the scene more realistically, so the hologram can make the scene come alive, allowing viewers to immerse themselves in a more realistic view.

Smart Wearables

Smart wearable devices are smartwatches, smart clothes, shoes, and different smart accessories. Clothes may contain electronic parts that collect information. The information produced from the skin or sweat in contact with the fabric may include the wearer's pulse, blood sugar level, body temperature, blood pressure, and blood oxygen level. The instructor can use the indicators to develop future training plans and formulate competition strategies.

Drone

For first-person view (FPV) drone racing, drone pilots wear FPV goggles that show the video image from the onboard camera to control the drone and complete a set course as quickly as possible. Another example is drone light shows performed by illuminated, synchronized, and choreographed groups of drones, which arrange themselves into various aerial formations.

Smart Bicycle

Smart bicycles with speed and cadence sensors enable direct user interaction. Companies can analyse cycling, consumption, and users' behaviour data to plan market strategies and meet user service needs. Enterprises can perform precise business decision-making and improve customer service with big data analysis. Cycling tracking and nearby stores searching can be also performed with a mobile application in smartphones.

Motion Gaming

Motion games increase players' game enthusiasm. Motion sensors that detect the movement and body posture of users improve players' game experience, allowing their virtual characters to act the same way as in the real world. A camera can also be used to perform face recognition and voice recognition to identify users and create a skeleton image of the player.

AR/VR Gaming

AR games integrate the game's audio and visual content into the user's environment. Players can explore a new city and even experience a part of a town they have never been to before with the game. VR games use headsets to form a 3D environment and allow players to interact with the game world. Players can also experience and influence the gaming environment through other VR gaming devices, such as gloves with sensors.

Interactive Performances

Extended Reality (XR), which covers AR, VR, and Mixed Reality (MR), can immerse users in a multi-sensory music experience. VR headsets allow audiences to experience what it is like to be in the front row of a concert at home. AR glasses can display interactive elements like performing light shows and displaying lyrics in realtime. With MR, users can also play with many virtual instruments in a real environment.

From the survey, most of the respondents are very likely to invest in smart wearables in the future. Smart wearables like smartwatches are becoming more popular these days. They offer users more personal information for a better understanding of their health conditions during workouts. In addition, AR/VR-related applications such as smart fitness, games, and 3D calling/holograms are becoming more and more prominent in the market, possibly due to the emerging buzzword "Metaverse". Also, some of them like to invest in interactive performances.

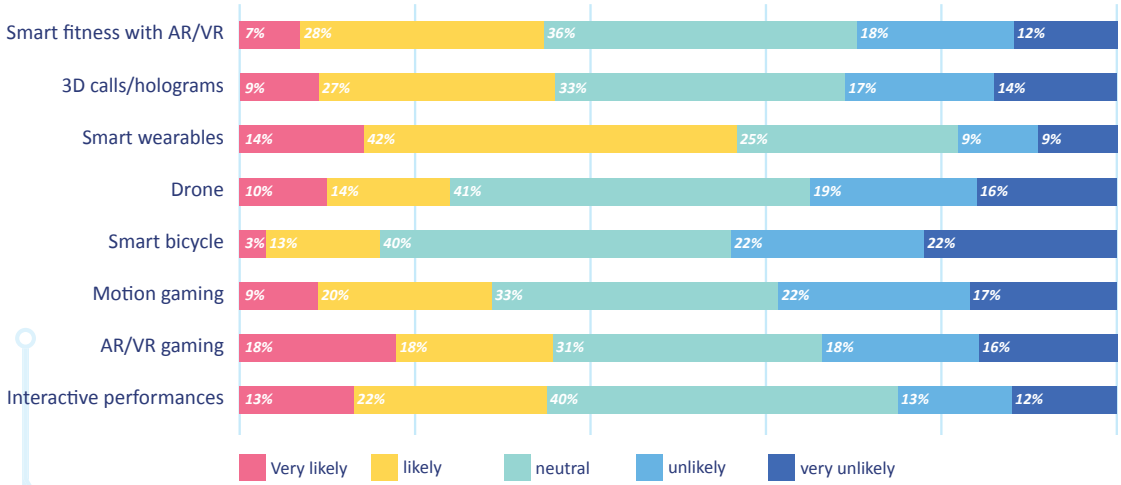


Figure 1.19 Entertainment Applications

1.5.4 醫療保健應用

遠程患者監護

能廣泛兼容傳統醫療傳感器和設備的可穿戴醫療傳感器平台可以令傳統醫療系統解決方案供應商快速提供有效的遠程患者監護服務，為患者、醫院和服務提供商提供高效便捷的服務。它能大幅降低成本，減少不必要的面診，從而提高患者的生活質素。

遠程診斷

遠程診斷可以避免醫護在與患者接觸時受到感染。它能監測患者的康復情況，幫助患者治理長期慢性疾病，促進健康和預防疾病。患者可以通過流動應用程式獲得醫療建議、診斷和其他醫療支援。早期輕症可以通過AI預警通知，讓醫生提前對症下藥。

機械人看護

臨床環境中的機械人可以支援醫務人員並加強患者護理，減低感染風險。護理機械人可以幫助清潔和整理病房，減少傳染病病房中人與人之間的接觸。它們還縮短了識別、比較和向醫院患者提供藥物所需的時間。它們為患者和醫務人員提供高水平的護理、高效的醫療流程和安全的環境。

機械人手術

機械人手術可以減少醫生失誤，精準及安全地進行手術。讓醫生能夠專注患者的病情。這不僅可以提高手術的成功率，還可以減少手術時間和手術過程中對醫務人員產生的壓力。因此，它亦降低了患者因全身麻醉而出現的風險。

跌倒偵測

跌倒偵測系統可以在危險情況下及時發出警報並分析跌倒原因，從而提高行動不便者的生活質素。具有跌倒偵測功能的智能可穿戴設備可以在檢測到跌倒時自動啟動緊急跌倒警報，並呼叫應急機構尋求幫助。機構可以評估設備上報告的情況並委派醫療人員以提供協助。

工作人員/患者/庫存跟蹤

患者跟蹤服務可以讓護士識別病人的位置，並快速引導病人移至指定區域，提升患者就醫體驗。當醫院需要緊急救助時，工作人員跟蹤可以迅速調配相關人員進行醫療救助，提高醫療效率。庫存跟蹤可以報告設備和庫存的使用狀態和位置，提高醫院營運效率。

用於醫療培訓的 VR

VR能作為一種教育工具來幫助沒有經驗的醫生了解各種醫療操作。它能用於模擬人體組織器官，進行模擬手術，以及幫助學生更快地了解手術要領。它可以顯示360度全景影像，以實現更好的模擬體驗。

智能救護車

智能救護車將患者的診療數據和監測影像實時傳輸至醫院。醫院內的醫生可以實時觀察患者的生理反應，並與救護車上的醫護人員進行溝通，提供遠程急救指導。醫院還可以在患者上救護車時，提前做好接收患者的急救診療準備。

數字孿生

透過傳感器獲得的人體數據可以為患者器官創建數字孿生。醫生可以利用其器官的數字孿生來模擬手術後患者能否得救。它不僅可以預測結果以避免不必要的手術，還可以預測哪些患者有機會生病以及患者對特定治療的反應，從而節省醫療費用。

根據調查，大多數受訪者未來很有可能投資於遠程患者監護。鑑於醫療資源稀缺，遠程患者監測是改善醫療保健營運的關鍵，因為它使臨床醫生能夠遠程了解患者的實時健康狀況。此外，一些受訪者傾向投資遠程診斷，尤其是在疫情期間，需求有所增加。另外，他們還對投資跌倒偵測和工作人員/患者/庫存跟蹤感興趣。

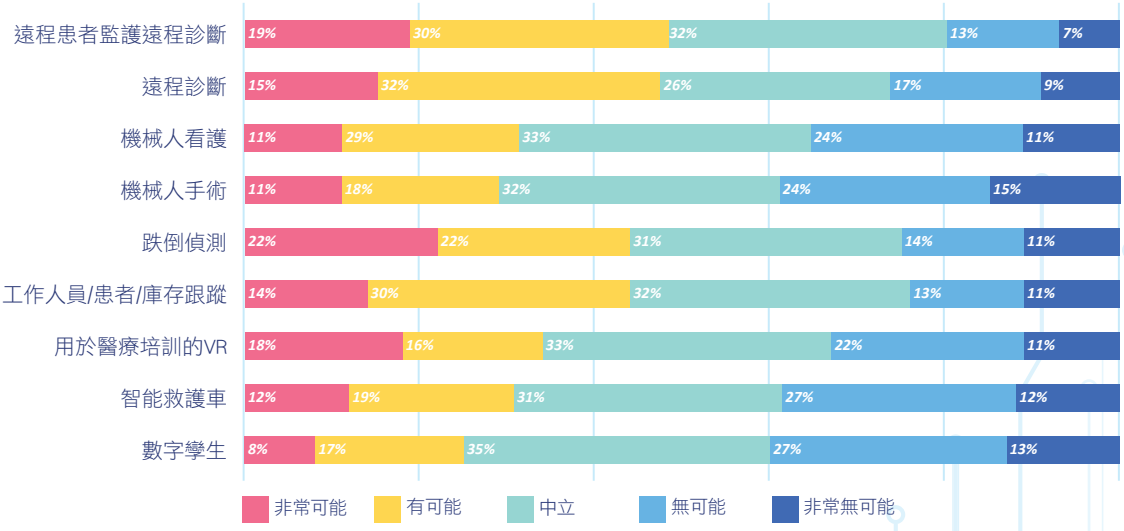


圖1.20 醫療保健應用

1.5.4 Healthcare Applications

Remote Patient Monitoring

With medical sensors and equipment, flexible and wearable medical sensor platforms can help traditional medical system solution providers quickly provide effective remote patient monitoring services, which are efficient and convenient for the patient, hospitals, and service providers. It minimizes costs, eliminates the need for some visits, and helps improve the patients' quality of life by avoiding travel inconvenience.

Remote Diagnosis

Remote diagnosis can avoid doctor-patient contact with the infection. It also monitors patients' recovery situations and helps patients manage long-term chronic diseases, promoting health and disease prevention. Patients can obtain medical advice, diagnosis, and other medical support through mobile applications. Earlystage mild illnesses can be notified by AI early warning so that doctors can prescribe the right medicine in advance.

Robotic Nursing

Robots in clinical settings can support medical workers and enhance patient care to help reduce exposure to infection. Robots help clean and prepare wards, reducing human-to-human contact in infectious disease wards. They also shorten the time required to identify, compare, and deliver drugs to patients in hospitals. They provide high-level patient care, efficient processes, and a safe environment for patients and medical workers.

Robotic Surgery

Surgical robots can help doctors avoid misjudgements and mistakes and perform safe and efficient surgery with precision. Doctors can then pay more attention to the patient's condition. Not only can the success rate of the operation be increased, but it can also reduce the surgery time and pressure generated during the operation. Therefore, it reduces the risk of patients due to general anaesthesia.

Fall Detection

A fall detection system can promptly issue an alarm in dangerous situations and analyse the cause of the fall, thereby improving the quality of life of persons with limited mobility. Smart wearables with fall detection can automatically activate the emergency fall alarm and call the emergency response agent for help when they detect a fall. The agent can evaluate the situation reported on the device and send medical personnel to help.

Staff/Patients/Inventory Tracking

Tracking service can allow nurses to identify a patient's location and quickly guide the patient to move to the designated area, which improves the patient's medical experience. When the hospital needs emergency assistance, staff tracking can quickly deploy relevant personnel nearby for medical assistance to improve medical efficiency. Inventory tracking keeps the use status and location of equipment and inventory and improves hospital operating efficiency.

VR for Medical Training

VR works as an educational tool to help inexperienced doctors understand various operations. It can simulate human tissues and organs, perform simulation operations, and help students understand the essentials of surgery faster. It can show a 360-degree panoramic view to achieve better simulation.

Smart Ambulance

Smart ambulance transmits patients' diagnosis and treatment data and monitoring images to the hospital in real-time. Doctors in the hospital can observe patients' physiological responses in real-time and communicate with medical staff in the ambulance to provide remote emergency guidance. Hospitals can also prepare for receiving patients in advance for first-aid diagnosis and treatment when patients get on ambulances.

Digital Twins

Human body data obtained by sensors can be used to create digital twins for patient organs. Doctors can use the digital twin of the organ to simulate whether the patient can be saved after the operation. It not only predicts the outcome to avoid unnecessary operations but also predicts which patients have the chance to get sick and how the patients respond to specific treatments, saving medical expenses.

According to the survey, most of the respondents have a high likelihood to invest in remote patient monitoring in the future. Given the scarcity of medical resources, remote patient monitoring is the key to improving healthcare operations as it enables clinicians to remotely understand the real-time health status of patients. Also, some of them like to invest in remote diagnosis, especially during the pandemic, the demand has increased. In addition, they are also interested in investing in fall detection, and staff/patients/inventory tracking.

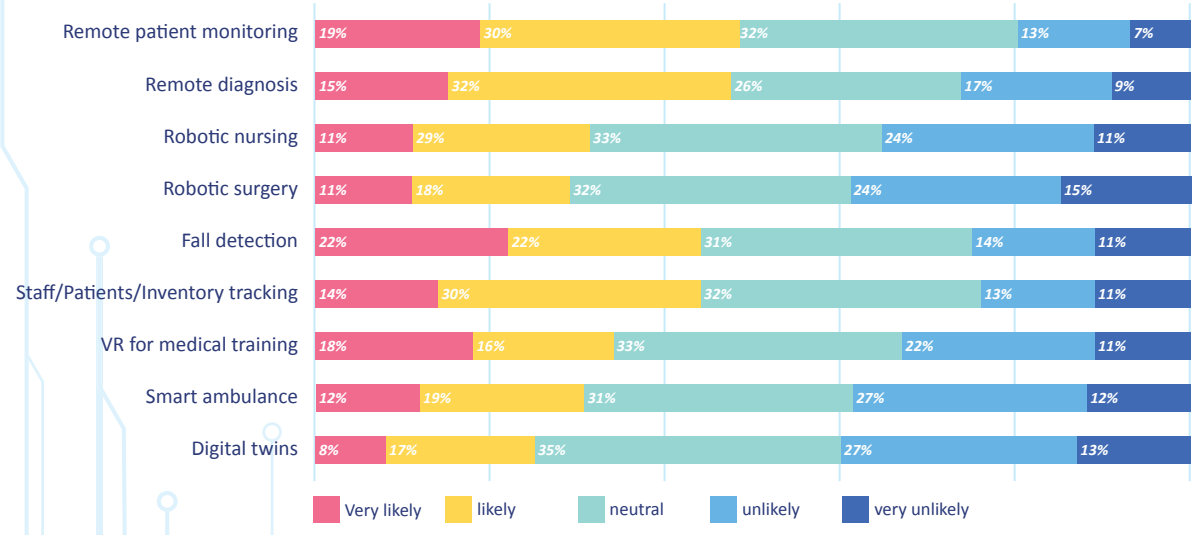


Figure 1.20 Healthcare Applications

1.5.5 能源和公用事業應用

智能報錶

智能報錶系統記錄電力、煤氣或水的消耗量，用於監控和計算費用。通過使用智能電錶/煤氣錶/水錶進行各種遠程數據讀取和控制功能，用戶可以了解其能源消耗，並進一步調整能源使用以節省成本。

無人機監控

無人機可以快速識別能源設備如風力發電機及太陽能電池板的所有損壞，防止潛在問題發生。它們可以快速識別異常情況、監控生產能源的進度並創建3D地圖。無人機還使公司能夠為服務產品和基礎設施改進方面做出更快、更準確的決策和分析。它們可以加強檢查水平、安全性及保障性，並快速回應偵測到的事故。

智能電網

智能電網提供更多的服務以提高電網的可靠性、耐受性和反應能力。公用事業公司可以實現細緻和準確的實時能源需求。這使它們能夠更好地預測和應對突然增長的需求，防止停電。

資產監控

資產監控可以確保油氣資源開採和運輸的安全性。它創建了一個更高效、反應更迅速的基礎設施，並使供應鏈更高效、更安全。傳感器數據用於預測鑽機和其他關鍵設備組件的潛在故障，以避免停機。公司可以確定何時需要自動關閉設備以防止災難。

實時水質監測

水質監測系統隨時跟蹤建築物的水質。放置在管道中的濁度傳感器用於測量水的透明度，以檢查水樣是否混濁或不透明。持續的水質監測可以確保大廈供水維持正常的濁度水平。

數字孿生

數字孿生可以在施工前複製公用事業資產的物理和營運特徵，並有助於改善物理裝置的運作和維護。它能協助營運商取得更好的能源管理，營運商可以在不干擾實物資產營運的情況下，控制數字資產的狀況進行場景規劃。

調查顯示，大多數受訪者未來可能會投資智能報錶。長期以來，電力、天然氣和水供應商最依賴人工操作。智能報錶可以有效幫助企業節省人力資源，減少人為錯誤。此外，一些受訪者還傾向投資實時水質監測。香港水務署現已開始試行無人船系統，在水塘進行水質監測和取樣。另外亦有一些受訪者還對投資智能電網和無人機監控感興趣。

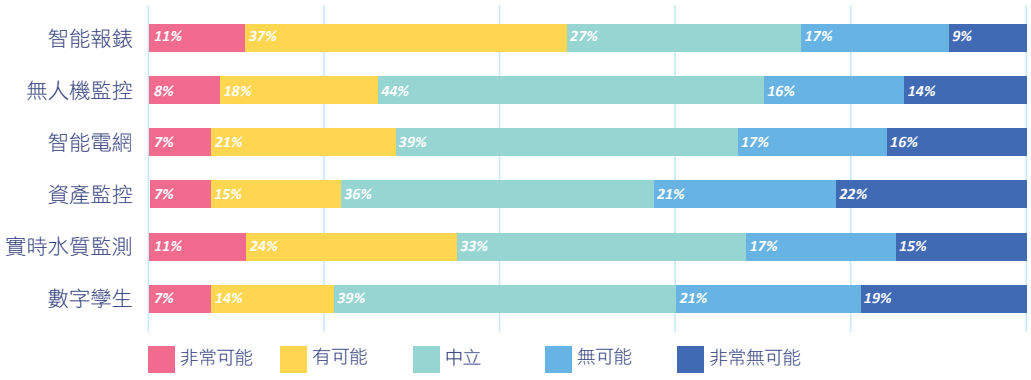


圖1.21 能源和公用事業應用

1.5.6 零售和消費電子產品應用

AR/VR購物

AR讓買家虛擬地體驗影像化的產品。它幫助用戶在購買前獲得更真實的產品體驗來了解產品。例如購物者可以虛擬試妝。VR能以虛擬商店的形式為買家提供身臨其境的深度體驗。它可以模擬不存在或購物者難以訪問的各種場景。購物者亦可以在購買前虛擬地嘗試不同的衣服。

店內體驗/客流量監控

基於視頻的流量監控可以了解客戶是否停留在某產品區域。員工可以實時指導及幫助顧客或調整店面佈局，提高顧客拜訪效率。此外，它還可以通過實時觀察店內客流量和客戶需求來調整店內購物體驗。它亦允許商戶在商店或通過客戶的流動裝置進行個性化營銷。

1.5.5 Energy and Utilities Applications

Smart Metering

Smart meters record the consumption of electricity, gas, or water for monitoring and billing purposes. By using smart meters for various remote data reading and control functions, users can understand the energy consumption for their spaces and further adjust their energy usage to save energy and costs.

Drone Surveillance

Drones can quickly identify all damage from wind turbines to solar panels to prevent potential problems. They can identify abnormalities quickly, monitor progress, and create 3D maps. Drones also enable companies to make faster and more accurate decisions and analyses for service products and infrastructure improvements. They can enhance the inspecting process, safety, security and provide quick responses for detected incidents.

Smart Grid

A smart grid provides more services and improves grid reliability, survivability, and responsiveness. Utility companies can realize real-time energy demand with granularity and accuracy. It allows them to better predict and respond to sudden demand increases, preventing power outages.

Asset Monitoring

Asset monitoring can be used to ensure the safety of oil and gas resource extraction and transportation. It creates a more efficient and responsive infrastructure and makes the supply chain more efficient and safer. Sensor data is used to predict potential failures of rigs and other critical equipment components to avoid outages. Companies can determine when an automatic shutdown of equipment is required to prevent disasters.

Real-time Monitoring of Water Conditions

A water quality monitoring system keeps track of the water quality of the building at any time. A turbidity sensor placed in the pipe measures the clarity of the water to check whether it is turbid or opaque. Continuous water quality monitoring can ensure the building's water supply maintains a normal turbidity level.

Digital Twins

Digital twins can replicate the physical and operational characteristics of utility assets before construction and help improve operation and maintenance during the life of the physical installation. They enable better management of energy resources. Operators can manipulate the conditions of digital assets for scenario planning without interfering with the operation of physical assets.

The survey shows that most of the respondents will presumably invest in smart metering in the future. Electricity, gas, and water suppliers have long relied the most on manual operations. Smart metering can effectively help companies to save human resources and minimize errors. In addition, some of them also like to invest in real-time monitoring of water conditions. We have seen that the Hong Kong Water Supplies Department has also begun to pilot an unmanned surface vessel system for water quality monitoring and sampling at impounding reservoirs. And some respondents are also interested in investing in smart grid, and drone surveillance.

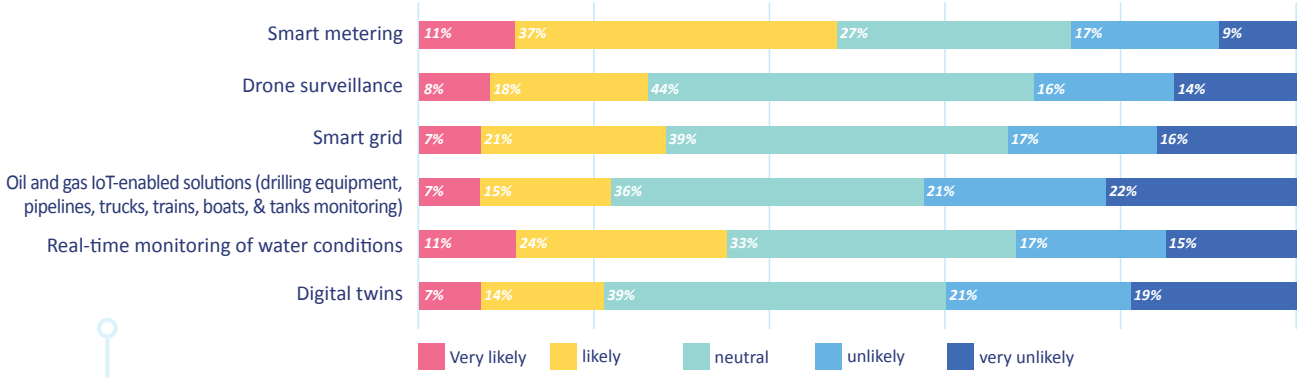


Figure 1.21 Energy and Utilities Applications

1.5.6 Retail and Consumer Electronics Applications

AR/VR Shopping

AR makes it easier for buyers to visualise products. It helps users get to know the product to get a more authentic product experience before buying. For example, shoppers can try on makeup virtually. VR provides buyers with a deeply immersive experience in the form of a virtual store. It can simulate various scenarios that do not exist or are difficult for shoppers to access. Shoppers can virtually try different clothes before buying.

In-store Experience/Foot-traffic Monitoring

Video-based traffic monitoring can see if customers dwell over a product area. Employees can instruct to help customers in real-time or adjust the store layout to improve the efficiency of customer visits. Besides, it can customize the existing in-store shopping experience by observing in-store traffic and customer needs in realtime. It allows implementing personalized marketing in the store or through customers' mobile devices.

店舖營運/智能配送

零售商可以跟蹤貨物從倉庫到交貨的運輸過程，並可持續監控倉庫內物品的溫度、濕度等狀況。公司可以監控其運作、提高透明度並節省成本。它還有助於實時跟蹤貨車並預測倉庫中某些貨物的需求。

倉庫自動化

自動化機械人可以將貨物運送到指定區域，節省人手並提高操作透明度。當庫存降至特定的存貨水平時，傳感器便會發出信號，提醒訂購，避免短缺，從而增加利潤。它將幫助零售商做出以客戶為中心的決策並增強客戶體驗。

預測性設備維護

預測性設備維護使用傳感器來跟蹤設備的狀態，並預測何時需要更新、維修甚至更換以避免出現故障。它能減少停機時間，因為系統能夠在問題發生之前就發出預警。零售商可以透過預測維護問題節省資金，甚至可以監控溫度以確保產品質量。

自動結帳

當客戶離開商店時，結賬系統會識別每個產品上的標籤，並自動從客戶的流動支付應用程式中扣除商品金額。自動結賬系統允許顧客「進入商店，拿完就走」而無需親自結賬。它可以幫助零售商騰出人力資源，節省大量資金，同時提高客戶滿意度。

智能貨架

當缺貨或物品放置不正確時，配備重量傳感器的智能貨架可以通知員工。它不僅可以節省時間，還可以消除導致積壓和貨品短缺的人為錯誤。此外，一旦客戶靠近貨架，貨架就可以推薦相關商品。如果客戶在他們的流動應用程式上建立了購物清單，智能貨架還會顯示物品的位置。

機械人員工

機械人可以確保產品處於正確的位置。他們可以釋放商店員工的人力並改善客戶溝通。具備可擴展機械臂的機械人可以快速及輕鬆地進入狹窄的通道和利用高貨架，從而增加商店使用空間的方式。機械人還可以幫助顧客拿取較高貨架上的物品以及存放在鎖定區域後的昂貴物品。

根據問卷調查結果，大部分受訪者未來可能會投資於倉庫自動化。人們認為高度依賴勞動力的長期影響是顯而易見的，而倉庫自動化是可持續增長的必要條件。此外，一些受訪者還對投資AR/VR購物、店內體驗/客流量監控、店舖營運/智能配送等感興趣。這些應用還可以減少商店中的人數，這尤其對零售商在 COVID-19疫情期間更有幫助。此外，其中一位受訪者還有意投資於具有支付功能的智能戒指。

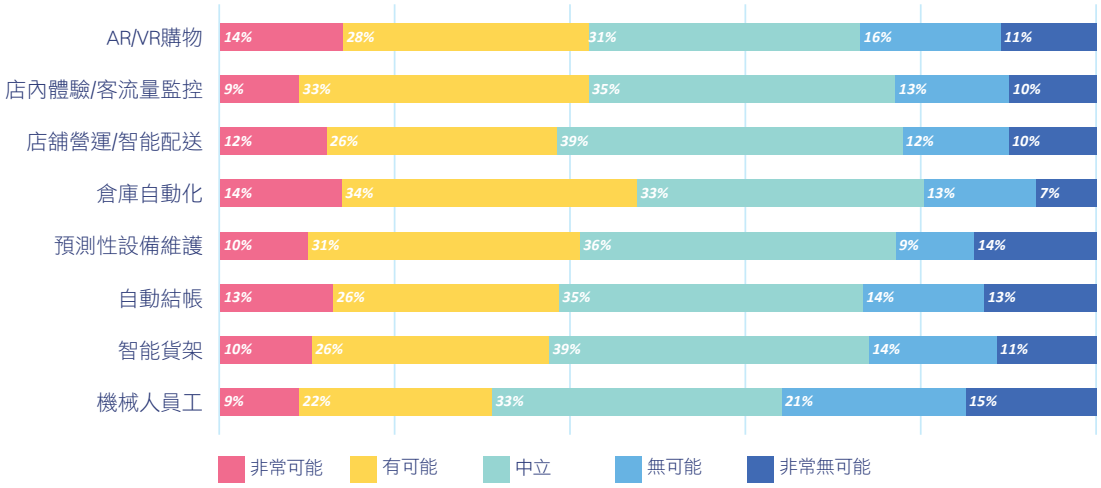


圖1.22 零售和消費電子產品應用

1.5.7 公共部門應用

傳感器網絡

傳感器網絡是由許多分佈式傳感器組成的電腦網絡，用於協同監測不同位置的環境狀況。它可以實時監控、感知和處理各種環境或監控對象的信息。如今，無線傳感器網絡被廣泛應用於環境生態監測、交通控制等多個領域。

智能停車

智能停車使用智能手機和其他傳感裝置，例如設於停車位走道的攝像鏡頭和傳感器，來確定停車場空置停車位。它提高了停車效率並減少了燃料使用，因為司機不需在街道上繞圈尋找停車位，還可以節省停車時間和金錢。

Store Operations/Smart Fulfilment

Retailers can track the transportation of goods from warehouse to delivery. Temperature, humidity, and other conditions of the items in the warehouse can be monitored continuously. Companies can monitor their operations, increase visibility, and save costs. It also helps track trucks in real-time and predicts the demand for certain goods in the warehouse.

Warehouse Automation

Automated robots can transport goods to the designated area. They save labour and increases operation transparency. When the inventory reaches a set level, sensors can also signal an autonomous reordering, avoiding shortages, thereby increasing profits. It will help retailers make customer-centric decisions and enhance customer experience.

Predictive Equipment Maintenance

Predictive equipment maintenance uses sensors to track the status of equipment and predicts when it needs to be updated, repaired, or even replaced to avoid malfunctions. It reduces downtime because the retailer will know that there may be a problem before it occurs. Retailers can save money by predicting maintenance issues and even monitor temperature fluctuations to ensure product quality.

Automated Checkout

A checkout system recognizes labels on each product when a customer leaves the store and automatically deduces the cost from the customer's mobile payment application. The automated checkout system allows customers to walk in, take what they want, and then leave the store without checking out in person. It can help retailers free up human resources and save a lot of money while improving customer satisfaction.

Smart Shelves

When out of stock or items placed on the shelves incorrectly, smart shelves equipped with weight sensors can notify employees. It not only saves time but also eliminates manual errors that cause backlogs and shortages. Also, once customers are close to them, recommendations can be displayed. If customers have built a shopping list on their mobile applications, smart shelves will display the location of the items.

Robot Employee

A robot can ensure products are in correct positions. They can free store employees' time and improve customer communication. Robots designed with expandable arms can quickly and easily access narrower aisles and overhead shelves, increasing the way the store uses space. Robots can also help customers access the items on higher shelves and more expensive items stored behind locked areas.

According to the results of questionnaire survey, most of the respondents will probably invest in warehouse automation in the future. It is believed that the long-term impact of a high reliance on labour is clear, and warehouse automation is a necessity for sustainable growth. Besides, some of them are also interested in investing in AR/VR shopping, in-store experience/foot-traffic monitoring, and store operations/smart fulfilment. These applications can also reduce the number of people in the store, especially during the COVID-19 pandemic.

In addition, one of them also likes to invest in smart rings with payment technology.

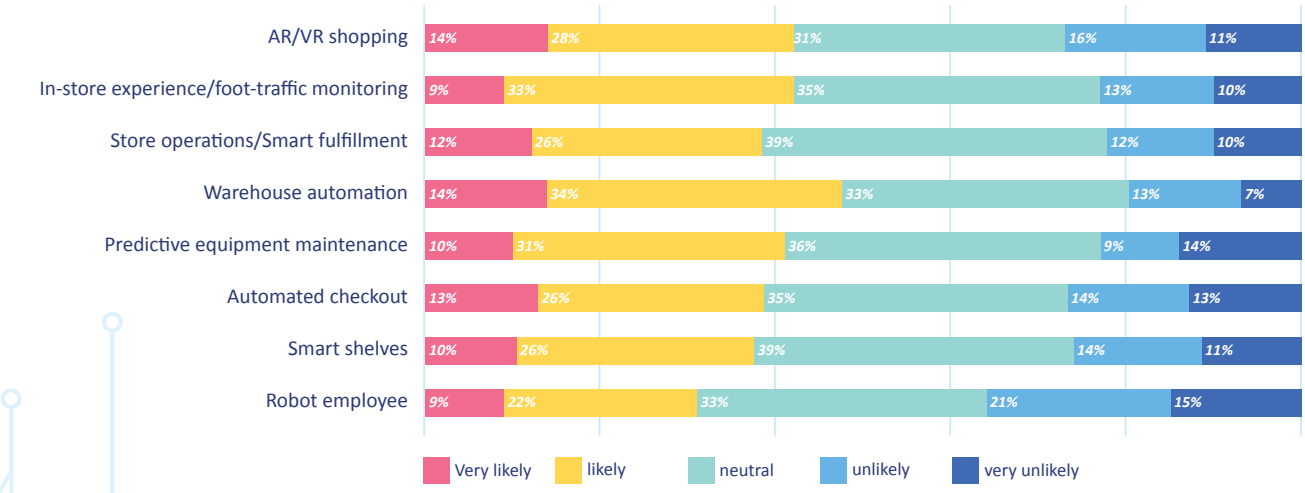


Figure 1.22 Retail and Consumer Electronics Applications

1.5.7 Public Sector Applications

Sensor Networks

A sensor network is a computer network composed of many distributed sensors to cooperatively monitor environmental conditions in different locations. It can monitor, perceive, and process information of various environments or monitored objects in real-time. Nowadays, wireless sensor networks are used in many fields, such as environmental and ecological monitoring, and traffic control.

Smart Parking

Smart parking uses smartphones and other sensing devices, such as cameras and sensors embedded in the sidewalk of a single parking space, to determine parking structure or floor occupancy. It improves parking efficiency and reduces fuel usage because drivers will not circle the streets looking for parking spaces. Drivers can also save money and time on parking.

智能燈柱

智能燈柱收集城市數據，向公眾發布更多實時信息。交通探測器和全景攝像鏡頭，以及天氣和空氣質量傳感器的使用均加強了城市和交通管理。例如，監控不同的交通狀況和交通事故來實現更智能、更安全的交通。

智能垃圾桶

智能垃圾桶內的填充狀態傳感器可以檢測垃圾桶的裝滿程度。清潔公司可以優化垃圾收集路線和頻率，以及垃圾桶的位置。智能安全傳感器亦有助於確保安全。例如檢測到火災，傳感器將發出警報，而垃圾桶會自動滅火。它可以減少人力、排放和改善環境。

視頻監控

監控攝像鏡頭有助於快速反應和預防嚴重事故。視頻監控還可以監控車輛/人流並解決擁堵問題，改善交通管理、城市交通和公共安全。透過分析實時和歷史交通數據，當局能夠預測高峰時間並做出相應的準備。

智能洗手間

跟蹤洗手間和供應品使用情況的智能洗手間可提供靈活的清潔安排。如果人流突然增加並且需要補給品，智能洗手間可以提醒清潔工。設施經理可以循證決策，以保持高水平的客戶滿意度，同時減少客戶或員工的投訴。

智能停車咪錶

智能停車咪錶允許用戶在流動應用程式中實現現場或遠程支付停車費。它們可以提供實時信息幫助司機尋找空置停車位，減少車輛在路上徘徊尋找停車位的時間和交通流量。它們提升用戶體驗並幫助交通管理人員識別停車模式和交通流量。

環境監測

質量監測傳感器網絡可以監測空氣質量、水質和環境噪音水平。通過對污染源的檢測，可以對城市採取糾正措施來改善環境。政府部門可以根據城市的污染情況，制定城市可持續發展和交通路線規劃的政策。

洪水檢測

在關鍵區域的傳感器可以檢測水位並實時報告洪水或潛在的洪水事件。在結合天氣數據進行分析後，政府部門可以更準確地報告信息。這可確保市民免受洪水事件的影響，適當審查新的開發項目以避免洪水，並保護當地流域。

智慧鐵路

智慧鐵路讓鐵路系統中的機器相互通信。透過沿軌道和在火車車廂放置的傳感器和攝像鏡頭，工作人員可以實時查看機器狀態。它使操作人員可以清楚地了解列車的運行狀況，改善列車的維護情況。操作人員還可以知道哪些單元需要維護，從而降低維護成本。

數字孿生

數字孿生允許在實施之前模擬計劃，在問題變為現實之前找出問題。住房、無線網絡天線、太陽能電池板的設置和公共交通方面均可以通過數字工具進行規劃和分析。政府部門可以有效地分析數據，改善人民生活，創造經濟機會，振興更緊密的社區。

調查顯示，大多數受訪者未來很有可能投資於傳感器網絡和視頻監控。傳感器網絡能實現在公共部門的不同的 5G 物聯網應用。此外，許多國家現正在部署公共視頻監控作為監控交通和預防犯罪的工具。部分受訪者也可能會投資於智能停車應用，而這些應用在香港亦越來越受歡迎。 而且，一些受訪者亦對投資於空氣質量/水質/環境噪音水平等環境監測感興趣。

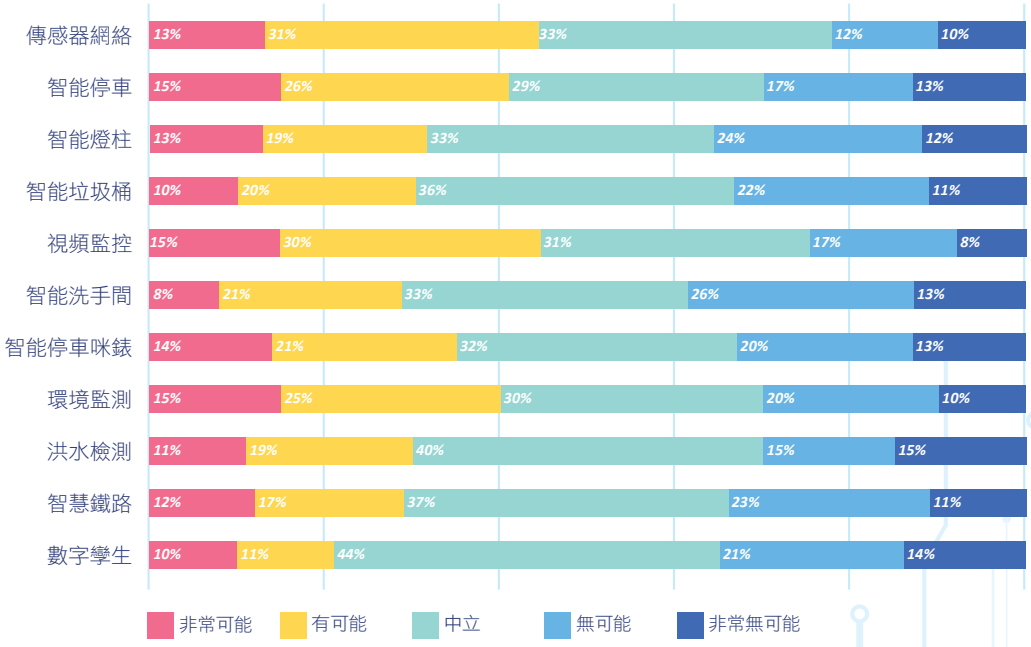


圖1.23 公共部門應用

Smart Lampposts

Smart lampposts collect city data and release more real-time information to the public. Traffic detectors and panoramic cameras, as well as weather and air quality sensors, strengthen city and traffic management. For example, monitoring different traffic conditions and traffic accidents, achieving smarter and safer transportation.

Smart Waste Bins

Smart waste bins embedded fill-level sensors can detect the fullness of the waste bins. The route and frequency of garbage collection, and placement of bins can then be optimised. Smart safety sensors embedded can help to ensure safety. If a fire is detected, an alarm will be sent, and the bin automatically extinguishes the fire. It results in less manpower, emissions, and environmental improvement.

Video Surveillance

Surveillance cameras help quickly respond to and prevent serious incidents. Video surveillance can also monitor the flow of vehicles/humans and solve congestion problems, improving traffic management, urban mobility, and public safety. Analysing real-time and historical traffic data over time allows authorities to predict peak times and prepare accordingly.

Smart Restrooms

Smart restrooms that track restroom and supplies usage allow flexible cleaning arrangements. If the traffic suddenly increases and supplies are required, the cleaner can be alerted. Facility managers can make evidence-based decisions to maintain a high level of customer satisfaction while reducing the frequency of customer or employee complaints.

Smart Parking Meters

Smart parking meters allow users to pay parking fees on-site and remotely in a mobile application. Real-time information can be provided to assist drivers in finding vacant parking spaces, reducing the time and traffic flow of vehicles wandering on the road looking for parking spaces. They improve the user experience and help traffic managers identify parking patterns and traffic flow.

Environmental Monitoring

A network of quality monitoring sensor nodes can monitor air quality, water quality, and environmental noise levels. Through the detection of pollution sources, cities can take corrective measures to improve environmental health. Government departments can check pollution exposure in the city and develop strategic plans for sustainable urban expansion and transportation route planning.

Flood Detection

Sensors installed in key areas can detect water levels and report flood events or potential flood events in realtime. The government department can then analyse the data combined with weather data to report information. It can ensure better protection of citizens from flood events, proper review of new development projects to avoid flooding, and protection of local watersheds.

Smart Railway

A smart railway allows machines in rail systems to communicate with each other. Sensors and cameras are placed along the tracks and train cars to see their status in real-time. It allows operators to clearly understand the train's operating conditions, improving the train's maintenance status. Information about which units need maintenance can also be found, reducing maintenance costs.

Digital Twins

Digital twins allow the simulation of plans before implementation, exposing problems before they come to reality. Architectural aspects that can be planned and analysed through digital tools include housing, wireless network antennas, solar panels, and public transportation. Government departments can effectively analyse the data, improving citizens' lives, creating economic opportunities, and revitalising closer communities.

The survey shows that most of the respondents are very likely to invest in sensor networks, and video surveillance in the future. Sensor networks are required to enable different 5G IoT applications in the public sector. Besides, many countries now deploy public video surveillance as a tool to monitor traffic and prevent crimes. In addition, some respondents may also invest in smart parking applications, which are gaining popularity in Hong Kong. Thirdly, some of them like to invest in air quality/water quality/ambient noise level monitoring.

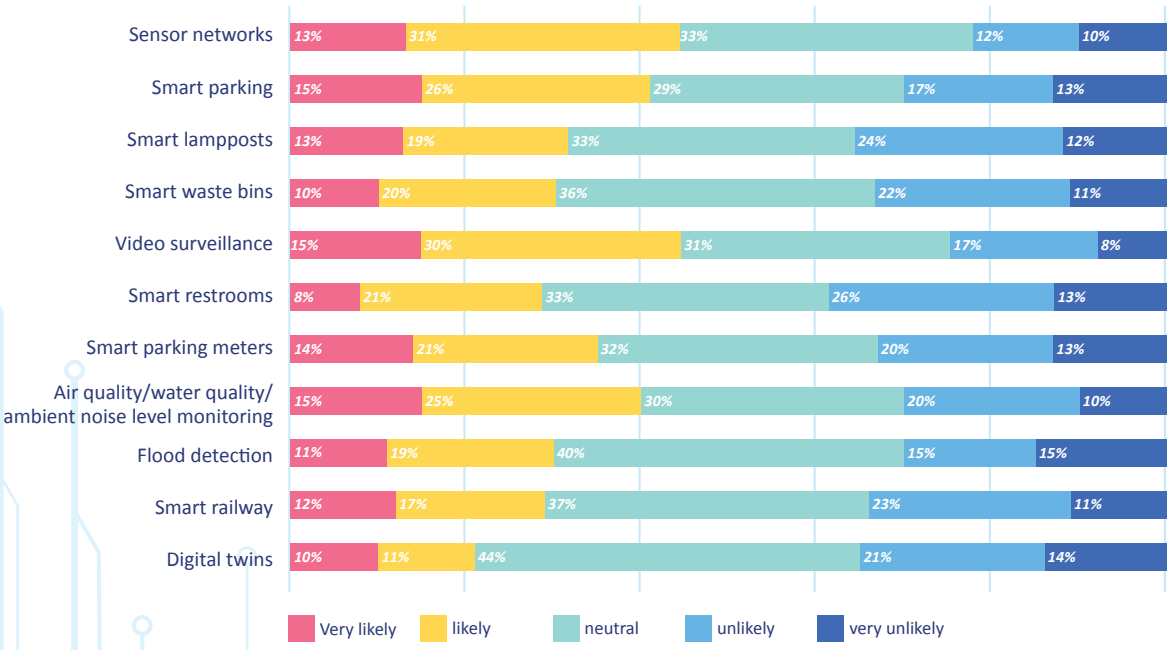


Figure 1.23 Public Sector Applications

1.5.8 家庭自動化應用

出入管制

智能門鎖為用戶提供了更便利的出入管制，用戶可以從任何地方遠程鎖定和解開門鎖，並允許訪客、朋友或親戚通過智能手機應用程式到訪他們的家居。除了遙控功能，智能門鎖還保留開鎖記錄，方便用戶查閱。

視頻監控

安裝在家裡的智能攝像鏡頭可以為用戶提供視頻監控服務，實時監控家中情況。它可以通過圖像識別和語義分析來識別是否有陌生人正在進入家居或對用戶帶來傷害。監控系統有需要時會報告給用戶的手機或當局以採取行動。

智能家電

用戶可以通過手機、平板電腦或雲端控制智能家電，和了解家電當前的運行狀態。例如，先進的掃地機械人可以規劃路線並對家中特定角落的進行清潔。用戶亦可以設定掃地機械人每天在固定時間進行清潔。

輔助機械人

智能家居機械人可以控制主要的智能家居設備，提高用戶的生活質素。它們可以提供專門的服務，例如陪伴老人和教育孩子。用戶亦可以通過語音指令來執行操作，給用戶帶來方便和舒適。

感應條

帶有不同傳感器（例如濕度傳感器）的磁條可以將任何家庭空間或設備變得智能。它們可以貼在家中的物件上，以監控和保護貴重物品。它們非常輕巧，可用於許多獨特的物品，如藝術品，以進行活動監控。傳感器可用於報告門窗是否打開、或異常情況等。

智能能耗監控系統

智能能耗監控系統可以幫助監控能耗，保護環境，降低電力成本。它可以讓用戶了解其能源使用模式，從而進行適當的調節或家電的升級。它還可以根據特定需求動態調整能源使用狀況，避免出現潛在浪費的情況。

太陽能表面

輕質太陽能表面可以連接到窗戶、門、屋頂，甚至可以連接到設備上，將它們轉化為環保、自充電的物件。它們使屋主和其他太陽能投資者能夠使用太陽能和進行預防性維護，以找出潛在的故障。用戶可以管理他們的太陽能資源，以作出數據驅動的決策並探討電力使用趨勢。

個人助理

個人助理可以讓用戶使用語音指令操作家庭電器，提供更互動和方便的生活體驗。它可以通過語音指令完成任務，例如調節恆溫器或檢查水壓。隨著更多設備支持，用戶可以透過語音指令進行更多的操作。這項不需要人手控制的功能讓用戶的居家生活更輕鬆。

調查顯示，大部分受訪者未來投資智能家電、出入控制、視頻監控的可能性很大。它們很受歡迎的原因是因為它們為房主提供了便利並改善了安全條件。此外，部分受訪者還喜歡投資「智能能耗監控系統」及「太陽能表面」。這些應用有助於減少碳排放。而且，一些受訪者可能會投資於個人助理，因它可以為家用電器增值。

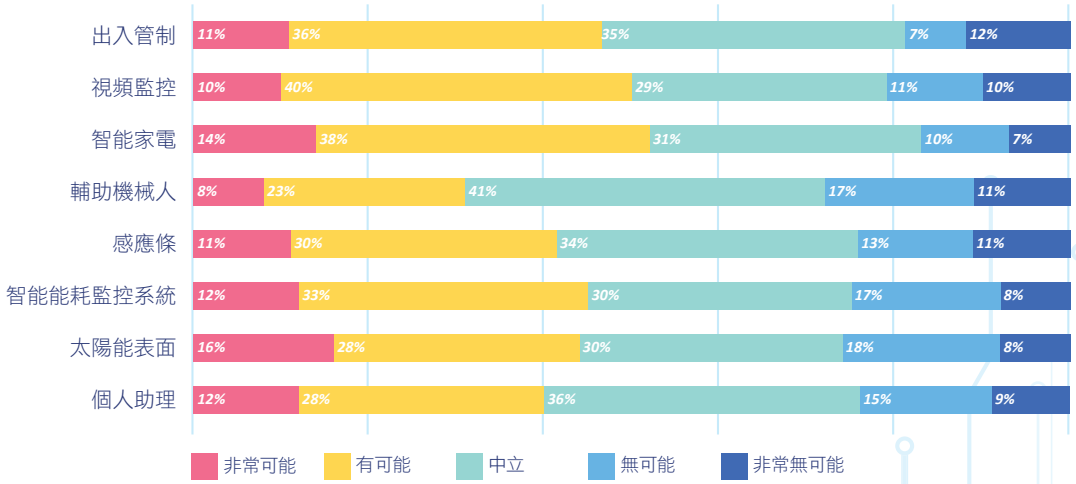


圖1.24 家庭自動化應用

1.5.8 Home Automation Applications

Access Control

Smart lock provides users with a higher level of access control, allowing them to remotely lock and unlock their home from anywhere and access for visitors, friends, or relatives to come to their home through a smartphone app. In addition to the remote-control function, the smart lock also retains the unlocking record, allowing users to manage the personnel entering and exiting easily.

Video Surveillance

A smart camera installed at home can provide video surveillance services for the owner to monitor the realtime home situation. It can identify whether a stranger is approaching through image recognition and semantic analysis, and determine whether the approaching person will cause harm. The monitoring system will then report to the owner's mobile phone or authorities to take action.

Smart Appliance

Users can control smart home appliances through mobile phones, tablets, or the cloud, allowing them to know the current operating status of home appliances at any time. For example, advanced robot vacuums can plan routes and strengthen the cleaning of specific corners of the home. It can also set a schedule to allow robot vacuums to attend at a fixed time every day.

Assistive Robots

Smart home robots can control all major smart home devices, improving users' quality of life. They can perform specialized services, such as accompanying the elderly and educating children. Actions can be performed by voicing an order. In the control of smart home equipment, it brings convenience and comfort to users.

Sensor Strips

Magnetic strips with different sensors, such as humidity sensors, can turn any home space or device into a smart one. They can be attached to objects in the home to monitor and protect valuables. They are very lightweight and can be used for many unique items, such as artwork, to monitor activities. Sensors will be used, for example, to report whether doors are open, to notify leaks or to identify anomalies in windows.

Intelligent Energy Consumption Monitoring & Control System

Intelligent energy consumption monitoring and control systems can help monitor energy consumption, protect the environment, and reduce electricity costs. They can provide energy usage patterns to allow users to make appropriate changes and upgrades at home. They can also dynamically adjust the state according to changing conditions, avoiding the use of energy at potential waste points.

Solar Power Surfaces

Lightweight solar surfaces can be connected to windows, doors, rooftops, even on devices to convert them into green, self-charging objects. They enable homeowners and other solar investors to use solar energy and preventive maintenance, mapping out the potential breakdown. Users can govern their solar energy resources to make data-driven decisions and investigate power usage trends.

Personal Assistants

A personal assistant can help users interact with household appliances using voice commands to provide a more interactive and user-friendly life experience. It can complete household commands, such as adjusting the thermostat or checking the water pressure all at a voice command. As more devices are connected, voice commands will control more at home. The hands-free capabilities make daily life easier for users' home life.

According to the survey, most of the respondents have a high likelihood to invest in smart appliances, access control, and video surveillance in the future. They are popular because they provide house owners convenience and improve security conditions. In addition, some respondents also like to invest in "intelligent energy consumption monitoring and control system", and "solar power surfaces". These applications can help to reduce carbon emissions. Thirdly, some of them may invest in personal assistants, which can add value to common household appliances.

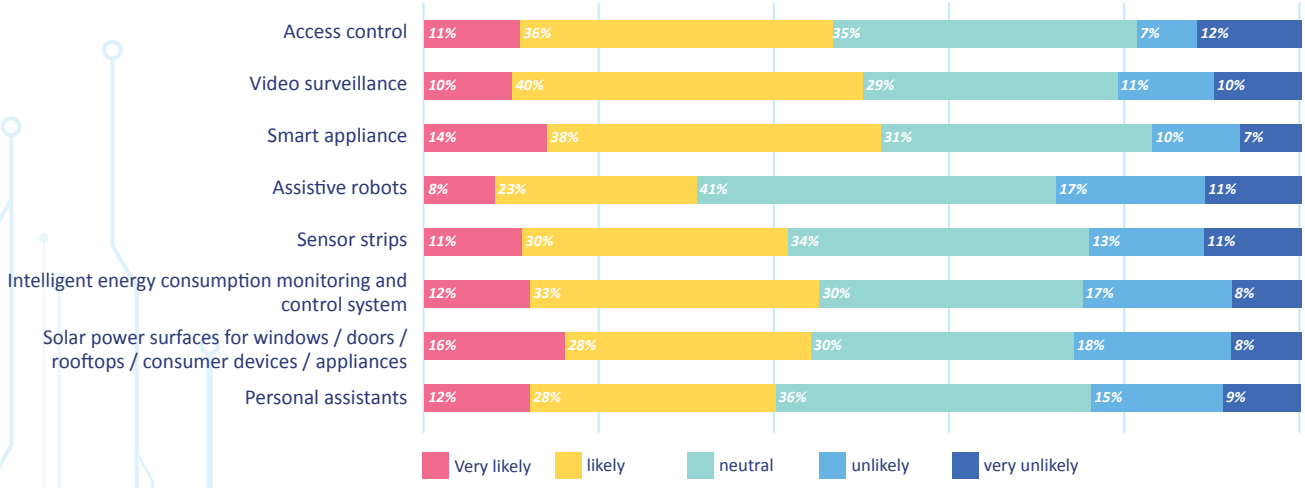


Figure 1.24 Home Automation Applications

1.5.9 建築技術應用

設備狀態監控

設備狀態監控有助於監控和報告設備狀態信息，例如位置、速度、發動機溫度和振動。它可以幫助施工現場管理人員協調設備並跟蹤所有設備的整體健康狀況，從而提高安全性。久而久之，這些數據可以用作預測性維護計劃，使管理人員能夠減少意外的停機時間、維護成本和維修次數。

用於建築材料的可追蹤物聯網標籤

當設備在非工作時間運行或從特定地理區域移動時，建築工地可以利用智能標籤來追蹤，從而發出安全通知。它可以對被盜物品進行定位，並提供資訊方便保險索賠。建築經理還可以在多個建築工地項目上使用這類標籤，以確保機器的正確的位置，從而避免將機器放於錯誤地方而造成昂貴的停機時間。

實時現場地圖

實時現場地圖讓建築經理可以監控現場情況、危險區域、危險環境、現場員工人數和正在進行的工作。無人機還可用於收集視覺數據，這些數據可以轉化為詳細的3D地圖。現場管理人員不再需要每天走遍整個地盤來跟蹤進度。它有助於使建築工地更可預測、更易於控制，並且對工人來說更安全。

用於工人的智能可穿戴設備

智能可穿戴設備可以監察身體不適的情況，包括脈搏加快和血壓升高。它可以幫助公司降低事故管理成本。可穿戴設備還可以向用戶提供附加信息。例如，工人可以在執行特定任務時通過智能眼鏡查看工作指令，提高他們的效率。

車隊管理

智能車隊管理使管理人員能夠作出業務決策，以提高生產力、促進業務發展並改善日常營運。公司可以了解和控制他們的車隊營運。施工車隊管理涉及車隊車輛的規劃、指導、監督和活動報告。它提高了生產力並改進了收費及預算過程、預測能力和合規性。

遠程設備控制

當叉式起重車、托盤搬運車或泵車裝載、卸載和運輸貨物時，遠程設備控制通過實時控制和調整機器來幫助工人跟蹤進度。它允許機器不需任何人在場的情況下在污染或危險的環境下工作。它還可以避免工人使用危險設備，降低工地工人的風險。

預測性維護

配備傳感器的設備可以為建築項目提供有價值的數據，例如溫度和承載能力。這些數據影響工地的維護計劃和安全決策。通過預測性維護，操作員可以在設備出現故障前對其進行維護，從而大幅降低深度維修的成本並避免項目延誤。

數字孿生

數字孿生有助滿足建築行業對新設施的需求。它對新設施的工作流程和安全屬性進行建模，在新設施投入使用之前識別和糾正任何瓶頸。它使公司能夠基於建築信息模型（BIM）來分析及模擬，以協助建築公司的管理。

調查顯示，大多數受訪者未來可能會投資於遠程設備控制和智能可穿戴設備。建築工人經常暴露在危險的工作條件下，使他們處於危險之中。 安全是建築業最關心的問題。遠程設備控制和智能可穿戴設備可有效幫助現場管理人員提高現場安全性。此外，一些受訪者可能會投資於預測性維護和實時現場地圖應用。

此外，其中一位受訪者還對投資XR監控有興趣。它通過可視化施工活動和有用信息來實現互動式現場檢查。

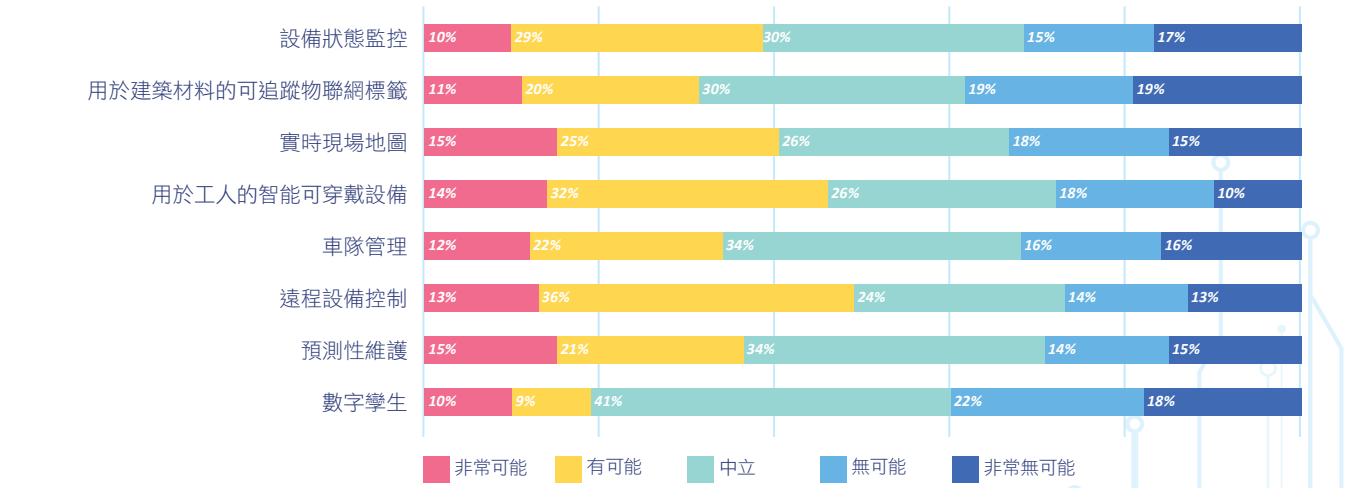


圖1.25 建築技術應用

1.5.9 Construction Technology Applications

Equipment Condition Monitoring

Equipment condition monitoring helps monitor and report equipment status information, such as location, speed, engine temperature, and vibration. It helps construction site managers coordinate equipment and track the overall health of all the equipment, improving safety. Over time, the data can be used as part of a predictive maintenance plan, enabling managers to reduce unplanned downtime, maintenance costs, and repairs.

Traceable IoT-enabled Tags for Construction Materials

Construction sites can use asset tracking with smart tags to trigger safety notifications when the device is operating during non-working hours or moving from a specific geofenced area. It helps to locate stolen items and verify insurance claims. Site managers can also use tags on multiple construction site projects to ensure that machines are in correct locations, thereby avoiding costly downtime when it is sent to the wrong site.

Real-time Site Maps

Site conditions, highlighting hazardous areas, hazardous environments, number of employees on-site, and work in progress can be monitored. Drones can also be used to collect visual data, which can be transformed into detailed 3D site maps. Site managers no longer need to walk the entire site every day to track progress. It helps make construction sites more predictable, easier to control, and safer for workers.

Smart Wearables for Workers

Smart wearables can detect physical discomforts, including increased pulse rate and increased blood pressure. It helps business owners reduce accident management costs. The wearables can also provide additional information to the users. For example, workers can view work instructions while performing specific tasks, improving their performance through smart glasses.

Fleet Management

Smart fleet management enables managers to make business decisions to increase productivity, promote growth, and improve daily operations. Companies can understand and control their fleet operations. Construction fleet management involves planning, directing, supervising, and reporting activities of fleet vehicles. It increases productivity and improves invoicing, budgeting, forecasting, and compliance.

Remote Equipment Control

When forklifts, pallet trucks, or pump trucks load, unload, and transport goods, remote equipment control helps humans track progress by controlling and adjusting the machine in real-time. It allows trucks to work in polluted or dangerous conditions without anyone present. It also prevents humans from using dangerous equipment, reducing the risks faced by workers on construction sites.

Predictive Maintenance

Sensor-equipped devices can generate valuable data for construction projects, such as temperature and load-bearing capacity. This data can influence maintenance planning and overall safety decisions on construction sites. With predictive maintenance, operators can maintain equipment before it fails, significantly reducing costs of in-depth repairs and avoiding project schedule delays.

Digital Twins

A digital twin helps to meet the demand for new facilities in the construction industry. It models the workflow and safety attributes of a new facility to identify and correct any bottlenecks before the new facility is in service. It allows the company to analyse and simulate based on Building Information Modelling (BIM) to assist in the management of construction companies.

The survey shows that most of the respondents will probably invest in remote equipment control and smart wearables for workers in the future. Workers on construction sites are often exposed to hazardous working conditions that put them at risk. Safety is the biggest concern for the construction industry. Remote equipment control and smart wearables are effective to help site managers to improve site safety. In addition, some respondents are likely to invest in predictive maintenance and real-time site maps applications.

Besides, one of them also likes to invest in XR monitoring. It enables interactive site inspections by visualisation of construction activities and useful information.

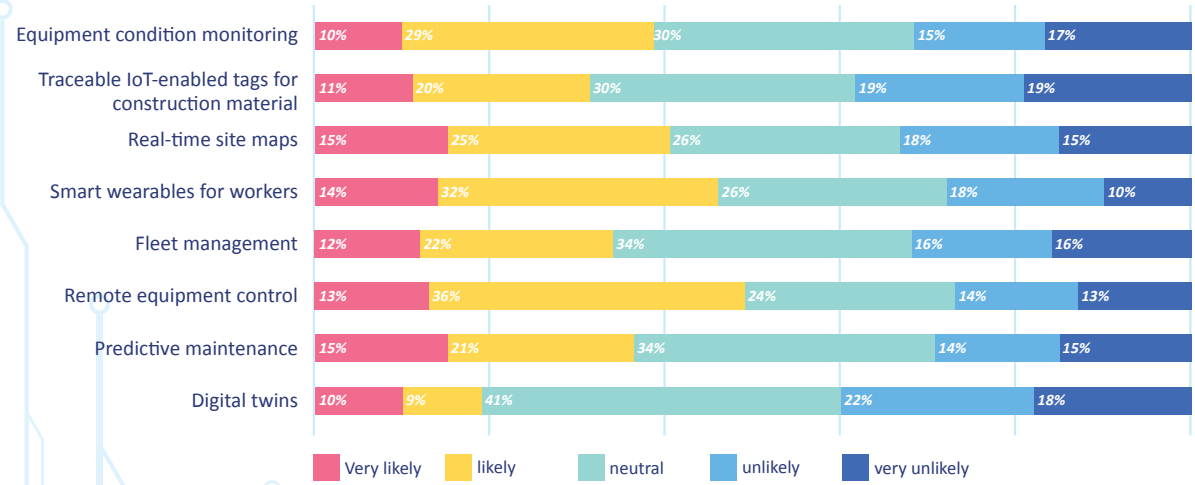


Figure 1.25 Construction Technology Applications

1.5.10 智能樓宇自動化應用

智能資產管理

智能樓宇資產管理使公司能夠優化資源管理。合適的傳感器包括了房間或個別座位佔用檢測器、用於計算人流的傳感器以及用於檢測電子設備活動的功率計。它們提供有關使用模式的詳細信息，以達至資源最佳化及安全要求。

智能照明

建築物可以感知其使用模式，智能地調節燈光。燈內的傳感器可以追蹤用戶活動行為、電力使用、環境光線和溫度。它們可以實現節能和空間活動偵測。自動照明控制有助於營造更舒適、更節能的環境。設施經理還可以設置照明時間表以節省能源。

出入控制

智能出入控制提供人臉識別、體溫監測、位置定位等服務，實現在疫情期間更安全的訪問管制。它取代了傳統門鎖控制，人們無需通過閘口驗證身分即可進入建築物。樓宇中的自動化智能出入控制系統可以幫助用戶提高安全性和簡化出入過程。

能源管理

房間沒有人的時候，能源管理系統會自動關閉電燈和暖氣。天氣數據可在無人干預下用於調整恆溫器。傳感器還可以測量供暖、空調、通風和供水系統的質量。智能報錶可用於幫助監控能源消耗和測量系統效率，提供指標讓公司考慮升級到新的模型。

預測性維護

預測性維護可以更好地控制維護過程，從而減少浪費並避免代價高昂的停機時間。從營運數據中獲取的資訊使公司能夠更好地規劃維護活動。它們可以優先進行最需要維護的設備，並更有策略地管理人員。它們還可以在發生故障之前訂購更換的零件或新設備，從而加快維修速度。

視頻監控

實時視頻監控提高透明度及安全性並防止重大損失。它通過及早檢測樓宇中的火種、煙霧或溢出物，這在安全預防中發揮著重要作用。視頻分析結合人工智能和其他技術可以在早期檢測到事故並可靠地觸發警報。優先考慮樓宇安全將可以降低保險風險和保費。

舒適度監測

設施管理人員可以遠程訪問建築物中房間的參數，例如空氣質量、濕度、溫度以及噪音水平。它有助創造一個理想的空間環境，以確保居住者、員工和訪客的安全和舒適度。環境傳感器也可以配置成在環境質量達到不可接受的水平時發出通知和警報。

智能辦公室生產力解決方案

配備不同傳感器的辦公室可以為訪客、員工和管理人員提供良好的互動體驗。智能辦公用品幫助員工提高工作效率和幸福感。員工可以知道自己一天或一周內的行為數據。而智能鏡子亦可用於辦公室，為客戶和訪客顯示有用的信息，給他們對公司留下良好的第一印象。

數字孿生

數字孿生用於理解、分析、操作和優化智能樓宇中的工作程序。它降低了與設施管理相關的勞動力成本。例如，當空調系統需要維修時，技術人員可以使用數字孿生作幫助。他們可以在設備上找到故障位置，並使用數字孿生中獲取的資訊來解決問題。

根據問卷調查結果，大部分受訪者非常有可能投資於智能照明、舒適度監測和能源管理。公司之所以對這些應用感興趣，是因為他們認為樓宇的便利性及舒適性對居住者/辦公室很重要。它還可以幫助減少碳排放並改善企業形象。而一些受訪者希望投資於出入控制和視頻監控，以提高建築物的安全水平。

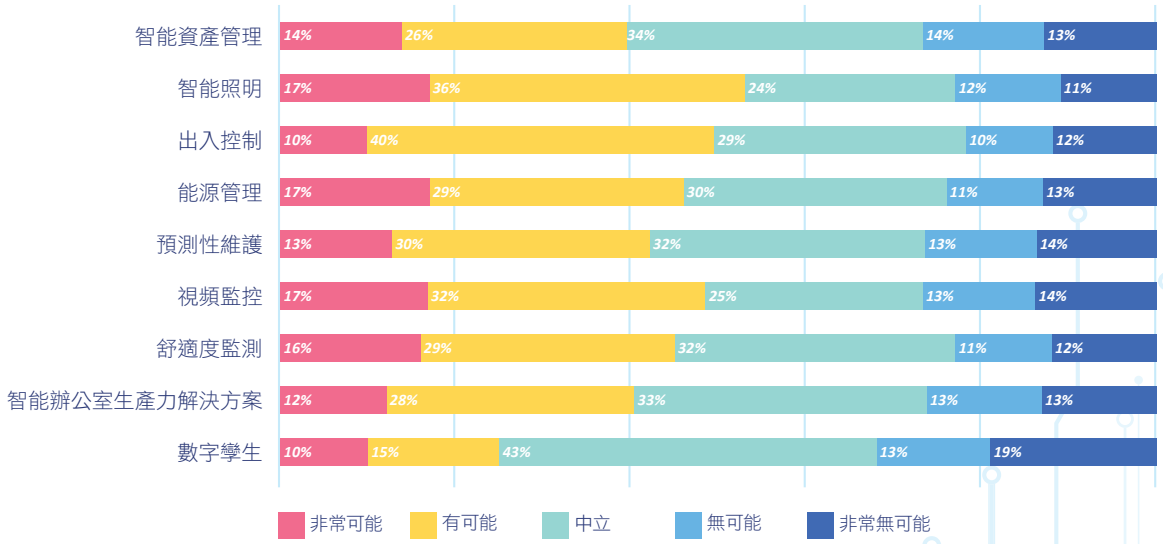


圖1.26 智能樓宇自動化應用

1.5.10 Intelligent Building Automation Applications

Smart Asset Management

Smart building asset management allows companies to optimize the management of resources. Suitable sensors include presence detectors in rooms or individual seats, sensors for counting the number of people, and power meters for detecting electronic device activity. They provide detailed information about usage patterns to determine the best use of resources and achieve safety requirements.

Smart Lighting

Buildings can sense occupancy patterns and become smarter to control lighting easily and automatically. Sensors in lamps can track movement, power usage, ambient light, and temperature. They enable energy-saving and occupancy monitoring. Automatic lighting control helps create a more comfortable and energy-saving environment. Facility managers can also set lighting schedules to save energy.

Access Control

Smart access control provides services such as face recognition, body temperature monitoring, and location positioning. It achieves better access management and control during the epidemic. It replaces traditional access control that people can enter the building without verifying their identity through gates. Intelligent automated access control in smart buildings can help users achieve better security and streamlined operations.

Energy Management

Lights and heating can be automatically turned off when the room is empty. Weather data can be used to adjust the thermostat accordingly without manual intervention. Sensors can also measure the quality of heating, air conditioning, ventilation, and water supply systems. Smart meters can be used to help monitor energy consumption and measure system efficiency to consider upgrading to a new model.

Predictive Maintenance

Predictive maintenance can better control the maintenance process, thereby reducing waste and avoiding costly interruptions. Insight derived from operational data allows operators better plan maintenance activities. They can prioritize maintenance that has the most need and manage the personnel more strategically. They can also order replacement parts or new equipment before failures occur, allowing faster repairs.

Video Surveillance

Real-time video surveillance increases transparency, improving safety and preventing major losses. It plays an important role in safety prevention by detecting flames, smoke, or spills in buildings early. Video analytics combined with AI and other current technologies can detect such events at an early stage and trigger alarms more reliably than humans. Prioritizing building safety can reduce insurance risks and premiums.

Comfort Monitoring

Facility managers can remotely access parameters about the condition of rooms and spaces in their buildings, such as air quality, humidity and temperature, and noise level. It helps create an ideal space to ensure the safety, wellbeing, and comfort of building occupants, employees, and visitors. Environmental sensors can also be configured to trigger notifications and alerts when the environment quality decreases to unacceptable levels.

Smart Workplace Productivity Solutions

Workplaces equipped with different sensors can provide an enhanced interactive experience for visitors, employees, and managers. Smart office furniture helps employees improve work efficiency and happiness. They can also read data about their behaviour for the day or week. Smart mirrors can be used in the workplace to display useful information for customers and visitors, helping the company make a good first impression.

Digital Twins

A digital twin is used to understand, analyse, operate, and optimize processes in smart buildings. It reduces labour costs associated with facility management. For example, when the air conditioning system needs repairs, technicians can use digital twins to help. They can find the fault location on a device and use the data captured in the twins to solve the problem.

According to the results of questionnaire survey, most of the respondents are very likely to invest in smart lighting, comfort monitoring, and energy management. The reason why companies are interested in these applications is that they consider the convenience, comfort of a building is important for occupants/offices. It can also help to reduce carbon footprint and improve corporate image. Besides, some of the respondents would like to invest in access control and video surveillance to increase the safety levels of the building.

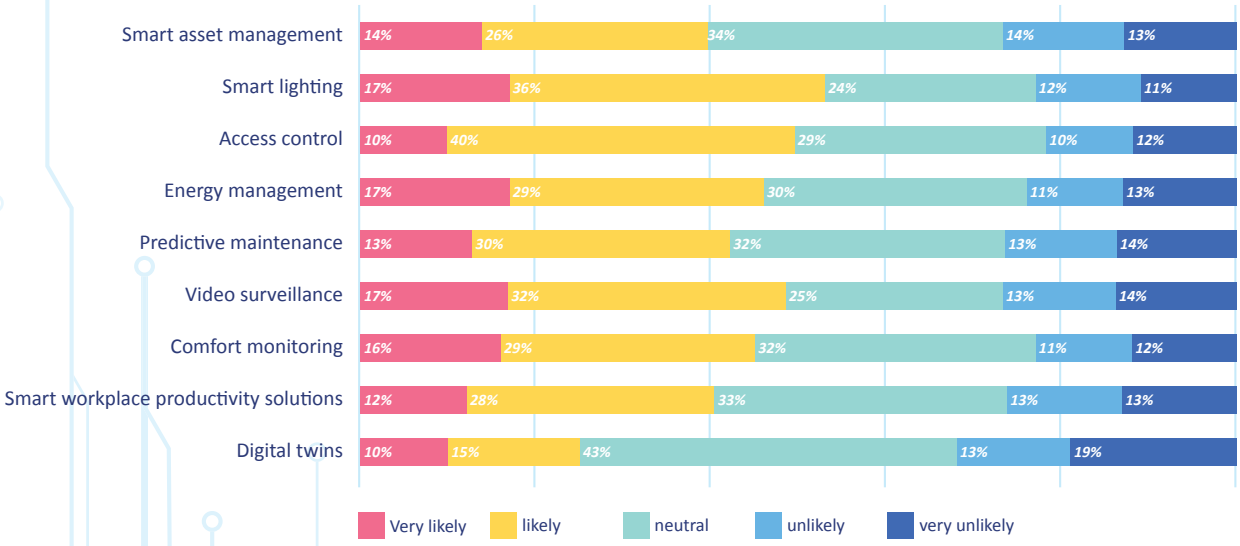


Figure 1.26 Intelligent Building Automation Applications

1.5.11 食品技術應用

食品狀態監測

放置在儲存設施中的傳感器可以監測溫度、濕度、重量或其他參數，以確保食品安全。如果冰箱的溫度高於或低於安全範圍，系統會向管理人員發出警報。持續的狀態監測有助於避免浪費食物，及人為錯誤包括未能定期記錄、測量不準確或監測不足。

食品追蹤和追溯

公司可以放置具有實時追蹤能力的傳感器或智能標籤於貨櫃、運輸貨車、或獨立的儲存單元上。通過供應鏈提供有關商品的詳細信息，供應商和買家之間的溝通會得到改善，以簡化營運管理系統。

預測性維護

預測性維護使公司能夠有效地分析並預測機器何時需要進行維護或處於故障邊緣。公司可以關閉即將發生故障的機器，以減少它們傷害員工的可能性。食品行業的公司更可以減少或消除機器故障或損壞造成的停機時間，降低機器維護的總成本，節約營業成本。

智能自動售賣機

智能自動售賣機比無人商店便宜得多。他們還減少了員工壓力和結帳時間。公司可以對收集到的數據進行分析，靈活調整產品供應以增加銷量。工作人員還可以直接查閱營收和產品狀態，並可以在多個自動售賣機中找出最暢銷的產品，並實時調整供應量和產品分佈。

庫存管理

傳感器收集到的食品消費數據可以幫助預測和及時補充庫存，從而節省庫存成本。這能讓公司了解客戶每日或每週的消費情況，並實時預測客戶消費模式。員工還可以通過庫存管理系統查看實時的庫存可用性和消費紀錄，以便更好地進行預測和計劃。

遠程設備監控和維護

實施遠程設備監控可以在問題發生之前預測問題，從而節省時間和金錢。透過設備中傳感器收集的數據，公司可以預測問題何時發生，並在設備造成不必要的停機之前進行維護。工作人員還可以通過流動裝置解決問題，公司無需派員檢查設備狀況。

遠程控制

智能運輸容器和冰箱允許工人遠程控制食品儲存環境。例如，工人可以調節冷藏庫內的溫度，以防止農產品和其他較敏感的食品因環境條件不合適而變壞。在新鮮農產品到達時系統會發出警報，這能減少食物等待處理的時間以及減低被盜或損壞的風險。

根據調查，大部分受訪者未來可能會投資於庫存管理和遠程控制。為了滿足消費者的需求，公司需要確保它們有足夠的食品庫存。庫存管理和遠程控制可以讓他們擁有更智能的供應鏈。此外，一些受訪者希望投資於食品狀態監測和食品追蹤和追溯應用。它們不僅減少了人力成本，還增加了消費者對食品的信心。

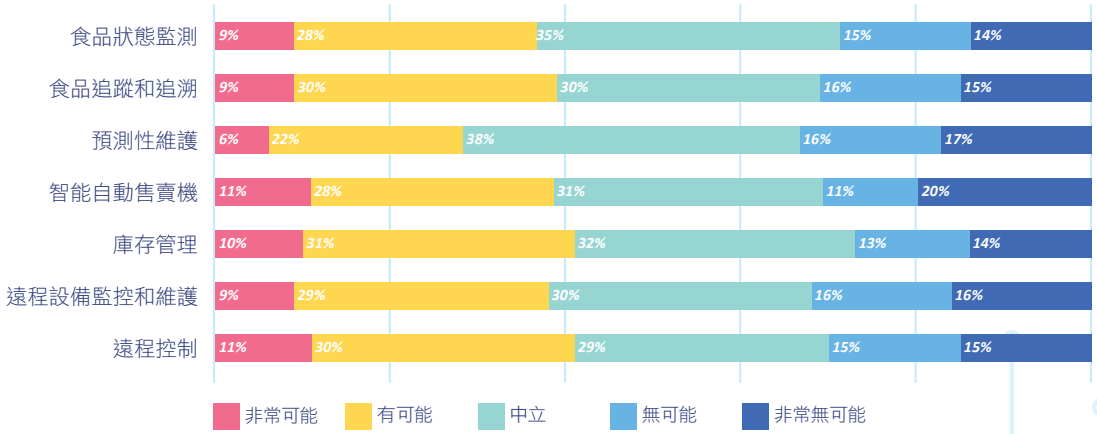


圖 1.27 食品技術應用

1.5.11 Foodtech Applications

Food Condition Monitoring

Sensors placed in storage facilities can monitor temperature, humidity, weight, or other parameters to keep the food safe. If the temperature of a refrigerator raises or drops below the safe range, an alert will send to the manager. Continuous condition monitoring helps avoid food waste without human error that includes failure to record regularly, inaccurate measurements, or insufficient monitoring.

Food Tracking & Tracing

Sensors or smart tags with real-time tracking capabilities can be placed in the cargo container, located in a transport truck, or placed on a separate storage unit. Providing detailed information about goods through a supply chain can improve communication between suppliers and buyers, streamlining operation management.

Predictive Maintenance

Predictive maintenance enables analysis to effectively predict when the machine needs maintenance or is on the verge of failure. Machines about to fail can be shut down to reduce the likelihood of them injuring employees. Companies in the food industry can reduce or eliminate downtime caused by machine failure or damage and reduce the overall cost of machine maintenance, saving costs.

Smart Vending Machines

Smart vending machines are much cheaper than unmanned stores. They also reduce staff pressure and checkout time. Operators can analyse the collected data and flexibly adjust product items to increase sales. The staff can also receive the first-hand revenue and product status, and then find out the best-selling products in different vending machines and change the supply quantity and distribution in real-time.

Inventory Management

Food consumption data collected by sensors can help predict and replenish inventory promptly, thereby saving inventory costs. It can understand daily or weekly consumption and predict consumption patterns in real-time. Employees can also view the real-time status of current availability and consumption history through the inventory management system for better forecasting and planning.

Remote Equipment Monitoring and Maintenance

Implementing remote device monitoring can predict problems before they occur, saving time and money. Using data collected by sensors in the equipment, companies can find patterns that indicate when problems may occur and repair the equipment before they cause unnecessary downtime. They can also solve problems over mobile devices without sending staff to check the equipment condition.

Remote Control

Smart transportation containers and refrigerators allow workers to control the food storage environment remotely. For example, workers can adjust the temperature in the cold storage to prevent agricultural products and other sensitive foods from being lost due to incorrect environmental conditions. It can also make alerts when fresh produce arrives, reducing waiting time for processing and the risk of theft or damage.

According to the survey, most of the respondents will presumably invest in inventory management, and remote control in the future. To fulfil consumers' demand, companies require to ensure they have enough food stocks all the time. Inventory management and remote control can allow them to have a smarter supply chain. Besides, some of the respondents would like to invest in food condition monitoring and food tracking & tracing applications. Not only do they reduce manpower, but they also increase consumer confidence in food.

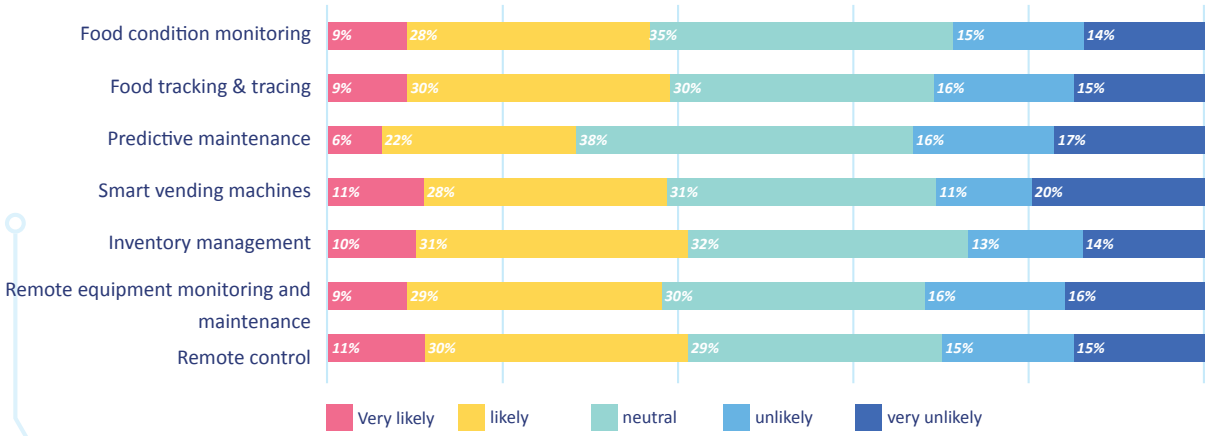


Figure 1.27 Foodtech Applications

1.5.12 生物技術應用

智能自動化設備及配件

在智能實驗室中，研究人員可以遠程操作儀器並接收實時故障警報，以降低成本並提高實驗效率。這還可以改善實驗室的運行以及研究的準確性和速度，使研究人員能夠在最佳的時間於集成的工作環境，遙控並自動地使用已連接的儀器進行實驗。

實驗室自動化

自動化和機械人技術可以提高工作效率，降低實驗室成本，讓研究人員有更多創新。重複性任務，例如移液、移動實驗室玻璃片和補充工作，都可以自動化。過去花費大量時間執行繁瑣和重複性任務的研究人員可以花更多時間設計後續項目或進行其他開發項目。

藥物狀態監測

持續記錄和維護藥物狀態對於確保正在處理或儲存中的藥物完整性是必須的。例如，疫苗需要進行溫度控制，否則它們有可能失去效力。實時監測情況可以確保疫苗處於理想狀態。當出現溫度偏差時，系統會通知操作員有關情況並讓其在疫苗損毀之前作出反應。

庫存跟蹤和追溯

監控實驗室設備和資產的定位及使用情況，使實驗室能夠快速地找到丟失的設備。它還有助於監控設備使用率並優化維護和校準計劃，大大減少停機時間並提高生產力。智能標籤可以用於識別和跟蹤在實驗室內或實驗室之間移動的設備。

預測性維護

分析串流數據以評估設備狀態、識別警告信號和在故障前修復設備的能力，可以防止設備停機時間的高昂代價。通過預測潛在問題，管理人員可以制定計劃將實驗樣本移至正常運行的設備，同時安排其他設備進行維護。他們可以作出適當的安排以進行關鍵設備的維護或更換。

調查顯示，少數受訪者希望在未來投資智能自動化設備及配件，以及實驗室自動化。準確性在研究活動中至關重要，因為即使是相對較低的錯誤率也可能產生深遠的影響。自動化可以有效地幫助生物技術人員避免人為錯誤並提高生產力。

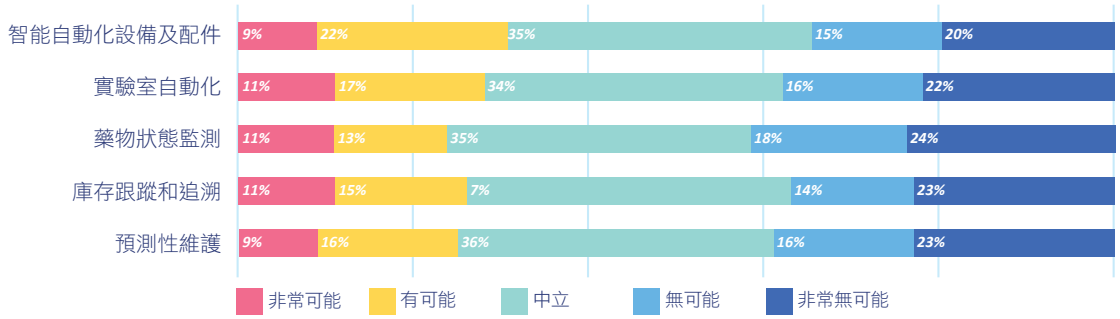


圖 1.28 生物技術應用

1.5.12 Biotechnology Applications

Smart and Automated Equipment and Accessories

In a smart laboratory, researchers can remotely operate instruments and receive real-time fault alerts to reduce costs and improve experimental efficiency. It enhances laboratory operations and the accuracy and speed of research, allowing researchers to remotely and automatically use connected instruments to conduct experiments at the best time in an integrated working environment.

Laboratory Automation

Automation and robotics can improve work efficiency, reduce laboratory costs, and create more time for researchers to innovate. Any repetitive tasks, such as pipetting, moving plates, and supplementing, can be automated. Researchers who used to spend a lot of time performing tedious and repetitive tasks can spend more time designing follow-up projects or working on other development projects.

Drugs Condition Monitoring

Conditions must be recorded and maintained consistently to ensure the integrity of goods handled or stored. For example, vaccines need to be temperature controlled, or they are more likely to lose effectiveness. Monitoring of real-time conditions can ensure that the vaccine is in the desired state. Operators can be notified of these temperature excursions and react before the vaccine is damaged.

Inventory Tracking and Tracing

Monitoring the location and usage of laboratory equipment and assets enables laboratories to locate lost equipment quickly and save time in finding equipment. It also helps to monitor equipment utilization and optimize maintenance and calibration plans to minimize downtime and increase productivity. Smart tags can identify and track equipment moving in or between laboratories.

Predictive Maintenance

The ability to analyse streaming data to assess conditions, identify warning signs, and repair equipment before failure can prevent costly equipment downtime. By anticipating potential problems, a plan can be made to move the samples to properly operating equipment, while other equipment is scheduled for maintenance. Appropriate procedures can be outlined to schedule maintenance or replacement of critical equipment.

From the survey, a few respondents would like to invest in smart and automated equipment and accessories, and laboratory automation in the future. Accuracy is critical in research activities as even a relatively low error rate may have a profound impact. Automation can effectively help biotechnologists to avoid human error and increase productivity.

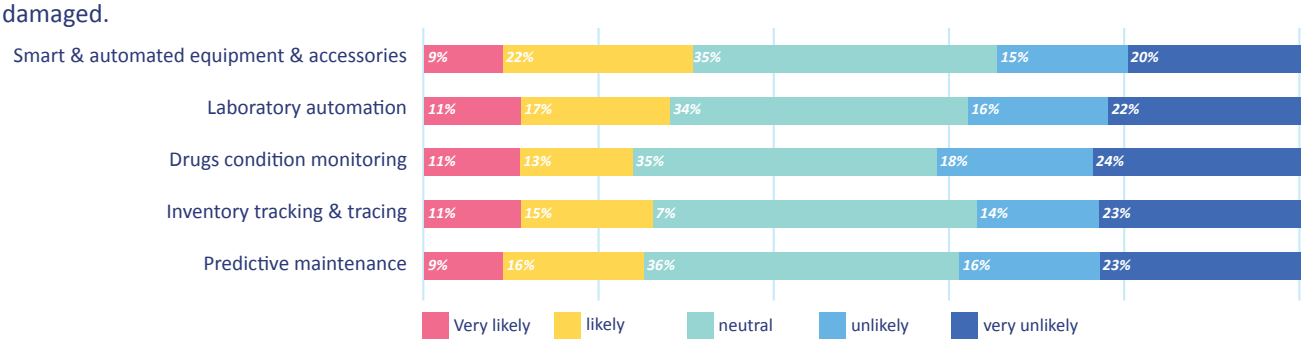


Figure 1.28 Biotechnology Applications

1.5.13 金融機構應用

智能資產跟蹤和監控

商業銀行可以使用生物識別技術和位置傳感器來跟蹤資產，向獲貸款的企業，實時監控其在貨櫃船上的貨物於運送途中的位置。此外，用於企業運輸和製造鏈上的傳感器可以收集實體物理、性能和行為數據，為缺乏信用記錄的客戶提供新的信用承保機會。

可穿戴設備的非接觸式支付

語音識別和行為分析可用於生物特徵檢查。可穿戴設備提供的獨特生物特徵信息可以加強安全性，使遠程交易更加可靠和安全。銀行和其他金融公司將不再需要僅依賴單一形式的生物特徵認證。

基於使用的保險（UBI）

UBI 根據司機的實際駕駛行為評估風險。保險公司可以根據從車載的遠程信息處理裝置所收集的數據，向客戶收取更準確的保費，避免人手數據收集和自主報告的主觀性、偏見和潛在的不誠實行為。他們還可以提供度身定制的保險計劃予安全駕駛和不常駕駛的司機。

智能銀行分行和自動櫃員機（ATM）

智能分行促進銷售並改善客戶體驗。當客戶走進分行時，員工可以立即存取特定客戶的有關信息。智能 ATM 提供遠程管理服務並提供更好的客戶體驗。它們可以使用生物特徵認證來確認客戶身份。

即時支援和個性化

藉著智能手機充當信標，可以收到客戶到達通知，優化客戶服務並改善客戶體驗。金融科技公司還可以透過流動應用程式將客戶引導至其營業處所。客戶無需在銀行找路，合適的專員會根據他們的到訪原因解決客戶的問題。這提高了效率、改善了服務和客戶體驗。

欺詐識別

可以檢測未經授權活動的個人設備，會在懷疑有欺詐行為時提供數據給相關金融機構，並提醒機構採取主動保護措施。通過其他保安程序，如人臉識別，可以增強生物認證，從而減少欺詐檢測的錯誤。通過結合檢測多種只有細微差異（如步態）的生物識別措施，能可靠地驗證用戶身分。

零售銀行/流動ATM中的聯網汽車

設置保險箱和自動提款機的車隊會在用戶需要存款時提供服務，這可以節省客戶尋找ATM的時間。用戶可以通過智能手機應用程式免費請求這項服務。流動ATM將到達取款點，讓客戶存款或取款。車隊管理會監察和調動車隊，有效運用資源。

虛擬助理/聊天機械人

透過語音指令虛擬助理/聊天機械人，用戶可以輕鬆地以日常語言控制智能物聯網設備。例如，用戶可以通過智能冰箱訂購午餐。

根據問卷調查結果，部分受訪者未來很有可能會投資於可穿戴設備的非接觸式支付。如今，可穿戴設備已成為流動支付的渠道。消費者希望更高效、更快捷地購買產品。非接觸式支付體驗開始成為消費者的期望。此外，一些受訪者可能會投資於即時支援和個性化，以及欺詐檢測應用。

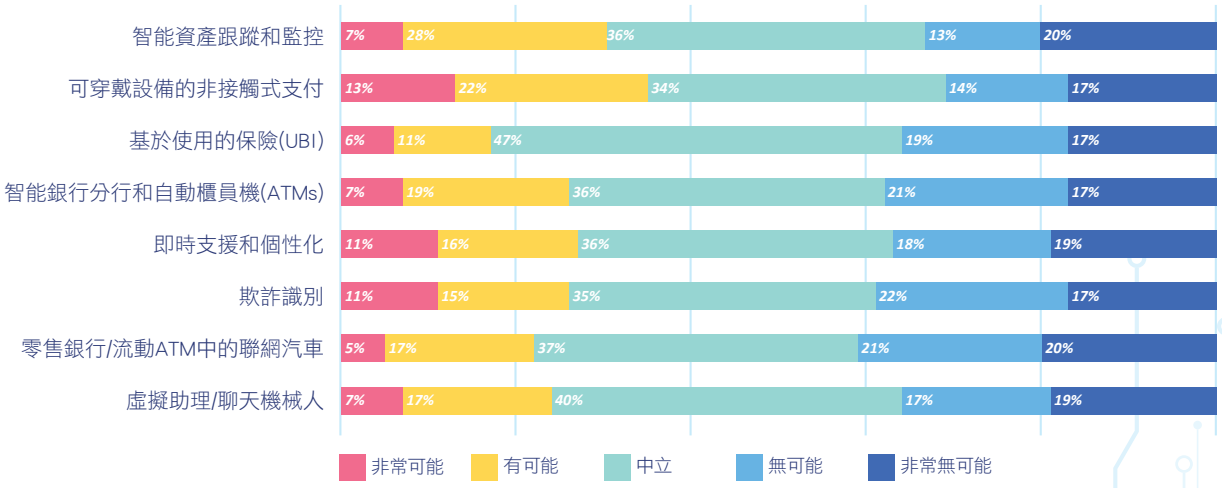


圖 1.29 金融機構應用

1.5.13 Financial Institution Applications

Intelligent Asset Tracking and Monitoring

Commercial banks can use biometrics and location sensors to track asset and monitor the location of cargo on container ships they finance from origin to the point of destination in real-time. In addition, sensors for corporate transportation and supply chain can collect physical, performance, and behavioural data to provide new opportunities for credit underwriting, for customers who lack credit history.

Contactless Payment with Wearables

Voice recognition and behaviour analysis can be used for biometric checks. The unique biometric information provided by wearable devices can strengthen security and make remote transactions more reliable and safer. Banks and other financial companies will no longer need to rely on only one form of biometric authentication.

Usage-based Insurance (UBI)

Usage-based Insurance (UBI) assesses risk based on the driver's actual driving behaviour. Insurance companies can provide more accurate premiums based on the data they collect from in-vehicle telematics devices, avoiding the subjectivity, bias, and potential dishonesty of manual data collection and self-reporting. They can also implement tailor-made insurance plans to compensate drivers who drive safely and infrequently.

Smart Bank Branches and Automated Teller Machines (ATMs)

Smart branches boost sales and improve customer experience. When a customer walks into the branch, service staff can instantly access information about specific customers. Smart ATMs offer remote management and provide a better customer experience. They use biometric authentication to confirm customer identities.

Immediate Support and Personalization

Smartphones act as beacons to notify the customer's arrival, optimizing customer service and improving customer experience. Fintech companies can also navigate customers to their business premises through mobile applications. Customers do not need to find their way at banks, they can get matched immediately to meet the right experts to solve problems by their stated visiting reasons. It improves efficiency, service delivery, and customer experience.

Fraud Detection

Personal devices that detect unauthorized activities extract data and alert relevant financial institutions to take protective and proactive measures when suspected. Biometric authentication will be enhanced through other security processes, such as facial recognition to reduce fraud detection errors. Multi-modal biometric security measures that combine nuances such as the customer's gait can reliably verify the identity of mobile users.

Connected Cars in Retail Banking/Mobile ATMs

The fleet has been customized with safety deposit boxes and ATMs. It saves time on going to the ATM every time the user needs to deposit. Users can request this service for free through a smartphone app. The mobile ATM will arrive at the pick-up point, allowing customers to deposit or withdraw money. The fleet management provides managers monitoring and tracking abilities, providing detailed insights to utilize resources effectively.

Virtual Assistants/Chatbots

Users can manage smart IoT devices in everyday language easily through voice commands with virtual assistants/ chatbots. For example, users can order lunch through a smart refrigerator.

According to the results of questionnaire survey, some respondents are very likely to invest in contactless payment with wearables in the future. Wearable devices have become a popular channel for mobile payments these days. Consumers would like to pay for products more efficiently and quickly. Contactless payment experiences are starting to become an expectation to consumers. In addition, a few of them have a likelihood to invest in immediate support and personalization, and also fraud detection applications.

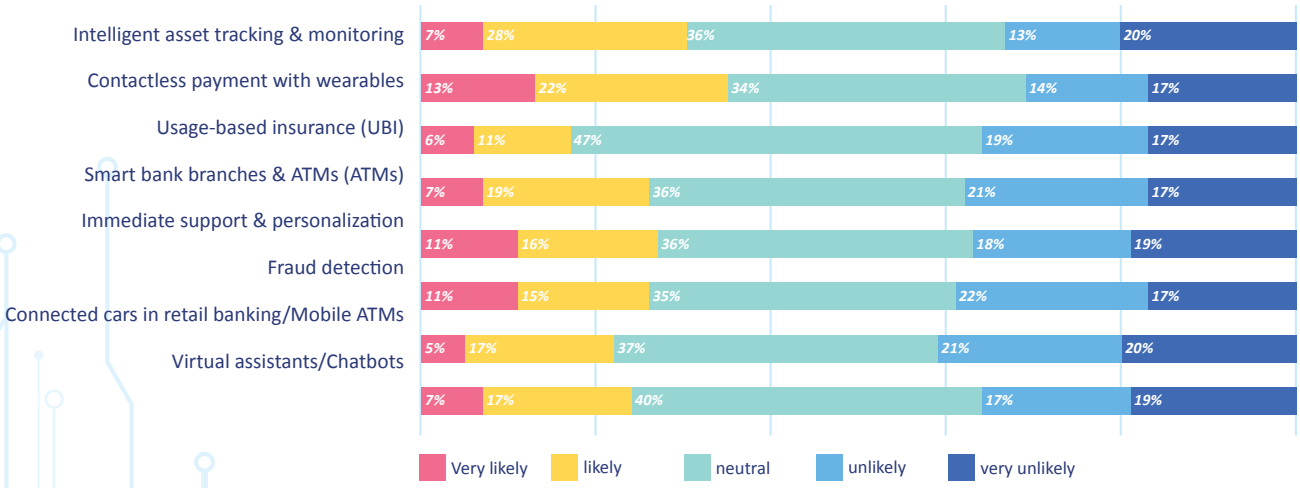


Figure 1.29 Financial Institution Applications

2 香港再工業化與5G發展的關係

2.1 從工業 1.0 到 4.0 的演進

在18 世紀末，由英國開始，工業 1.0 引入了使用水和蒸汽動力的大規模生產，而不是純粹的人力和畜力。產品由機器生產，不再是單純手工製作。

一個世紀後，工業2.0引入了生產線以及石油、天然氣和電力的使用。這些新的能源和更先進的電話和電報通信，促進了大規模生產並為製造過程帶來了一定程度的自動化。

自20世紀中葉開始，工業3.0在製造過程中，使用電腦、先進電信和數據分析。工廠在機器中嵌入可編程邏輯控制器，以幫助自動化流程並收集和共享數據。

在2010年代初，德國提出工業4.0。它的特點是使用更高的自動化，並採用數據化的智能工廠，更有效地生產商品。由於靈活性的提高，製造商可以使用大規模的客製化，更好地滿足客戶需求，並同時達到最小生產批量。通過由工廠車間收集更多數據，結合其他業務營運數據，智能工廠便能做出更好的決策。

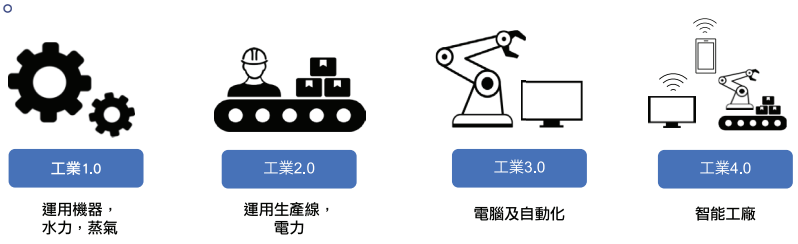


圖 2.1 從工業 1.0 到 4.0 的演進

2.2 再工業化

近年香港政府正積極地推動再工業化，即工業4.0。透過運用創新科技，提升香港製造業的競爭力。以下是工業4.0的一些特點[11]：

以數碼方式連繫

工業4.0意指工業製造系統和產品在設計、製造、運作和服務上的急速轉型。簡而言之，製造業務內部和周圍的一切，包括供應商、工廠、分銷商，甚至產品本身，都是以數碼方式連繫，成為一個高度整合的價值鏈。

自動化

工業4.0將製造工序演化成更高層次的自動化技術，讓物理工業世界和數碼資訊科技世界融合，組成信息物理系統。信息物理系統透過電腦和網絡應用，將物理世界不同來源的各種資源（例如原材料和機器），加以匯聚和運用。系統在電腦和網絡之間持續運算交換資料，達致自動化運作，生產出具成本效益的度身訂製產品，以及構建嶄新的商業模式。

採用特定技術

上述自動化發展要得以成功，有賴若干特定科技，包括：

- **人工智能**
  機器系統能夠執行需要人類技術與能力的智能工作
- **大數據及數據分析**
  可供分析的大量結構化或非結構化數據，用於辨識規律和趨勢
- **區塊鏈科技**
  分布式的數據庫和分類帳，由儲存於大量機器內的區塊所組成，可供追查資料及提高數據穩健性
- **物聯網**
  感應器或機器等實體物件與互聯網之間建立的聯繫，能夠回應環境變化、處理資料和進行機器對機器通訊
- **快速成形**
  有別於傳統物料製作及清除技術，相關科技會應用電腦輔助設計及積層製造（亦稱3D打印）等配套科技，生產部件及原型產品。

[11] 鍾浩邦（2020，7月14日）。資料摘要：選定地方推動再工業化的措施。取自香港特別行政區立法會網址：https://www.legco.gov.hk/research-publications/chinese/1920in15-measures-to-promote-re-industrialization-in-selected-places-20200714-c.pdf

2 Relationships of Hong Kong Re-industrialization and 5G Development

2.1 Evolution of Industry 1.0 to 4.0

Beginning in the late 18th century in Britain, Industry 1.0 introduced mass production with the use of water and steam power instead of purely human and animal power. Finished products were made by machines, not painstakingly made by hand.

A century later, Industry 2.0 introduced assembly lines and the use of oil, natural gas, and electricity. These new power sources and more advanced communications via telephone and telegraph have brought mass production and a certain degree of automation to the manufacturing process.

Beginning in the middle of the 20th century, Industry 3.0 added computers, advanced telecommunications, and data analysis to the manufacturing process. The digitization of factories starts with embedding programmable logic controllers (PLCs) into machines to help automate processes and collect and share data.

In the early 2010s, Industry 4.0 (I4.0) was first introduced by Germany. It features increased automation and the adoption of data-informed smart factories to produce goods more efficiently. Due to the increased flexibility, manufacturers can use mass customisation to better meet customer needs - ultimately seeking to achieve efficiency with, in many cases, a lot size of one. By collecting more data from the factory floor and combining it with other business operating data, smart factories can make better decisions.

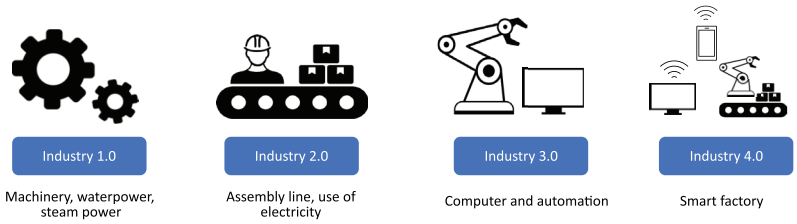


Figure 2.1 Evolution of Industry 1.0 to 4.0

2.2 Re-industrialization

The Hong Kong government has been actively promoting re-industrialization, also known as I4.0, in recent years to enhance the competitiveness of the manufacturing industry in Hong Kong through innovative technologies. Below are some of the features of I4.0:[11].

Digitally Connected

I4.0 is a term that applies to the rapid transformation of the design, manufacture, operation and service of manufacturing systems and products. In short, everything in and around a manufacturing operation, including suppliers, plant, distributors, even the product itself, is digitally connected, providing a highly integrated value chain.

Automation

Under I4.0, the manufacturing process will be evolved to a higher level of automation where the physical world of industrial production merges with the digital world of information technology, forming cyber-physical systems. Under these cyber-physical systems, resources from different sources in the physical world, such as raw materials and machines, can be brought and utilized together with the use of computers and networks.

With the constant exchange of data within computers and networks, it is possible to achieve cost-effective production of customized products and develop new business models autonomously.

Adoption of Specific Technologies

Several specific technologies contribute to the successful development of such automation. They include:

- **AI**
  The ability of a machine-based system to perform tasks requiring skills and abilities associated with human intelligence
- **Big Data and Analytics**
  Large sets of structured or unstructured data can be analysed to reveal patterns and trends
- **Blockchain Technology**
  Distributed databases and ledgers made of blocks stored on a large number of machines to support traceability and data robustness
- **IoT**
  Connections between physical objects like sensors or machines and the Internet, resulting in the ability to respond to the environment, process data, and engage in machine-to-machine communication
- **Rapid Prototyping**
  A complementary set of technologies, such as computer-aided design and additive layer manufacturing (also known as 3D printing), is used to produce parts and prototypes instead of traditional material forming and removal techniques

[11] Chung, K. (2020, July 14). Information Note: Measures to Promote Re-Industrialization in Selected Places. Retrieved from Legislative Council of the Hong Kong Special Administrative Region: https://www.legco.gov.hk/research-publications/english/1920in15-measures-to-promote-re-industrialization-in-selected-places-20200714-e.pdf

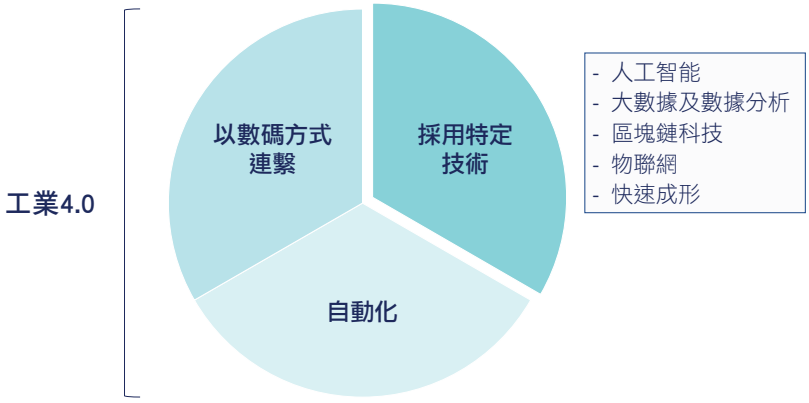


圖 2.2 工業4.0的特點 - 採用特定技術

2.3 在製造業中使用 5G 的好處

5G在促進製造業數字化，實現再工業化並加速邁向工業4.0，發揮著關鍵作用。

更高速度和更低時延

在製造過程中，需要在近鄰中使用許多資料密集型機器，例如使用大量自動化機械人、可穿戴設備和VR眼鏡。5G的高速度和低時延特性能使通訊更有效率，成就智能工廠的未來。

可連接更多物聯網設備

5G可以支持大量的機器類通信，每平方米可支援多達百萬台設備，這項特性允許在製造場所中實現物聯網的廣泛使用物和實時互動。

網絡切片

在製造場所中，可能要運用數百種不同的工業4.0應用。它們可能需要在吞吐量、時延、可靠性和端點數量方面有不同的要求。這需要一個能覆蓋整個生產場所，並為所有網絡應用提供最高級別的可靠性和低時延，以及高峰值頻寬的5G網絡。這些不同的應用需求，需要放到不同的訂製網絡切片中。使用網絡切片，可以將同一個實體網絡劃分為多個虛擬網絡，每個虛擬網絡都針對其特定要求進行了優化。這樣便可以隨時改變網絡的規模，以應付時刻改變的要求。

2.4 工業 4.0 中 Wi-Fi 與 5G的比較

雖然近年Wi-Fi技術不斷改變，由Wi-Fi 5到Wi-Fi 6的頻寬有所提升。然而，在複雜的製造場所環境中，以及用戶和應用需求下，很難實現所需的網絡吞吐量。

一篇論文[12]探討並檢視了在廣泛的製造和供應鏈相關用例中應用Wi-Fi和4G/5G移動網絡之間的技術和營運差異。以下是5G相比於Wi-Fi具備了的多項優勢：

流動性

基本上，移動網絡是為可靠地支持流動用戶和設備而設計的。它可以在高速列車上，支持無間斷的語音通話。隨著數據服務的發展，同樣的流動支援要求被轉化至互聯網和私人網絡的連接上。在移動網絡，基站切換/漫遊決策是集中協調的。在5G uRLLC 的製造生產使用案例中，基站切換的時延要求，非常接近 0 毫秒。

可是Wi-Fi網絡中的接入點切換決策依賴於設備，這是一個緩慢且不太可靠的過程。即使對於高端網絡和實施可選Wi-Fi標準（包括IEEE 802.11 k、r、u 和 v）的設備，也可能需要30毫秒以上的時間才能完成[13]。

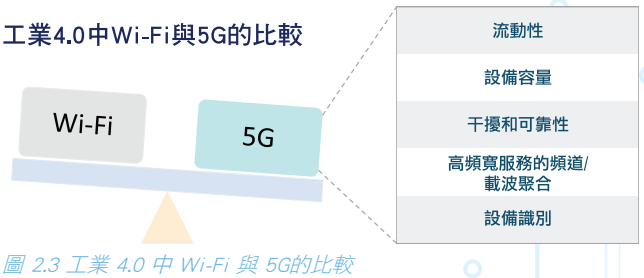


圖 2.3 工業 4.0 中 Wi-Fi 與 5G的比較

在先進的工業控制使用案例中，例如自動導引車（AGV）及更智能的自動移動機械人，可靠的基點切換至關重要。通過 5G 網絡，便可在工廠和倉儲中可靠地運行這些用例。

[12] Groupe Speciale Mobile Association（GSMA）（2021）。5G for Industry 4.0 operational technology networks。取自GSMA網址：https://www.gsma.com/iot/wp-content/uploads/2021/03/2021-03-GSMA-5G-Industry-4.0-Op-Tech-Networks.pdf

[13] 測試結果表明，快速漫遊將客戶端重新連接設置時間提高了84%，從 203 毫秒減少到 31 毫秒。- Bahr, J.與Poletti, M.（2019，11月21日）。Field Trial Results Show Wi-Fi CERTIFIED Vantage™ Devices Offer Significant Improvement to Network Performance。取自CableLabs網址：https://www.cablelabs.com/converged-access-edge-controller

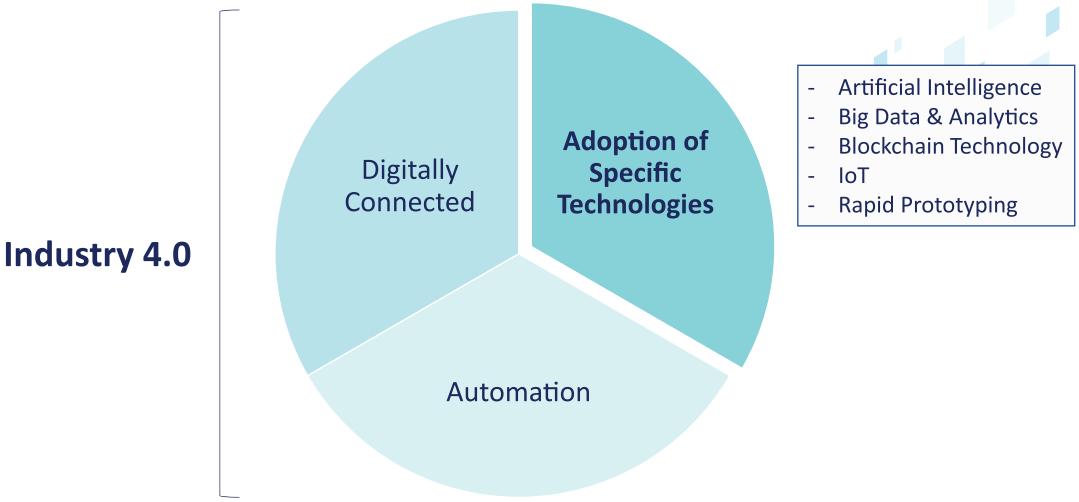


Figure 2.2 Features of I4.0 - Adoption of Specific Technologies

2.3 Benefits of Using 5G In Manufacturing Industry

5G plays a key role in accelerating the digitization of manufacturing in re-industrialization towards I4.0.

Higher Speeds and Lower Latency

In manufacturing, it is required to use many data-intensive machines within proximity. In such cases reliant on data-intensive machine applications, the higher speeds and low latency of 5G are required for effective use of automatic robots, wearables, and VR headsets, shaping the future of manufacturing.

Support of More Connected IoT Devices

5G can support huge machine-type communications, up to million devices per square kilometer, allowing extensive IoT adoption and real-time interaction within the manufacturing site.

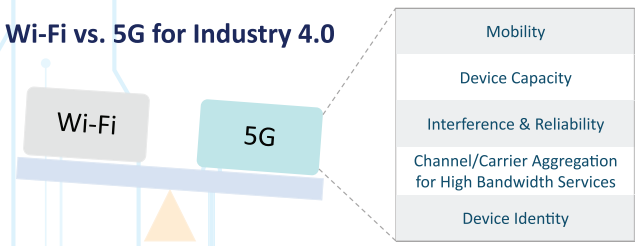
Network Slicing

In a manufacturing site, it may involve hundreds of different I4.0 applications. They may require connectivity with different requirements in terms of throughput, latency, reliability, and the number of endpoints. This requires an appropriate 5G network that covers the full site and provides the highest levels of reliability and low latency, as well as peak bandwidth for all applications - all with different tailored network slices for different uses. Using network slicing, the same physical network can be divided into multiple virtual networks, where each one is optimized for its specific requirements. It allows to scale up or scale down the network to meet dynamic needs.

2.4 Wi-Fi vs. 5G for Industry 4.0

Wi-Fi technology has continued to improve in recent years. There are significant bandwidth gains over earlier generations of Wi-Fi networks in Wi-Fi 5 and Wi-Fi 6. However, in the complex physical environment and user and application demands of the manufacturing site, overall throughput is rarely achieved.

A paper explores the technical and operational differences between Wi-Fi and 4G/5G mobile networks and reviews a broad range of manufacturing and supply chain-related use cases to apply these connectivity options[12]. Below are the pros of 5G over Wi-Fi in more detail:



Wi-Fi vs. 5G for Industry 4.0

Mobility

Mobile networks are basically designed for supporting user and device mobility reliably. It can support the continuity of voice calls on high-speed train services. With the development of data services, the same mobility support is translated into the Internet and private network connections. Handover/roaming decisions are coordinated centrally. In 5G uRLLC use cases such as manufacturing, cell handover latency is required to be very close to 0 milliseconds.

However, access point switching decision in Wi-Fi networks relies on each device and it is a slow and much less reliable process. It can take upwards of 30 milliseconds to complete[13] even for high-end networks and devices implement optional Wi-Fi standards including IEEE 802.11 k, r, u, and v.

[12] Groupe Speciale Mobile Association (GSMA). (2021). 5G for Industry 4.0 operational technology networks. Retrieved from GSMA Website: https://www.gsma.com/iot/wp-content/uploads/2021/03/2021-03-GSMA-5G-Industry-4.0-Op-Tech-Networks.pdf

[13] Test results show that FT roaming improved client re-connection setup times by 84%, reducing it from 203 ms. to 31 ms. - Bahr, J., & Poletti, M. (2019, November 21). Field Trial Results Show Wi-Fi CERTIFIED Vantage™ Devices Offer Significant Improvement to Network Performance. Retrieved from CableLabs Website: https://www.cablelabs.com/converged-access-edge-controller

另外，在某些用例中，位置定位也很重要。而通過位置管理功能（Location Management Function），5G可以支持不同精確度的定位能力。根據高通的說法，5G的定位精確度可低至米、分米和厘米[14]。他們在巴塞羅那舉行的世界行動通訊大會MWC 2021上，展示了使用上行鏈路到達時間差（U-TDOA）和傳感器融合的5G工業精確定位，以幫助AGV以厘米級精度在工業室內環境中導航[15]。

對於任何需要持續低時延連接和移動性的使用案例，5G將是最佳解決方案。對於關鍵控制和安全相關使用案例，5G 也比 Wi-Fi優勝。

設備容量

5G網絡可以支持的連接密度，遠比 Wi-Fi 接入點為多。對於 Wi-Fi 802.11 協議，在使用加密（例如數據保護）時，一般每個接入點最多只可關聯數百個設備，具體數目取決於接入點的處理和密鑰儲存能力。

5G網絡每平方公里最多可支持 100 萬台聯網設備。此外，5G mMTC還支持有省電功能，配備長電池壽命的設備，如煙霧探測器、位置跟蹤器和定期監控等。

在需要高密度連接設備的使用案例中，例如工廠監控或跟蹤在生產線中的組件、組裝過程和產品，可能需要部署數千個設備，5G網絡將是更好的選擇。

干擾和可靠性

通常，Wi-Fi 網絡在共享（shared）或非授權頻譜（unlicensed spectrum）中運行，任何用戶都可以使用經批准的設備來部署網絡，這可能對網絡之間造成干擾。此外，一些在同一頻段工作的非 Wi-Fi 設備，如藍牙裝置、微波爐等，也會對部分Wi-Fi網絡產生干擾。

相反，移動網絡主要在授權（licensed）或受控頻譜中運行，這意味著網絡營運商可以更好地管理環境中的干擾，並在需要時獲得當地監管機構和執法部門的支援。此外，移動網絡使用獨立於上行和下行鏈路數據傳輸的「控制通道」。這些控制通道確保客戶端設備，可以在基站的控制下更好地協調傳輸，更有效地使用可用頻寬，並實現所需的服務質量（QoS）。

由於干擾問題，在需要實時或近實時控制的工業使用案例（例如自動移動機械人）中，移動網絡都能提供有保證的上/下行鏈路頻寬和時延等所需的QoS。

高頻寬服務的頻道/載波聚合

在工業4.0 中，一些進行控制的使用案例，要使用實時或近實時的圖像和視頻處理，這需要高清視頻傳輸和高頻寬服務。例如生產線的自動化視覺分析，以及自動化移動機械人的導航和防撞系統。此外，高頻率的實時數據採集、VR和AR也需要高頻寬。

雖然5G和Wi-Fi都支持載波聚合（聚合頻譜以支持更高頻寬的服務），但仍存在一些分別。Wi-Fi 6支持160 MHz的頻道，而5G能支持高達1 GHz的頻譜聚合。

所以5G能夠更好地支持高頻寬服務。

設備識別

Wi-Fi設備使用MAC地址作為識別。但是，它可以被應用程序或某些設備上的操作系統所更改，因此不能保證它是全局唯一的。

而5G、4G及更早的移動網絡，通信模塊硬件標識符（國際移動設備標識符IMEI）與SIM/eSIM的唯一集成電路卡標識符（ICCID）和國際移動用戶身份（IMSI），可以結合起來用於網絡認證和授權。這些組合了SIM/eSIM和硬件設備標識符的識別碼，可用作訪問網絡的驗證及應用QoS和訪問網絡切片等政策的基礎。

[14] R17 將進一步提高定位精度、時延、容量，並下降到厘米級。 - Casaccia, L.（2019，12月13日）。3GPP charts the next chapter of 5G standards。取自Qualcomm網址：https://www.qualcomm.com/news/onq/2019/12/13/3gpp-charts-next-chapter-5g-standards
[15] Mukkavilli, K.與Zhang, X.（2021，12月17日）。5G: Bringing precise positioning to the connected intelligent edge。取自Qualcomm網址：https://www.qualcomm.com/news/onq/2021/12/17/5g-bringing-precise-positioning-connected-intelligent-edge

Reliable handovers are crucial for advanced industrial control use cases including autonomous guided vehicles and their smarter equivalent autonomous mobile robots. This can be achieved with 5G networks to have reliable operation throughout a manufacturing plant, or its correlated warehousing.

Besides, in some use cases, location positioning is also important. 5G can support a range of positioning capabilities in the form of a Location Management Function. According to Qualcomm, the positioning accuracy is down to the meter, decimetre, and centimetre[14]. They demonstrated industrial precise positioning with 5G using uplink time difference of arrival (U-TDOA) and sensor fusion to help automated guided vehicles (AGVs) navigate industrial indoor environments with centimetre-level precision at MWC 2021 in Barcelona[15].

For any use case that requires continuous low-latency connectivity and mobility, 5G will be the best solution. For critical control and safety-related use cases, 5G will outperform Wi-Fi.

Device Capacity

5G networks can support connection densities far beyond Wi-Fi access points.

For the Wi-Fi 802.11 protocol, the actual number of devices that can be associated with a given access point is typically limited to the order of hundreds of devices when using encryption (such as data protection), depending on the processing and key storage capability of the access point in general.

5G network can support up to 1 million connected devices per square kilometre. Besides, the 5G mMTC service also supports power-saving features for devices that require long battery life, such as smoke detectors, location trackers, and periodic monitoring.

In use cases that require a high density of connected devices, such as plant monitoring or components, assemblies, and product tracking through a production line, it may require the deployment of thousands of devices. 5G networks will be a better choice.

Interference and Reliability

Generally, Wi-Fi networks operate in a shared or unlicensed spectrum, and any user can deploy the provided network with approved equipment and setups. It can lead to higher levels of interference between networks. Besides, some non-Wi-Fi devices operating in the same frequency band, such as Bluetooth and microwave oven devices, will also interfere with some Wi-Fi networks.

On the contrary, mobile networks principally operate in the licensed or controlled spectrum, which means the licensed network operator can better manage the interference environment and get support from local regulators and law enforcement when needed. Besides, mobile networks use "control channels" separate from the uplink and downlink data transmissions. These control channels ensure that client devices can better coordinate transmissions under the control of base stations, use the available bandwidth more efficiently, and achieve the required Quality of Service (QoS).

Due to interference issues, in any industrial use case that requires real-time or near-real-time control (such as automated mobile robots), the mobile network is best able to deliver the required QoS, including guaranteed uplink/downlink bandwidth and latency.

Channel/Carrier Aggregation for High Bandwidth Services

In I4.0, some applications which use real-time or near-real-time image and video processing for control purposes require high-definition video transmission and high-bandwidth services.

Some examples are automated visual analysis on production lines and navigation and collision avoidance systems for automated mobile robots. In addition, high-frequency real-time data acquisition, VR and AR also require high bandwidth.

While both 5G and Wi-Fi support channel bonding (aggregation of carrier spectrum to support higher bandwidth services), there are some differences. Wi-Fi 6 supports channels up to 160 MHz, while 5G supports up to 1 GHz of the spectrum for aggregation.

Therefore, 5G would be better to support applications that require high bandwidth.

Device Identity

For Wi-Fi devices, the MAC address is used for identification. However, it can be overridden by applications or the device operating system on some devices, so it is not guaranteed to be globally unique.

For 5G, 4G and earlier mobile networks, the unique integrated circuit card identifier (ICCID) and international mobile subscriber identity (IMSI) of the SIM/eSIM, together with the communication module hardware identifier (international mobile equipment identifier or IMEI) are used for network authentication and authorisation. These combinations of the SIM/eSIM and hardware device identifiers can be used as a verification to access the network and as the basis for applying policies, including QoS and access to network slices.

14 R17 will further enhance positioning accuracy, latency, capacity, and down to cm-level. - Casaccia, L. (2019, December 13). 3GPP charts the next chapter of 5G standards. Retrieved from Qualcomm Website: https://www.qualcomm.com/news/onq/2019/12/13/3gpp-charts-next-chapter-5g-standards

15 Mukkavilli, K., & Zhang, X. (2021, December 17). 5G: Bringing precise positioning to the connected intelligent edge. Retrieved from Qualcomm Website: https://www.qualcomm.com/news/onq/2021/12/17/5g-bringing-precise-positioning-connected-intelligent-edge

2.5 傳統電子產品/技術的使用

如之前所述，在工業4.0中使用 5G 網絡是較Wi-Fi 有利的。然而，立即將 Wi-Fi 網絡（如 Wi-Fi 路由器和光纖）切換到 5G， 對工業4.0的企業來說，可能會過快。Wi-Fi網絡可以用於支持工廠的IT領域，而5G網絡則可以用於生產領域。

此外，在網絡基礎設施中，傳統的光纖仍然有重要的位置。它具有更高的速度、更低的衰減、抗電磁干擾、較小型和接近無限的頻寬等優點，適合用於回程網絡，或接駁無線回程網絡至光纖回程網絡。它也適合用於「前傳」，接駁密集的5G小型基站。

2.6 通過專用/公共無線網絡實現工業 4.0

無線移動網絡可分為專用/公共， 一般移動通訊服務都是使用公共移動網絡。雖然它的部署時間較短，但覆蓋範圍有限、客制化程度低、安全性低以及需要與他人共享頻譜，它不太適合在工業4.0中使用。

專用5G移動網絡與公共移動網絡相類似，也需要公共網絡中的所有類似元素，但它由建造或購買它的組織所擁有和控制。

使用專用無線網絡，網絡數據不需要來回發送到遙遠的核心網。所有數據流量都可以保持在本地，從而減少時延、提高速度、安全性和隱私性。此外，可以通過建立廣泛的冗餘、備用電源和額外的站點、修復系統、以及支持遠程覆蓋和更遠距離的操作，來提高網絡可用性。但是部署時間可能會較長，企業需要根據自己的應用來考慮這些網絡的優劣。企業可以建立自己的專用無線網絡，或將其外判予電訊服務提供商。例如，香港國際機場設有專用5G網絡，為營運商提供獨立及可靠的無線網路服務。

使用授權或非授權頻譜建構專用網絡

專用無線網絡可以在授權或非授權頻譜上運行，而使用哪一種頻譜去建構網絡，取決於所用位置、用戶要求和預算。

由於目前授權頻譜是在電訊服務提供商手中，企業需要從他們那裡轉租。如要使用非授權頻譜，企業可以與移動服務提供商合作，或自行建設自己的專用無線網絡。後者適用於中小企、如短期建築工地新場景、或任何難以使用授權頻譜的流動場景。使用非授權頻譜是免費的，但它不能應用於關鍵任務。

2.7 在製造業中使用5G物聯網

5G可以支持關鍵通信，例如機器和製造機械人的無線控制。5G物聯網設備的大規模運用，將釋放工業4.0 的所有潛力。

2.7.1 改善製造過程的視頻監控

藉由5G 的寬頻譜，可以更密集地部署更高解像度閉路電視，提高生產線的遠程安全監控。使用人工智能攝像鏡頭，可以解決特定的業務問題，例如遠程實時監控、生產質量控制和更有效的製造安全管理。

2.7.2 資產的實時跟蹤和遠程監控

使用視頻和傳感器監控與分析來研究生產模式和優化流程，可以幫助跟蹤和監控生產中的各層面。儘管現有的Wi-Fi攝像鏡頭和物聯網設備也可完成這些工作，5G具備了低時延特性和可以用於戶外場所，提高了網絡性能。

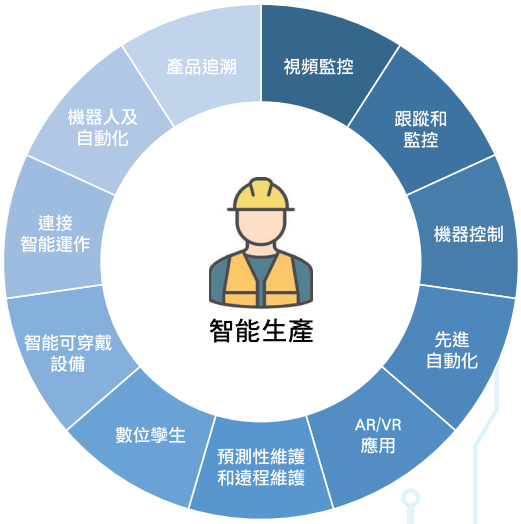


圖 2.4 在製造業中使用5G物聯網

2.5 Use of Traditional Electronics Products/Technology

As mentioned above, it is advantageous to use a 5G network instead of Wi-Fi in I4.0. However, immediately switching Wi-Fi networks (like Wi-Fi routers and optical fibre) to 5G may be too aggressive for I4.0 enterprises. Wi-Fi networks can be used to support the IT domain of factories, while 5G networks can support the production domain.

Besides, optical fibre is still required to support the wireless backhaul networks. Even in networks where this is not the case, wireless backhaul eventually needs to be connected to fibre optic backhaul. Fibre will also be preferred for what is known as "fronthaul", connecting the dense mesh of 5G small cells. Since fibre has increased speeds with lower attenuation, immunity to electromagnetic interference, small size, and virtually unlimited bandwidth potential, it is the right choice for this usage.

2.6 Enabling Industry 4.0 Through Private/Public Wireless Networks

There are two types of mobile networks, which are private and public. A public wireless network is the commonly used mobile service. Though it has shorter deployment times, limited coverage, low customization, low security, and shared bandwidth with others, it may not be suitable for the use cases in I4.0.

Private 5G wireless network is similar to the public wireless network that provides wireless broadband connectivity, but it is owned and controlled by the organization that built or purchased it. A private wireless network needs all the similar elements in a public network.

With private wireless networks, network traffic does not have to be sent back and forth to a distant core network. All traffic can remain local, improving speed, latency, security, and privacy. In addition, network availability can be increased by establishing extensive redundancy, backup power and additional sites, repairing systems when needed and supporting remote coverage and access over longer distances. However, the deployment time may be longer, enterprises need to consider the pros and cons for these networks based on their applications. They can build their private wireless network or outsource it to telecom service providers. For example, there is a private 5G network in the Hong Kong International Airport, providing independent and reliable wireless network services for operators.

Building private network with licensed or unlicensed spectrum

Private wireless networks can operate on both licensed and unlicensed spectrum. The choice between using a licensed or unlicensed spectrum will depend on the user locations, requirements, and budget.

In the case of using a licensed spectrum, since it is currently in the hands of telecom service providers, enterprises will need to sublease from them. In the case of using an unlicensed spectrum, enterprises can cooperate with a mobile service provider or building own private network by themselves. The latter case may be suitable for small and medium-sized enterprises and new scenarios like short term construction sites or any nomadic use cases that would be challenging for licensed spectrum. Using an unlicensed spectrum is free, but it cannot support mission-critical applications.

2.7 Use of 5G IoT Applications in Manufacturing Industry

5G enables critical communications, such as wireless control of machines and manufacturing robots, unlocking the full potential of I4.0, including the large-scale proliferation of 5G specific IoT devices.

2.7.1 Improve Video Surveillance of Manufacturing Processes

With the wide bandwidth in 5G, increased density of higher resolution CCTV can be deployed, improving the remote security surveillance of production lines. Using AI-powered cameras can solve specific business challenges such as real-time monitoring of remote sites, production quality control and more effective manufacturing safety measures.

2.7.2 Real-time Tracking and Remote Monitoring of Assets

Using video and sensor surveillance with analytics to study production patterns and optimize processes can help track and monitor different aspects of production. Although many of these activities can be done with existing Wi-Fi-based cameras and IoT devices, 5G can improve the performance with low latency and usage for outdoor venues.

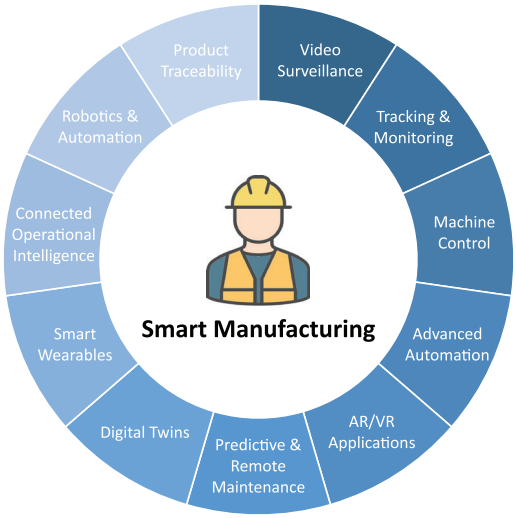


Figure 2.4 5G IoT in Smart Manufacturing

2.7.3 遠程實時控制

通過 5G 網絡保證的 QoS、可靠性和低時延，可以支持從中央指揮中心，到遠程工廠的時間關鍵型操作。使用物聯網傳感器，企業將能夠實時遠程監控和控制生產過程，以更快地檢測製造故障、發現問題並及時採取適當的補救措施。

2.7.4 先進自動化

5G網絡的安全性、高移動性和可靠性、低時延、高頻寬和高連接密度可使製造業擁有更先進的自動化。以下是一些使用案例：

無人機

無人機主要用於檢查和維護資產，於公司內部運送材料和零件，以及進行盤點，其中最突出的應用是檢查和維護。

配備雷達或激光掃描儀、紅外線或立體攝像鏡頭的無人機可以輕鬆檢測工業設備中的異常或缺陷。它特別適用於難以到達的區域，例如煉油廠、管道、礦場或其他大型設施，因為在那些地方進行人工檢查會很危險和不夠全面。因此，無人機有助於避免冗長、危險和昂貴的人工檢查。使用無人機掃描或檢查設施，可以比使用手持掃描儀的檢查員更準確地檢測缺陷。它們還有助於減少因檢查員受傷，而造成的保險費用。此外，他們還可以執行更多檢查，而大多數資產在檢查期間，不需要被關閉，可以繼續進行生產。無人機收集的數據可用於預防性維護和更好的資產管理。

無人機也可以用於公司內部運輸，在公司相鄰工廠之間運輸零件或材料。它也可用於庫存管理，配備條碼或 RFID 掃描儀的無人機，可以取代人手執行庫存檢查，並將數據傳輸到庫存管理系統。

AGV

由於Wi-Fi等傳統連接方案的不足，不能滿足AGV對通訊鏈路的時延和可靠性的需求，限制了AGV的性能和能力。5G可為AGV 增強能力：

- **增強AGV之間的協調能力**

  借助 5G 網絡的高速和低時延通訊，AGV機械人之間可以達到高水平的自主編隊和協作能力。因此，多個AGV機械人可以同時合作，完成以往單個AGV機械人所無法完成的任務。

- **提高人機之間交互的安全性**

  借助5G網絡的超低時延特性，AGV機械人可以感知和預測工人的行為和動作，與工人保持安全距離，確保安全。

- **實現實時遠程控制**

  5G 可實現對 AGV 機械人的實時控制，讓它們代替工人在高溫高壓工廠等惡劣環境中，執行危險任務。

- **實時收集數據和分析**

  通過5G網絡，可以將大量AGV互聯，收集物流搬運時間、停留位置和行動軌蹟等數據。透過實時分析這些數據，可以改進製造流程，並實現高效的車隊管理。

AGV可用於在倉庫內和倉庫之間運輸零件/貨物，它們可以在生產範圍中自行運送零件，無需固定路線，可按需要交付。材料的自主化供應，可減少等待時間以及工人走動，能夠支持最小生產批量。它們也減少交貨時間和所需的存倉/勞動力。

3D 分揀

借助頂尖的連接，配備先進視覺系統的機械人，將能夠在工作間的任何地方拿取零件，而現今大多數工廠機器，只能在固定的已知位置中拿取零件。由於增強的連接性可以允許在雲端或邊緣執行數據分析，此類機械人只需配備基本的內部處理能力。

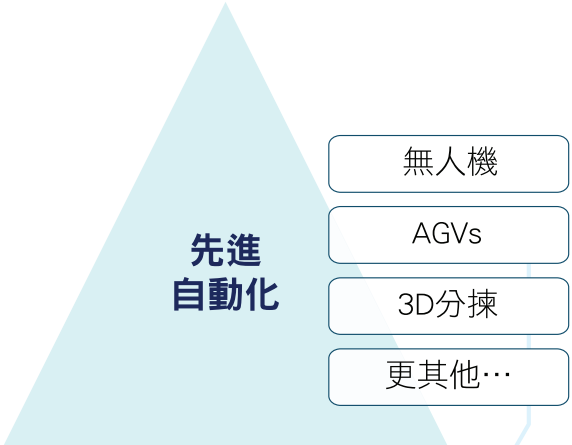


圖 2.5 先進自動化

2.7.3 Remote and Real-time Control

Time-critical operations from central command centres to remote factories can be supported with the QoS, reliability, and low latency guaranteed by 5G networks. Using IoT sensors, businesses will be able to remotely monitor and control production processes in real-time to detect manufacturing failures faster, identify problems, and take appropriate remedial actions promptly.

2.7.4 Advanced Automation

With the security, high mobility and reliability, low latency, large bandwidth, and high connection density of 5G networks, it enables the application of advanced automation in manufacturing. Some of the use cases are:

Drones

Drones are mainly for the following purposes: asset inspection and maintenance, transportation of materials and parts within the company, and inventory taking.

The most prominent application is inspection and maintenance. Drones equipped with radar or laser scanners, infrared or stereoscopic cameras can easily detect anomalies or defects in industrial equipment. It is particularly suitable for hard-to-reach areas such as refineries, pipelines, mines or other large facilities, because manual inspections are dangerous and incomplete to be performed there. Therefore, drones help to avoid lengthy, dangerous, and expensive manual inspections. Using drone to scan or inspect facilities can be more accurate in detecting defects than inspectors using handheld scanners. They also help save inspectors' insurance costs by reducing the probability of injury. Additionally, more inspections can be performed, and most assets do not need to be shut down during inspections, allowing production to continue. Data collected by drones can be used for preventive maintenance and better asset management.

Other uses of drones in the industry will be intra-company transportation, which means the transportation of parts or materials between adjacent factories of a company. Inventory management is another feasible application area for drones. Drones equipped with a barcode or RFID scanner can carry out inventory checks and transfer the data to an inventory management system, eliminating the need for manual inventory checks.

AGV

As the shortcomings of traditional connectivity solutions like Wi-Fi, requirements on latency and reliability of communication links cannot meet the needs of AGVs which limits the performance and capability of AGVs. 5G empowers AGVs in several ways:

- **Strengthen the coordination of AGVs**

  With the high-speed and low latency communication between AGVs in 5G networks, AGV robots can now have a high level of self-fleet organization and collaboration capabilities. Therefore, AGV robots can simultaneously cooperate to complete tasks that a single AGV robot could not complete alone in the past.

- **Improve safety in human-machine interactions**

  With the ultra-low latency feature of 5G networks, AGV robots can perceive and forecast workers' behaviour and movement to maintain a safe distance with workers to ensure safety.

- **Enable real-time remote control**

  5G enables real-time control of AGVs, which is essential to prevent workers from being injured when performing dangerous tasks in harsh environments, such as high-temperature and high-pressure factories.

- **Real-time data collection and analysis**

  The 5G network can interconnect a large number of AGVs to collect data such as logistics handling time, staying position, and movement trajectory. Data can be analysed in real-time to improve the manufacturing processes and achieve efficient fleet management.

AGVs can be used to transport parts/shipments in and across warehouses. They can deliver parts autonomously in the production area without fixed routes and on-demand. The use of autonomous material supply reduces waiting times as well as worker movements, enabling continuous material flow and lot size "1". It can reduce delivery times and stock values/less workforce needed.

3D Bin Picking

With the help of advanced cutting-edge connections, robots equipped with advanced vision systems will be able to find parts anywhere in the field, compared to most factory machines today, which can only do so in fixed, known locations. Because of the enhanced connectivity that can perform data analysis in the cloud or at the edge, such robots require minimal internal processing power.

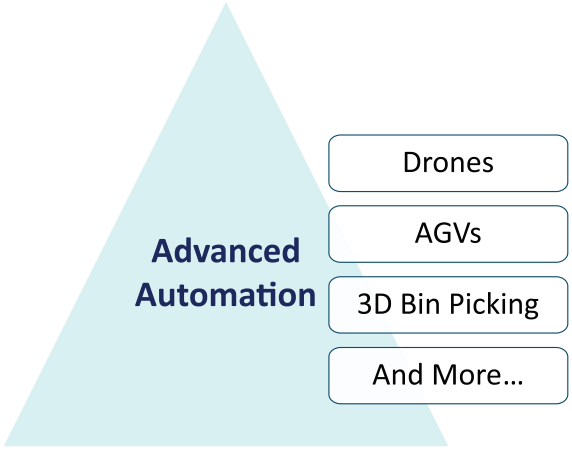


Figure 2.5 Advanced Automation

	應用事例	功用	5G + 先進自動化的優點
先進自動化	無人機	- 檢查和維護資產 - 於公司內部運送材料和零件 - 進行盤點	- 避免冗長、危險和昂貴的人工檢查 - 更準確地檢測缺陷 - 減少檢查員保險費用 - 可以作出預防性維護 - 有更好的資產管理
	AGV	- 在倉庫內和倉庫之間運輸零件/貨物	- 增強AGV之間的協調能力 - 提高人機之間交互的安全性 - 實現實時遠程控制 - 實時收集數據和分析
	3D 分揀	- 分揀物件	- 運用先進視覺系統，可以在非固定位置分揀物件 - 使用雲端或邊緣執行數據分析，機器人只需配備基本的內部處理能力

表 2.1 先進自動化例子

2.7.5 AR/VR應用

5G的超低時延和高頻寬特性，對於支持不同的AR/VR應用非常重要。而邊緣計算在這些應用中也很重要，因為它可以在更接近用戶的地方進行圖像處理, 比雲端計算提供更好的用戶體驗。

以下是工業4.0 中不同的 AR/VR 應用：

- **培訓**

  供應商可以將他們的零件或機器的構建說明，放在AR/VR頭戴設備中，以便買方的任何員工都可以組裝它。任何新入職者都可以按照儲存在AR/VR頭戴設備的指導，作正確的操作。 它們不僅可以減省資源，還可以減少錯誤。

  此外，在培訓員工方面, VR的潛力也很大。他們可以模擬現實訓練，遠程重複進行一些具危險性的情境訓練。

- **遠程專家指導/維護**

  通過工人佩戴的智能眼鏡，使身處另一地點的專家可以看到該工人的視角，以便指導在場工人設置機器或修理零件。它可以幫助提供更精確的遠程指導、減少意外停機時間、降低故障率並減少專家出差時間。

- **互動視覺**

  製造商可以互動地展示產品，通過AR/VR可以在一個應用程式中，展示許多不同產品的不同變體，允許用戶旋轉或放大以查看細節。

2.7.6 預測性維護和遠程維護

高級預測性維護方案，需要使用具大規模機器通訊的平台來支持。利用大量具AI能力設備收集的實時數據和進行分析，可以大大提高其維護質量。此外，憑藉5G的低時延和高可靠性，可以實現遠程維護。

2.7.7 數字孿生

數字孿生是物理實體的虛擬表示。在研究實體的各個重要功能相關區域中安裝各種傳感器，收集有關它在各個方面性能的資訊回饋，例如能量輸出、溫度、天氣條件等。然後將該數據饋送到處理系統並應用於數位副本上。借助這些數據，可以在數字孿生上進行模擬、分析性能問題和研究改進方法，建立可應用於物理實體上的各種有價值的洞見。

由於 5G具有低時延及支持大數據量的優點，它可以創建反應迅速、接近實時的數字孿生。

2.7.8 運用更多可穿戴設備提高工人安全

智能可穿戴設備能在複雜而艱鉅的任務中協助工作人員，提高安全，並將使用者與他們的工作以及其他工作人員聯繫起來。

由於5G可以連接更多設備，因此在製造場所中，可以使用更多可穿戴設備。

2.7.9 實時互聯營運智能

通過連接機器或設備，製造商可以建造智能網絡，只需操作員很少的參與便能讓網路中的各成員自主通信並互相協調。組織可以從遠端的製造設施和系統中收集數據，並將其相關聯到操作應用中。從而得到該系統的關鍵業績指標，通過它便可以更快發現問題及優化業務程序。此外，通過工業物聯網（IIoT），企業可以連接到不同的營運數據中心並整合它們，以實現跨製造系統的實時數據觀察。因此，支持物聯網的機械可以實現互聯營運智能，將所發現的洞見實時傳送給製造持份者，讓他們能夠遙距管理工廠。

	Use cases	Usage	5G + Advanced Automa-on Advantages
Advanced Automation	Drones	- Asset inspec-on and maintenance - Transporta-on of materials and parts within the company - Inventory taking	- Avoid lengthy, dangerous, and expensive manual inspec-ons - Detect defects more accurately - Save inspectors' insurance costs - Enable preven-ve maintenance - Enable beBer management
	Automated Guided Vehicles (AGVs)	- Transport parts/shipments in and across warehouses	- Strengthen the coordina-on of AGVs - Improve safety in human-machine interac-ons - Enable real--me remote control - Enable Real--me data collec-on and analysis
	3D Bin Picking	- Find parts anywhere in the field	- Able to operate anywhere with advanced vision systems, but not fixed/known loca-ons only - Require minimal internal processing power with cloud & edge compu-ng

Table 2.1 Examples of Advanced Automation

2.7.5 AR/VR Applications

The ultra-low latency and high bandwidth characteristics brought by 5G are very important to support different AR/VR applications. Edge computing is also important in these applications because images can be rendered closer to end-users to enhance the user experience compared to cloud computing.

The followings are different AR/VR applications in I4.0:

- **Training**

  Suppliers can bundle their parts or machinery with building instructions stored onto AR/VR headsets so that any employee at the buyer can assemble it. Any newcomers to a company can follow guidance stored in AR/VR headsets to carry out actions correctly. They can not only reduce required resources but reduce errors.

  Also, there is a great potential for training employees with VR. They can do realistic training and repeat some potentially dangerous situations over and over again remotely.

- **Remote Expert/ Maintenance**

  An expert at another location can see the worker's view through the smart glasses worn by the worker. Experts can instruct workers on-site, whether setting up machines or repairing parts. It can help provide more precise remote support, reduce unplanned downtime, reduce failure rates, and reduce expert travel time.

- **Interactive Visualization**

  Manufacturers can display products interactively. AR/VR can be used to showcase all the different variations of many different products in one app, allowing users to rotate or zoom in to see details.

2.7.6 Predictive Maintenance and Remote Maintenance

Advanced predictive maintenance solutions need to be supported by massive machine-type communication using a single platform. Collecting real-time data from many devices powered by AI and Analytics can greatly improve the quality of advanced predictive maintenance. In addition, with the low latency and high reliability of 5G, it enables remote maintenance.

2.7.7 Digital Twins

A digital twin is a virtual representation of a real physical object. The object under study is equipped with multiple sensors related to important functional areas. These sensors collect data on various aspects of physical object performance, such as energy output, temperature, weather conditions, and more. This data is then fed to a processing system and applied to a digital copy.

With these data, virtual models can be used to run simulations, investigate performance issues, and analyse possible improvements to generate valuable insights that can be applied back to the original physical object.

As 5G have the pros of low latency and can support large data volumes, it can create responsive, near real-time digital twins.

2.7.8 More Smart Wearables to Improve Workers' Safety

Smart wearables can improve safety and awareness, assist workers in complex and demanding tasks, and connect users with their work and each other.

Since 5G promises to connect more devices, more smart wearables can be used on the manufacturing site.

2.7.9 Real-time Connected Operational Intelligence

By connecting machines or equipment, manufacturers can generate intelligent networks that can autonomously communicate and coordinate with each other with little operator involvement. Organizations can collect data from remote manufacturing assets and systems and associate it with operational applications. As a result, providing a proactive view of key performance indicators can identify issues faster to optimize business operations. In addition, through the Industrial Internet of Things (IIoT), companies can now connect to different operational data centres and unify them to achieve real-time data visibility across various manufacturing systems. As a result, IoT-enabled machinery can achieve connected operational intelligence and transmit real-time insights to manufacturing stakeholders, enabling them to manage plant units remotely.

2.7.10 機械人智能自動化和實時遙控

使用無線機械人可以提高生產力和靈活性，但它需要一個可靠且超低延遲的網絡，該網絡還需支持密集的物聯網機器，以目前的連接技術很難滿足這些要求。由於 5G 可以提供超低時延傳輸，並支持高密度設備連接，它可以用作同步控制這些機械人。此外，使用5G加上超寬頻（UWB），可使資產定位及跟蹤的精確度達厘米級。

通過廣泛使用可獨立執行命令並自主協調的聯網自動化機器，可以提高生產過程的靈活性，提高材料使用效率，精簡生產程序和停機時間。

2.7.11 實時產品追溯

5G可以改善產品跟蹤，由製造到交付的整個供應鏈中，可接近實時地收集數據，有助於更快地回應需求。在工廠中，可在產品和貨車上裝上支持5G的跟蹤傳感器。由於5G可支持大量移動設備，因此可以準確地跟蹤製造商的整條供應鏈。如果途中出現延誤，管理人員可以檢查並查看產品的確切位置、溫度或其他環境因素。

由於5G可以以低時延快速傳輸大量數據，供應鏈管理人員可以通過傳感器監察各種能影響產品質量的重要因素。此外，將5G與人工智能和機器學習結合，可以更準確地預測產品運輸至客戶的時間。

調查顯示，大部分受訪者對5G的興起將給香港製造業帶來的影響持樂觀態度。他們中的大多數人都同意5G的興起「可實現即時資產跟蹤和監測」，「使用物聯網大數據分析，可更快捷地找出洞見，如預測性維護」。

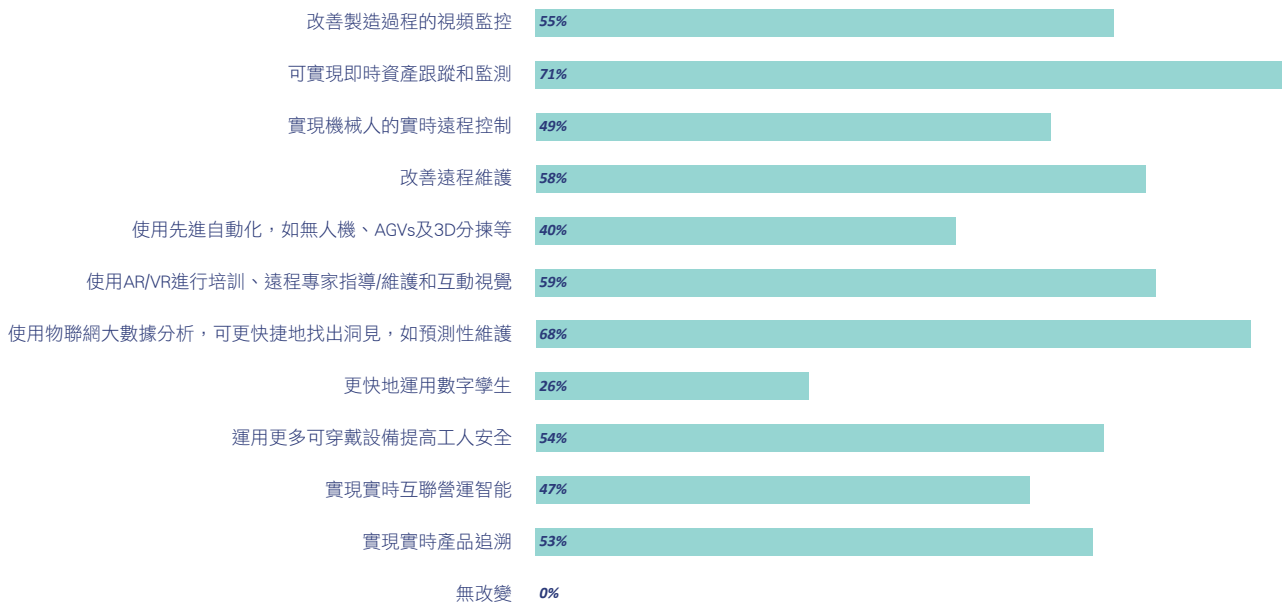


圖 2.6 5G的興起將給香港製造業帶來的影響

2.8 機械人賦能工業製造

5G的低時延、高傳輸速度，能帶來新一代機械人應用。通過無線傳訊，機械人可以自由走動，不再受有線通信的線路捆綁，並具備雲端計算和數據儲存資源的巨大優勢。借助這些功能，機械人可以近乎實時地執行精確的動態控制，並在本地和全球範圍內與人和機器連接。在製造業，它們可用於智能自動化工序、在醫療保健方面，可以用作機械人護理和機械人手術。此外，在施工現場，它們還可以用來掃描進度，以及在物業管理方面作為保安機械人。　因此，使用5G是機械人技術的關鍵成功因素。

2.7.10 Smart Automation with Robots and Real-time Remote Control of Robotics

Using wireless robots can increase productivity and flexibility, but it requires a reliable and ultra-low latency network that also supports higher densities of IoT machines. These requirements will be difficult to meet with current connectivity technologies. Since 5G can provide ultra-low latency transmission and support a high density of connected devices, these robots can be controlled in sync with 5G. In addition, using 5G+UWB, asset positioning and tracking accuracy can reach a centimetre level.

Through the extensive use of connected automated machines that independently execute requests and automatically coordinate themselves, it is possible to increase the flexibility of the production process, improve material efficiency, and reduce complexity and downtime.

2.7.11 Real-time Product Traceability

5G capabilities can improve product tracking. Data can be captured near real-time across the supply chain from manufacturing to delivery, helping to improve responsiveness to demand trends.

In factories, 5G-enabled IoT tracking sensors are installed on products and trucks. Since 5G can support mobile devices at scale, it is possible to accurately track manufacturers' complete supply chains. If there are delays along the way, managers can check and see the exact location of the product, temperature, or other environmental factors.

Since 5G can transmit large data volumes fast with low lag, the supply chain managers measure factors critical to their product quality from tracking sensors. Besides, combining 5G with AI and machine learning could more accurately predict the arrival time of the products in transit to customers.

From the survey, the majority of the respondents are positive about the rise of 5G will bring to the Hong Kong manufacturing industry. And most of them agree the rise of 5G will enable real-time tracking and remote monitoring of assets, and big data analytics can help to draw insights from numerous IoT device data, such as predictive maintenance, in a faster way.

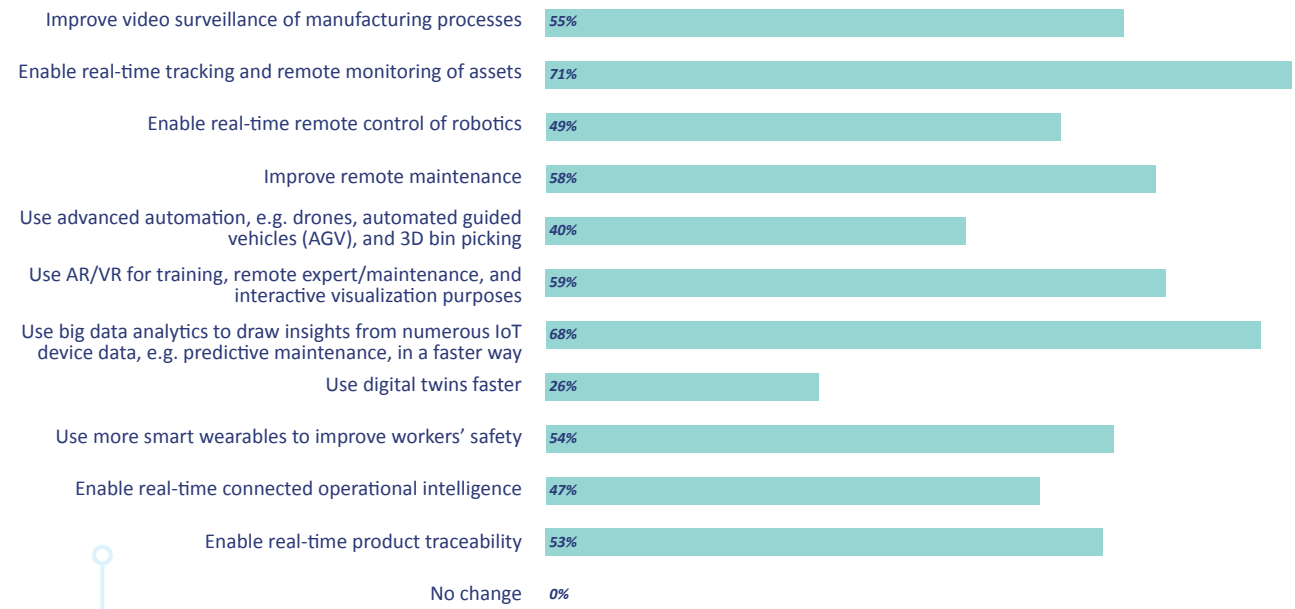


Figure 2.6 Effects of the Rise of 5G Will Bring to Hong Kong Manufacturing Industry

2.8 Leveraging the Use of Robots

With the low latency, and high transmission speed of 5G, it can smooth the path for a new generation of robots. Some of the robots can roam freely through wireless rather than wired communication links and take advantage of the cloud's vast computing and data storage resources. With these capabilities, robots can perform precise dynamic control in near real-time and connect with people and machines locally and globally. They can be used in the manufacturing area for smart automation, and in the healthcare area for robotic nursing and robotic surgery. Besides, they can also be used in the construction for scanning the progress on site, and in the property management field as security robot. Therefore, using 5G is a key ingredient for the success of robotics.

2.9 數據中心的角色

再工業化會產生大量數據，此類大數據經過收集、分析和處理後，可以產生新的見解並支持決策。但是，有部分製造場所中現有的IT設施，可能不足以處理它們。企業可能需要在數據中心使用雲端計算來進行數據處理。

雲端運算可透過互聯網「雲端」傳遞伺服器、儲存體、資料庫、網絡、軟體、分析、智慧功能等。

與在生產地方設置IT設施的傳統思維相比，使用雲端運算有多個好處。它降低了設置成本，無需為購買軟硬件、建設和運行數據中心或管理設施作出任何資本開支。此外，也更加容易升級到最新快速高效的運算硬體。對於大多數雲端運算，只需簡單操作，即可按照需求完成資源部署，使企業能夠靈活地回應不斷變化的容量需求。此外，數據備份可以鏡像儲存到雲端供應商網絡上的多個備援站台，這比儲存在單一站台上更加可靠。

由此可見將會有更多企業將轉向使用雲端運算服務並增加對數據中心資源的需求。

部署雲端服務有三種不同的方式：公用雲端、私人雲端或混合式雲端。 企業根據自己的需要選擇合適的類型。

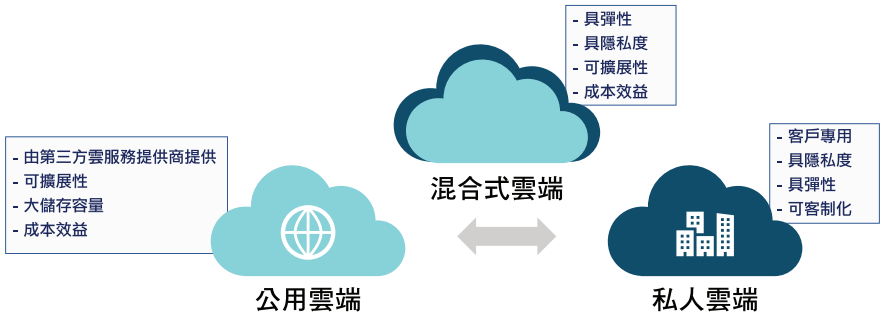


圖 2.7 公用雲端、私人雲端或混合式雲端

公用雲端

公用雲端由第三方雲服務提供商擁有和運作，他們透過互聯網提供運算資源（例如伺服器和儲存體）。所有軟硬體及其他基礎結構均由雲提供商擁有和管理。與私人雲端不同，它為企業節省了購買、管理和維護內部部署硬體及應用程式基礎結構的昂貴成本。用戶可以透過互聯網存取這些服務並管理帳戶。

公用雲端的部署速度比內部部署基礎結構要快，而且它是近乎可以無限擴展的平台。

Amazon Elastic Compute Cloud（EC2）、Microsoft Azure、IBM Cloud及Google Cloud是一些公用雲端的例子。

私人雲端

私人雲端是指通過互聯網或私人內部網絡提供的運算服務，並且只提供給選定的用戶而不是公眾。它是在私人網絡上提供基礎設備和服務。它的實體可以放置於公司的現場數據中心。除了有公用雲端的好處，如自助、延展性及彈性之外，它還可以通過本地部署的計算基礎結構，從專用資源進行額外的控制和客制。

此外，使用放置於公司現場數據中心的私人雲端，可以為涉及計算機視覺、AR/VR 和機器學習的應用提供所需的高效率、低時延和高頻寬。

Hewlett Packard Enterprise Private Cloud Solutions、Microsoft Azure Stack、IBM Cloud Private及Elastra Private Cloud是一些私人雲端的例子。

混合式雲端

混合式雲端結合了公用雲端和私人雲端，允許在兩者之間共享數據和應用程式。通過允許數據和應用程式在公用雲端和私人雲端之間移動，混合雲提供了更大的彈性和更多的部署選項，並有助於優化現有的基礎結構、安全性和合規性。當運算需求增加，超過內部部署資料中心負荷時，混合式雲端容許企業將運算服務擴展到公用雲端。

2.9 Roles of Data Centres

In the process of reindustrialization, a large amount of data is generated. Such big data needs to be collected, analysed, and processed to generate new insights and support decision-making. However, the existing IT infrastructure at some manufacturing sites may not be sufficient to handle it. Businesses may need to use cloud computing for data processing in data centres.

Cloud computing is the provision of computing services, including servers, storage, databases, networking, software, analytics, and intelligence, over the Internet ("cloud").

Using cloud computing has several benefits compared to the traditional way of setting up IT infrastructure on a manufacturing site. It reduces setup costs. No capital expenditures are needed to buy hardware and software, build, and run an on-site data centre, or manage infrastructure on-site. Also, it will be easier to upgrade to the latest generation of fast and efficient computing hardware. For most cloud computing services, computing resources can be provisioned on-demand, with just a few clicks of the mouse, giving businesses the flexibility to respond to changing capacity needs from time to time. Additionally, backup data can be mirrored to multiple redundant sites on the cloud provider's network, which is more reliable than having it on a single site.

As a result, more enterprises will be changing to use cloud computing services and increase the demand for data centre resources.

There are three different ways to deploy cloud services: on a public cloud, private cloud, or hybrid cloud. Enterprises need to select the right type for their needs.

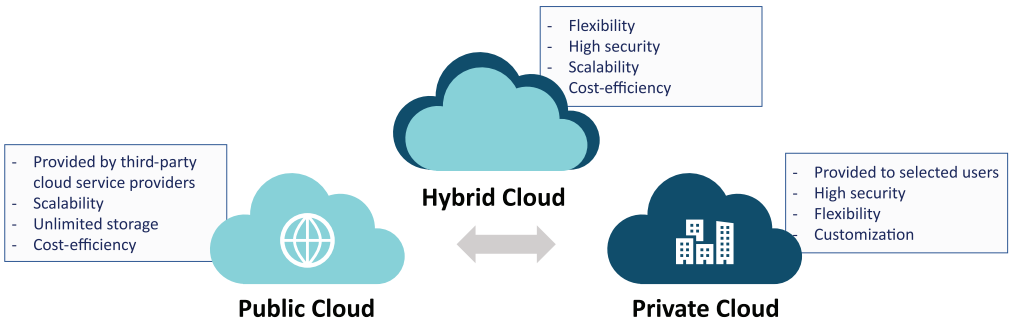


Figure 2.7 Public Cloud vs. Private Cloud vs. Hybrid Cloud

Public Cloud

Public clouds are owned and operated by third-party cloud service providers that provide their computing resources, such as servers and storage, over the Internet. For public clouds, all hardware, software, and other supporting infrastructure are owned and managed by the cloud provider. Unlike a private cloud, it saves businesses the expensive cost of purchasing, managing, and maintaining on-premises hardware and application infrastructure. Users can access these services and manage their accounts using a web browser.

The deployment speed of the public cloud is faster than the local infrastructure, and it has an almost infinitely scalable platform.

Here are some examples of public cloud: Amazon Elastic Compute Cloud (EC2), Microsoft Azure, IBM Cloud, and Google Cloud.

Private Cloud

A private cloud is defined as computing services provided over the Internet or a private internal network and only available to selected users and not to the public. It is a cloud that maintains services and infrastructure on a private network. It can be physically located in a company's on-site data centre. It provides enterprises with many public cloud benefits, including self-service, scalability, elasticity, additional control and customization from dedicated resources through locally hosted computing infrastructure.

In addition, using private clouds located in the company's on-site data centre can provide higher efficiency and low latency and high bandwidth needed for applications involving computer vision, AR/VR and machine learning.

Here are some examples of private cloud: Hewlett Packard Enterprise Private Cloud Solutions, Microsoft Azure Stack, IBM Cloud Private, and Elastra Private Cloud.

Hybrid Cloud

Hybrid clouds combine public and private clouds and allow data and application sharing between the clouds. By allowing data and applications to move between private and public clouds, hybrid clouds offer greater flexibility and deployment options and help optimize existing infrastructure, security, and compliance. When computing demand expands, hybrid clouds allow businesses to leverage cloud bursting to free up more space and expand computing services to the public cloud.

2.10 5G 的採用將如何影響數據中心

與 4G 相比，5G 可提供更高的頻寬、更低的時延和更高的連接密度。然而，5G 的採用將影響數據中心及其在廣域通信網絡中的角色。

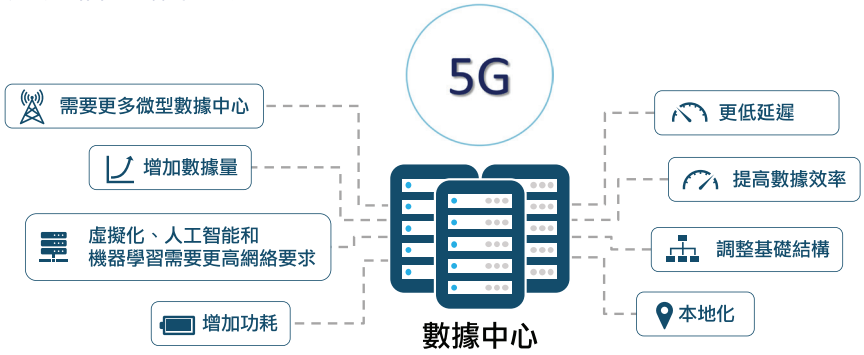


圖 2.8 5G 的採用對數據中心的影響

更低延遲

新的 5G 低時延物聯網應用，如遠程手術和無人駕駛汽車等，對數據處理、通訊通道和電力基礎設施都有一定要求，這將對數據中心產生重大影響。

提高數據效率

5G網絡將提升數據效率，它的傳輸速率比4G網絡高近 100 倍。這將使數據中心需要在不影響能源消耗和成本情況下，加入一些工具來管理資源密集型數據，如機器學習和虛擬實境。

調整基礎結構

5G技術對數據中心的影響與AI、AR/VR等先進技術類似。這項技術將促進更多大的和引人入勝的用戶體驗，並令數據中心有必要改進它的流程和基礎結構，以適應這些高度創新的內容和技術。

本地化

運用5G 邊緣計算，收集了的數據可以在本地節點處理，而不用傳輸到雲端中心，再提供有用的內容給用戶。它將加快整個流程並減少對傳輸線和傳輸方式的壓力，還將增加對本地數據中心的需求。

需要更多微型數據中心

5G 使用短波長傳訊，意味著需要使用小型基站而不是分散在全國各地的大型基站訊號塔。這些超高頻（30 GHz至300 GHz）傳訊需要設備靠近天線才有效。因此，需要在公共基礎設施周圍安裝多個發送和接收天線（MIMO）和更多的小型基站。

為了保持 5G 的低時延性能並滿足服務級別協議，數據中心需要靠近這些基站。在某些情況下，微型數據中心甚至可以部署在手機信號塔的底部，從而為自動駕駛等關鍵應用提供適度的數據處理和更快的反應時間。一些數據中心營運商會與電訊行業合作，使雲端和手機訊號塔更緊密地聯繫在一起。

這種趨勢可能導致較大的數據中心分拆為更小、更本地化的數據中心，並更靠近這些訊號塔。

增加數據量

由於5G促進使用更多傳感器來支持AI/大數據，因此需要處理不斷增加的數據量。使用網絡長距離傳送大數據量會帶來很大挑戰，故此應該在本地數據中心處理原始數據，並只將處理後的結果作長距離傳輸。

虛擬化、人工智能和機器學習需要更高網絡要求

使用更多虛擬化、人工智能和機器學習將擾亂數據中心。這些技術將需要更快的伺服器速度和更高的網絡容量，以支持更大量及日益複雜的邊緣運算服務。構建數據模型需要處理海量的數據池，在大多數情況下，最適合使用核心數據中心來處理。

大部分用於開發AI模型的數據將來自網絡邊緣，這代表了需要更大規模的雲端數據中心，來支持網絡中的潛在變化。其中一個情境是使用核心數據中心的能力，集合在網絡邊緣的數據來建立AI模型，然後將完成的模型啟動，提供本地化的低時延服務。這過程將會以反饋循環方式重複多次，來改進營運模型。

增加功耗

隨著數據流量和雲端計算使用的增加，以及與5G應用相關的物聯網設備的爆炸式增長，將大幅顯著增加數據中心的功耗。這將需要一個新的數據中心設計，以支持使用人工智能進行遠程管理，並在節能方面投放資源。

數據中心產生的廢熱，應重用於供暖和熱水等其他用途。當基站沒有流量服務時，應將其置於休眠狀態，關閉硬件組件，以消耗更少的能源。

在部署 5G物聯網應用時，企業需要了解上述採用 5G 對其數據中心所帶來的影響。

2.10 How 5G Adoption will Impact Data Centres

Compared with 4G, the introduction of 5G is expected to provide higher bandwidth, lower latency, and higher connection density. However, the adoption of 5G will impact data centres and their role within wide-area communications networks.

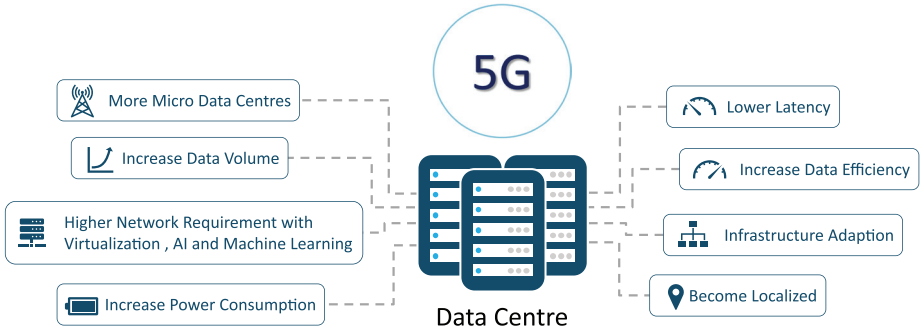


Figure 2.8 Impacts for Data Centres Brought by 5G Adoption

Lower Latency

New low-latency 5G IoT applications such as telesurgery and driverless cars will rely on data processing, communication channels and power infrastructure, which will have a significant impact on the data centre.

Increase Data Efficiency

5G networks will improve data efficiency. It will serve users at transfer rates nearly 100 times higher than 4G networks. It will make it necessary for data centres to look forward to introducing operations that can manage resource-intensive data, such as those related to machine learning and virtual reality, without affecting energy consumption and cost factors.

Infrastructure Adaptation

The impact of 5G technology on data centres is similar to that of advanced technologies such as AI and AR/VR in the industry. This technology will facilitate the flow of highly robust and engaging user experiences, which will make it necessary for data centres to improve their processes and infrastructure to adapt to such highly innovative content and technologies.

Become Localized

5G edge computing will encourage the collection and processing of data at local nodes instead of transferring the entire data to a cloud centre and then providing users with useful content. It will speed up the entire process and reduce tension on the transmission wires and methods. It will also bring more demand for local data centres.

Higher Demand for More Micro Data Centres

5G uses short wavelengths means small cells instead of large cell towers scattered across the country. These ultra-high frequencies (30 GHz to 300 GHz) are only effective when the device is close to the antenna. Therefore, MIMO antennas and more small cells will be installed around public infrastructure.

To maintain the low-latency performance of 5G and meet service-level agreements, data centres need to be close enough to these cells. In some cases, micro data centres can even be deployed at the base of cell towers, allowing limited data processing and faster response times for critical applications such as AVs. Some of the data centre operators collaborate with the telecommunications industry to bring cloud and cell towers closer together.

This trend could lead to the decomposition of larger data centres into smaller and more localized data centres closer to these units.

Increase Data Volume

As 5G encourages the growth of high-density edge sensor arrays, to support artificial intelligence (AI) / big data usages, it creates a need to process the increasing amount of data they generate. Long-distance networks will face the challenge of carrying these increased data volumes. It makes more sense to process the original data in the local data centre and only transmit the processing results over a long distance.

Higher Network Requirements When Using Virtualization, AI, and Machine Learning

The increased use of virtualization, AI and machine learning will disrupt the data centre. These technologies will require faster server speeds and higher network capacity to support a greater number of increasingly complex edge services. Building data models requires dealing with massive data pools that, in most cases, are best matched to core data centre capabilities.

Much of the data used to develop AI models will come from the edge. It hints at how larger cloud-scale data centres will support potential changes in the network. One scenario involves using the power of the core data centre to assemble data from the edge to develop models. The completed model will then be launched to provide localized low-latency service. The process will then be repeated, creating a feedback loop to improve the operating model.

Increase Power Consumption

With the increase in data traffic and usage of cloud computing and the explosion of Internet-connected devices associated with 5G applications, this will also significantly increase the power consumption of data centres. It will require a new data centre design with AI-enabled remote management and a significant investment in energy-saving features.

The waste heat produced by the data centres should be reused for other purposes such as heating and hot water. When there is no traffic to serve by the base station, it should be put into a sleep state, which means switching off hardware components, will consume less energy.

When deploying 5G IoT applications, enterprises require to understand the above impacts to their data centres brought by the adoption of 5G.

問卷調查顯示大部份受訪者都認同「由於5G物聯網應用涉及大量雲端計算/數據中心投資，5G物聯網應用的興起將有助於數據中心的發展。」(圖2.9)

企業應根據5G對其數據中心的影響，為其資源作相應行動。

大約有三分之一的受訪者表示會因應5G物聯網的應用，而增加其數據中心內相關的雲端資源(圖2.10)。過半數受訪者(56%)暫時未有定案，當中有部分是正在研究/計劃使用5G物聯網應用，另有部分暫無計劃使用。而在表示會增加雲端資源的受訪者當中，四成人士表示會增加超過兩成資源。由此可見他們認為部署5G物聯網應用會對數據中心有殷切的需求。

因此，可以預計5G物聯網的應用將需要更多數據中心作支持，並急劇增加對大型工作空間及能源的需求。

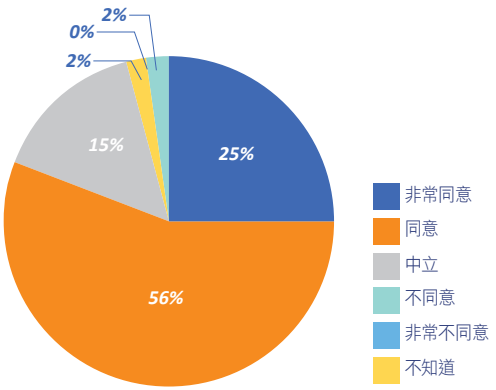


圖 2.9 「由於5G物聯網應用涉及大量雲端計算/數據中心投資，5G物聯網應用的興起將有助於數據中心的發展。」

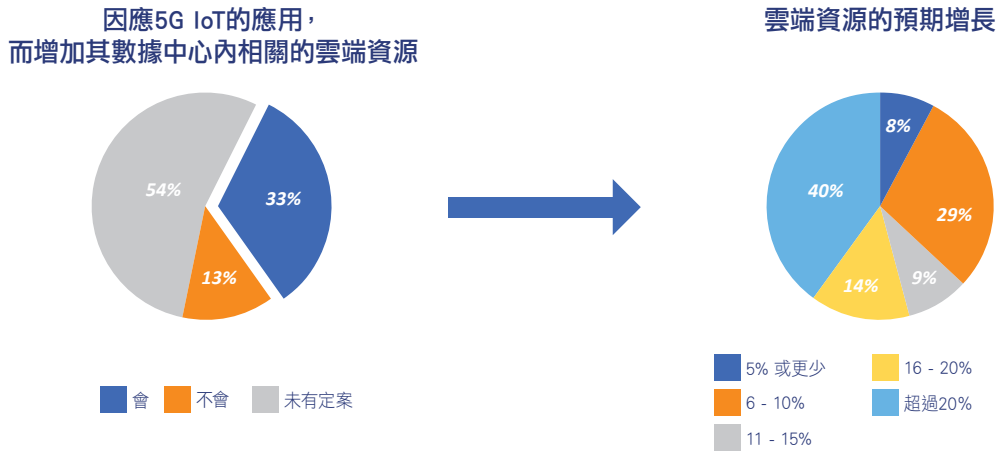


圖 2.10 因應 5G 物聯網的應用，而增加其數據中心內相關的雲端資源

The survey result (figure 2.9) shows the respondents are aware of this and most of the respondents agree that "Since 5G IoT applications involve a lot of cloud computing/ data centres investment, the rise of 5G IoT applications will contribute to the development of data centres".

Enterprises should take actions on their data centres' resources in light of the impacts that 5G brought to their data centres.

About one-third of the respondents (figure 2.10) will increase their cloud resources in their data centre(s). Most of them (54%) are not sure about this at this moment, as some of them are still studying/planning for 5G IoT applications and some of them actually have no plans to work on 5G IoT. Among those respondents who will increase their cloud resources, 40% of them may increase the resources by more than 20%, meaning they consider there is a bigger requirement for data centres when deploying 5G IoT applications.

Therefore, it is expected that the adoption of 5G IoT applications will increase the demand for the data centre. The demand for extensive working space and power consumption will be increased drastically.

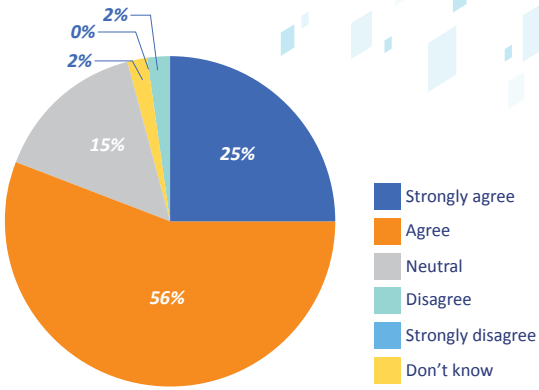


Figure 2.9 "Since 5G IoT applications involve a lot of cloud computing/data centres investment, the rise of 5G IoT applications will contribute to the development of data centres"

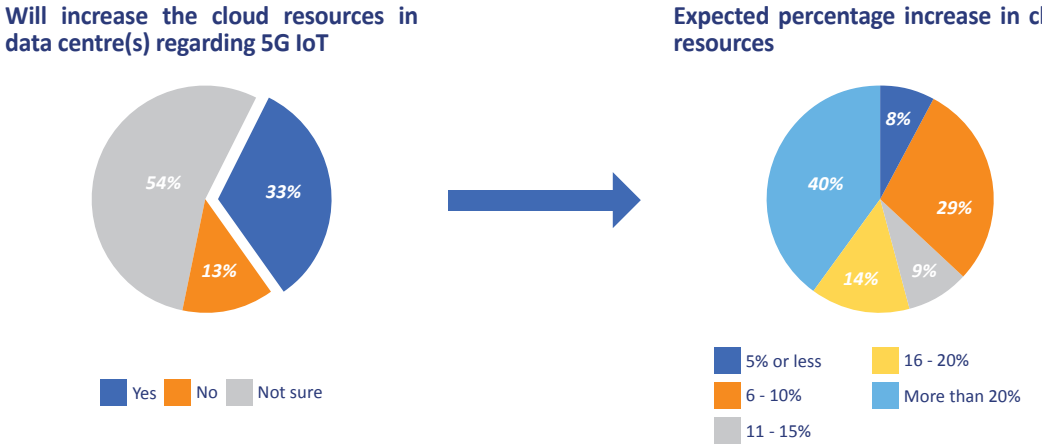


Figure 2.10 Increase in Cloud Resources in Data Centre(s) Regarding 5G IoT

3 網絡安全

物聯網基礎設施將設備連接到互聯網以發送/接收數據，該設施由幾個部分組成，而每個部分都要留意網絡安全，以防止數據洩露。

3.1 基本物聯網基礎設施

一般來說，物聯網基礎設施由幾個關鍵層組成：

- **終端設備層**：如感測器，驅動器等設備
- **通訊層**：網絡及閘道器
- **處理層**：如中介軟件，物聯網平台
- **應用層**：用戶端應用軟件

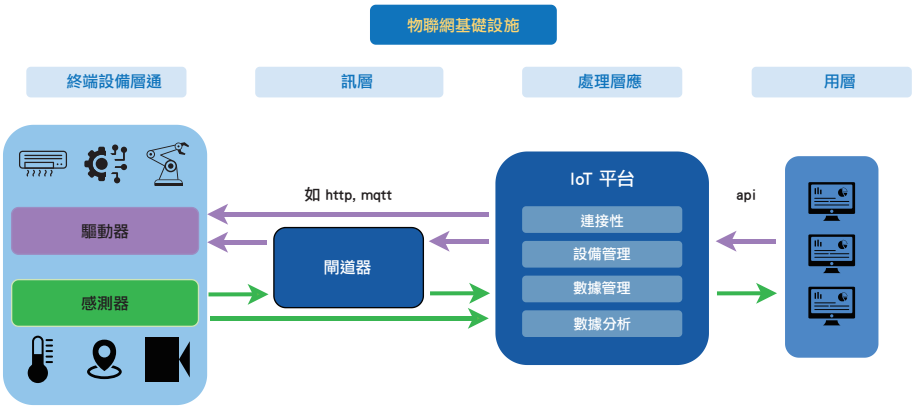


圖 3.1 物聯網基礎設施

終端設備層

終端設備是物聯網中的「物」，根據使用情況，它們通過不同的傳感器和/或驅動器與物理世界連接。另一方面，它們直接或通過閘道器連接到物聯網平台。在5G物聯網系統中，他們使用5G網絡與物聯網平台連接。

傳感器測量物理世界的不同參數，例如溫度，然後將它們轉換為電子數據，並將它們發送到物聯網系統。用戶便可以通過應用程式遠程監控物理世界。

驅動器從物聯網系統接收命令以執行某些操作，例如打開燈和移動機械臂。用戶可通過應用程式發出該命令。

通訊層

通訊層處理終端設備和物聯網平台之間的數據傳輸，包括整合來自終端設備的數據的實體有線/無線網絡和閘道器。 視乎不同系統，終端設備也可以在沒有閘道器的情況下直接與物聯網平台進行通訊。 對於5G物聯網系統，終端設備可以使用如HTTP/MQTT等協議，通過5G網絡與物聯網平台通信。

處理層

處理層從終端設備接收數據或向終端設備發送命令。另一方面，它通過所需的API來支持應用層，用戶通過API收取數據或控制設備，以下是一些該層處理的典型任務：

- **連接性**：確保所有物聯網組件能順暢地接收數據及互動
- **設備管理**：控制和配置物聯網網絡中的每個硬件，及更新設備和閘道器上運行的軟件
- **數據管理**：收集、處理和儲存數據
- **數據分析**：通過機器學習、預測分析和其他方法提取有價值的數據模式

應用層

應用層為終端用戶提供與物聯網系統互動的介面，根據所使用的系統，可以有數百個物聯網應用，以下是一些例子：

- **設備監測和管理**
- **實時跟蹤和遠程監控資產**

3 Cyber Security

Several components are required to make up the IoT infrastructure for connecting devices to the internet to send/receive data. Cybersecurity issues also need to be addressed to prevent data breaches in every part of the IoT infrastructure.

3.1 Basic IoT Infrastructure

In general, an IoT infrastructure consists of several key layers:

- **End device layer:** components such as sensors, actuators, and devices
- **Communication layer:** networks and gateway
- **Processing layer:** middleware or IoT platforms
- **Application layer:** software solutions for end-users

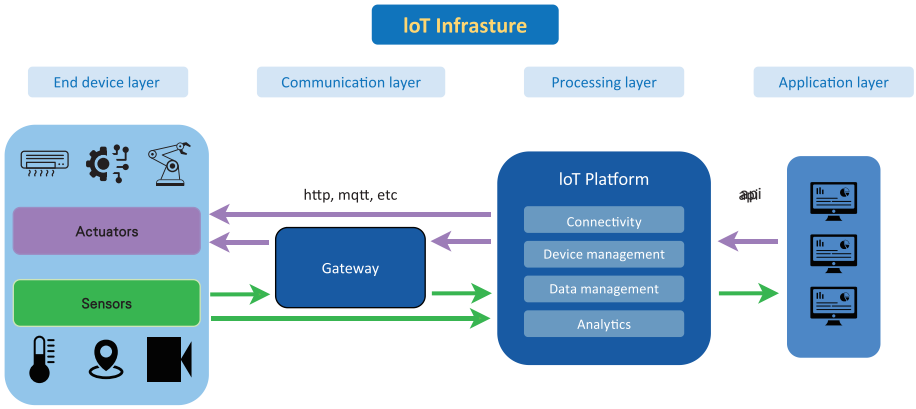


Figure 3.1 IoT Infrastructure

End Device Layer

End devices are the "things" of the IoT infrastructure. Depending on the usage, they interact with the physical world through different sensors and/or actuators. On the other hand, they link to the IoT platform directly or through a gateway. In the case of a 5G IoT system, they will use the 5G network to link with the IoT platform.

Sensors measure different parameters of the physical world such as temperature, then convert them into electronic data, and send them to IoT systems. Users can then monitor the physical world remotely through special applications.

Actuators receive commands from IoT systems to perform certain actions, such as turning on a light, and moving a robotic arm. This command can be sent by the user through an application.

Communication Layer

The communication layer handles the data transmission between the end device and the IoT platform. It includes physical wired/wireless networks and gateways that consolidate data from end devices. Depending on the different systems used, the end device may communicate with the IoT platform without the gateway. For 5G IoT systems, the 5G IoT device may communicate with the IoT platform through the 5G network, for example, using HTTP/MQTT protocol.

Processing Layer

The processing layer receives data from the end device and sends commands to the end device. On the other hand, it supports the application layer by providing the required APIs. Users interact with devices or exchange data through APIs. Some typical tasks handled by this layer are listed below:

- **Connectivity:** ensure data received smoothy and interactions between all IoT components
- **Device Management:** control and configure each piece of hardware in the IoT network as well as update software running on devices and gateways
- **Data Management:** collect, process, and store the data
- **Data Analysis:** extract valuable patterns with machine learning, predictive analytics, and other methods

Application Layer

The application layer provides the interface for the end user to interact with the IoT system. Depending on the system used, there are hundreds of IoT applications. Some examples are:

- **Device Monitoring and Control Software**
- **Real-time Tracking and Remote Monitoring of Assets**

3.2 一般網絡安全問題

正如其他IT系統，連接到互聯網的物聯網系統，同樣需要注重網絡安全，避免受到網絡攻擊。

如果物聯網設備存在安全漏洞，會成為分佈式阻擋服務攻擊（DDoS）的目標。DDoS攻擊是運用多個受感染的電腦系統，同時發送大量數據請求到目標系統，如中央伺服器，來阻止其運作，以致不能為用戶提供服務。近年，多次DDoS攻擊的出現，對組織和個人造成了嚴重破壞。缺乏安全保護的物聯網設備，將容易被網絡犯罪分子入侵，成為發動DDoS 攻擊的工具。

以2016年10月12日發生的大規模 DDoS 攻擊為例，它由 Mirai 殭屍網絡發動，導致美國東海岸的互聯網服務受阻。雖然物聯網設備不是電腦，但它們也具備相當的運算能力和連接至互聯網。這些設備，如家用路由器、安全攝像鏡頭及嬰兒監視器等，通常運行嵌入式、精簡的 Linux 系統。攻擊者會掃描互聯網，並試圖使用常用的用戶名和密碼連接上設備。通過這種方式，能夠集結一大批受感染的裝置，如閉路電視攝像機和路由器等，準備隨時進行攻擊。由於每個機械人看起來就像普通的互聯網設備，所以很難區分攻擊流量與正常流量。

另外，如果遭受入侵的設備是高速公路上的汽車、執行遠程手術的機械人或為城市供電的智能電網，那麼網絡攻擊便成為生死攸關的問題。即使它只是物聯網攝像鏡頭，攻擊者一旦攻破它，就可以進一步入侵，竊取Wi-Fi密碼，並獲得對更廣泛訪問網絡的權限。這是更廣泛攻擊的初始滲透點，通過它可以訪問重要的伺服器和數據。

3.3 5G物聯網中的網絡安全問題

由於5G可以為物聯網帶來前所未有的速度和規模，它帶來了新的安全威脅。使用更高的頻寬、支持更多網絡功能的軟件，以及更多的連接設備可能帶來額外風險。

調查顯示，59%受訪者對5G物聯網技術存在安全關注。其中，排名前三的安全問題是「未知的安全風險」、「更大的攻擊面」以及「由於連接的設備數量眾多而導致設備身份驗證困難」。因為各種安全問題，他們需要採取特殊措施來應付可能存在的漏洞。

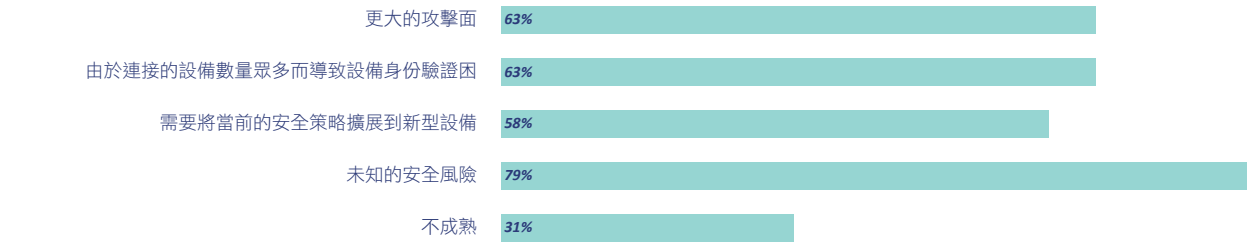


圖 3.2 5G物聯網技術的安全問題

3.2 General Possible Cyber Security Issues

Like other IT systems, an IoT system is connected to the internet, which is also vulnerable to cyber-attacks.

IoT devices can have security vulnerabilities that make them easy targets for Distributed Denial of Service (DDoS) attacks. In a DDoS attack, multiple infected computer systems block a target, such as a central server, by sending a large number of data requests simultaneously. It then causes a denial of service to users of the target system. Several DDoS attacks have wreaked havoc on organizations and individuals in recent years. Unsecured IoT devices will be easy targets for cybercriminals to exploit their weak security protections for DDoS attacks.

Taking the massive DDoS attack that happened on October 12, 2016, as an example, it caused internet inaccessibility on the U.S. east coast, which was created by the Mirai botnet. Although IoT devices are not computers, they still have the processing power and internet connection. These devices, ranging from home routers to security cameras to baby monitors, often include an embedded, stripped-down Linux system. The attacker tried to scan and connect the devices on the internet with a common username and password. In this way, it was able to amass an army of compromised closed-circuit TV cameras and routers, ready to do its bidding. Because each bot is a legitimate Internet device, separating the attack traffic from normal traffic can be difficult.

If the device is a car on the freeway, robot performing remote surgery or smart grid providing power to cities, cyberattacks can become a matter of life or death.

Besides, even if it is an IoT IP camera, an attacker can move horizontally once they compromise it. They have been able to steal Wi-Fi passwords, and gain access to the broader network, which is the actual initial infiltration point for a much broader attack. It can be used as a medium to access critical servers and critical data.

3.3 Cyber Security Issues in 5G IoT

As 5G can bring unprecedented speed and scale to IoT operations, it brings a new generation of security threats. 5G IoT services can use higher bandwidth, more software-enabled network capabilities, and more connected devices that may pose additional risks.

From the survey, 59% of the respondents have security concerns for 5G IoT technology. Among them, the top 3 security concerns are unknown security risks, greater attack surface, and difficulty in device authentication due to the massive number of devices connected. In addition, there are various security concerns regarding 5G IoT, therefore, special measures are required to mitigate possible vulnerabilities.

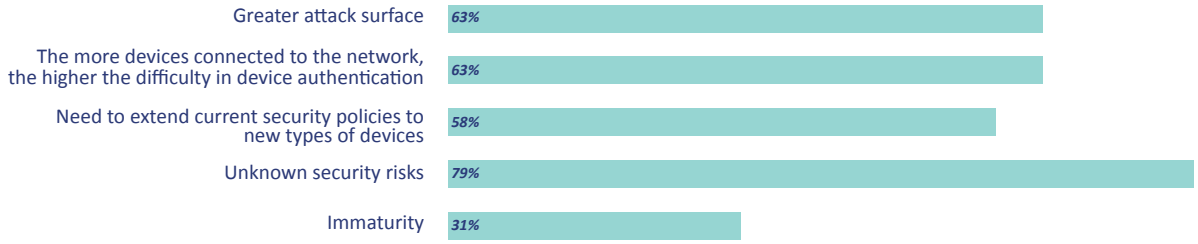


Figure 3.2 Security Concerns for 5G IoT Technology

3.4 解決 5G 物聯網中網絡安全問題的現有方法

大多數受訪者都採取了預防措施來應付與 5G 物聯網相關的安全問題，他們最常使用的方法是「執行數據備份和防病毒更新」。

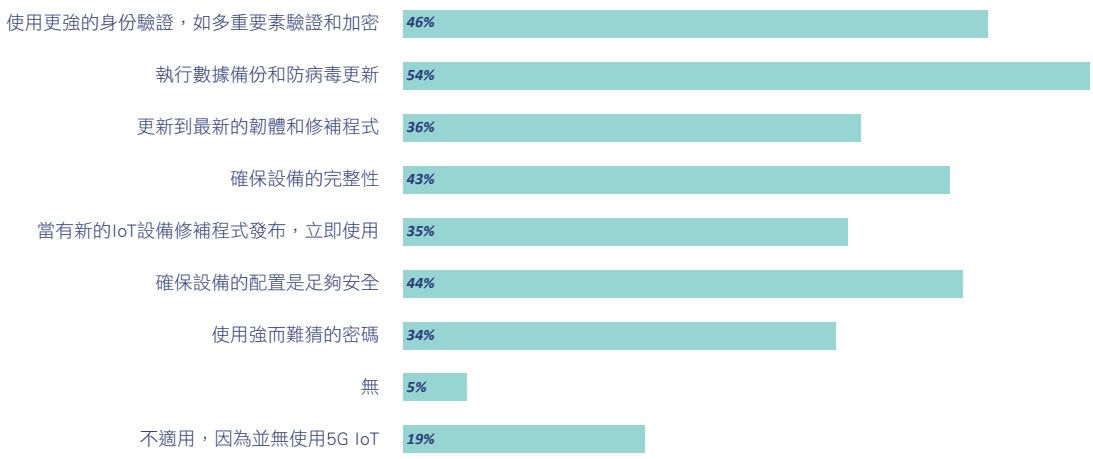


圖 3.3 5G 物聯網應付與 5G 物聯網相關的安全問題的預防措施

由於 5G 物聯網是由不同層面中的組件所構成，每個層面都要採取不同的安全措施，以免出現安全漏洞。

網絡/平台層面	裝置層面
1. 身分驗證和加密 2. 遠程設備管理 3. 持續設備監控 4. 數據備份 5. 防毒軟件更新 6. 威脅檢測/威脅情報 7. 網絡分段 8. 保安虛擬化 9. 零信任安全模型 10. 與網絡服務商的合作	1. 強密碼和強身份驗證 2. 設備的完整性 3. 數據安全與數據保護 4. 設備可見性與管理 5. 避免常用帳戶名稱

表 3.1 網絡/平台層面和設備層面的安全措施

3.4.1 網絡/平台層面

身分驗證和加密

有些5G物聯網設備，如攝像鏡頭，可以透過互聯網進行管理，這種情況下需要設定強密碼。舉例來說，如果工廠使用5G網絡安全攝像鏡頭，在遠程監控系統使用強密碼是相當重要，因為攻擊者可能會嘗試使用常用密碼登錄遠程監控系統。另外，如果該系統支持多重要素認證，就更應選用，因為即使洩露了密碼，也較有保障。

此外，如果5G物聯網設備以明文方式進行通訊，例如以明文形式向物聯網平台發送信息，客戶端設備或後端伺服器交換的信息可能會被中間人竊聽。攻擊者可透過檢查網絡流量而獲取敏感數據，例如登錄憑據。所以每當傳輸數據時，要確保使用加密傳訊，而儲存在設備上的敏感數據也需要加密。

遠程設備管理

由於5G物聯網可能用上數以百計的設備，而且它們可能在不同的位置使用，因此如果系統可讓用戶遠程管理它們將會很有幫助。例如，當設備需要修補程式時，透過遠程操作來修復某些漏洞。這些遠程管理功能應包括添加和刪除設備、重啟設備、更新固件、安裝修補程式和檢查設備狀態等功能。

持續設備監控

系統管理員應時常檢查5G物聯網設備狀態，並透過遠程設備管理系統監視網絡中任何惡意軟件活動。當發現設備受到威脅，應立即採取進一步措施，如將它從網絡中分離出來，以防止進一步滲透到系統中。

數據備份

假如5G物聯網平台受到勒索軟件攻擊，攻擊者會把數據加密。此時，可以使用最新的備份作為最後的手段來挽救系統以減少損失。因此，定期備份數據至關重要，管理人員也應作定期檢查和驗證。

防毒軟件更新

系統管理員應定期向設備供應商檢查任何防病毒保護更新或漏洞報告，並及早為設備安裝更新。

3.4 Existing Methods to Tackle the Cyber Security Issue in 5G IoT

Most respondents have precautions to alleviate the security concerns associated with 5G IoT. They perform data backups and anti-virus updates the most to alleviate the security concerns.

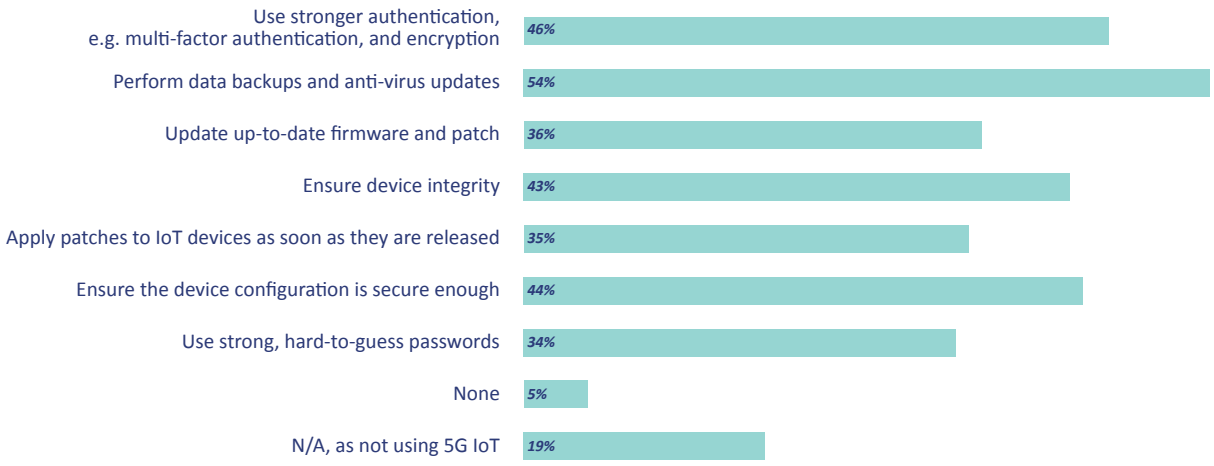


Figure 3.3 Precautions to Alleviate the Security Concerns Associated with 5G IoT

Since a 5G IoT system consists of components at different levels, and every part can be security breached, security measures for different levels are needed to be applied.

Network/Platform Level	Device Level
1. Authentication & Encryption 2. Remote Device Management 3. Continuous Device Monitoring 4. Data Backups 5. Anti-virus Update 6. Threat Detection/Threat Intelligence 7. Network Segmentation 8. Security Virtualisation 9. Zero Trust Security Model 10. Cooperation with Network Service Providers	1. Strong Password & Strong Authentication 2. Device Integrity 3. Data Security & Data Protection 4. Visibility & Management 5. Do Not Use Common Account Name

3.4.1 Network/Platform Level

3.4.1 Network/Platform Level

Authentication and Encryption

Some 5G IoT devices, such as cameras, can be managed through the internet, and it is important that the management system uses strong password. If the system supports multi-factor authentication, it is the preferred choice. It provides exponential security even if the password is compromised. For example, if a factory uses 5G cellular security cameras, it is important to configure a strong password for the remote monitoring system because attackers may try to log into the remote monitoring system using common passwords.

Remote Device Management

Since a 5G IoT system may consist of hundreds of devices and those may be deployed in different places, it is helpful if the system allows users to manage them remotely. For example, when there is device requires patches to fix certain vulnerabilities, it should be able to apply them remotely. Such remote management functions should include features such as adding and removing devices, rebooting devices, updating firmware, applying patches, and checking device status.

Continuous Device Monitoring

System administrators should continue to check the 5G IoT device status and watch out for any malware activity in the network through the remote device management system. When a device is compromised, it should be discovered. Further measures, such as detaching it from the network, should be taken immediately to prevent it from further penetrating the system.

Data Backups

If a 5G IoT platform is attacked by ransomware, data could be encrypted by attackers. In this case, an up-to-date backup can be used as the last resort to restore the system with minimal loss. Therefore, regular or periodic data backup is vital and should be checked and verified regularly.

Anti-virus Updates

System administrators should regularly check with device vendors for any updated antivirus protection or vulnerability report and apply patches to devices when available.

Threat Detection/Threat Intelligence

With the huge amount of data flowing through the network and the application-oriented nature of the 5G architecture, it can be particularly hard and expensive to address using the traditional deterministic Deep Packet Inspection (DPI) approach, where data is systematically inspected and analysed against malware signatures. AI would play a critical role in malware detection.

Using Deep Learning (DL) AI techniques to model malware can observe data moving in and out of edge devices and through the network core. Investigating detailed patterns and modelling "normal" data nature to spot inconsistencies and possible threats or vulnerabilities is a more effective, substantially less invasive, and costly way of securing any network when compared to DPI.

威脅檢測/威脅情報

由於大量數據流經網絡以及5G架構的應用面向的特性，使用傳統的確定性深度封包檢測（DPI）方法來解決問題可能特別困難和昂貴。這種方法會根據惡意軟件特徵系統地檢查和分析數據。而人工智能將在惡意軟件檢測中發揮重要作用。

使用深度學習AI技術對惡意軟件進行建模，可以用來觀察進出邊緣設備及通過網絡核心的數據。與DPI相比，調查詳細模式和對「正常」數據性質建立模型，以發現不一致和可能的威脅或漏洞，是一種更有效、入侵性和成本更低的方法來保護網絡。

市面上有不同的公司提供此類深度學習或機器學習威脅檢測產品，如Sophos[16]和Prisma Cloud[17]等。企業可以諮詢其內部/外判安全專家，獲取應用此類威脅檢測服務的建議。

網絡分段

在5G網絡中，網絡分段可將網絡實體分割成不同的部分以用於不同的應用。需要直接連接到互聯網的物聯網設備應該被分割到特定的網絡中，而禁止訪問公司網絡。例如，分開工業控制系統（ICS）和企業網絡，可以提高網絡安全性。另外，企業應監視網絡分段的異常活動，如果發現問題，要馬上採取行動。

保安虛擬化

5G網絡可以建立在實體網絡之上的虛擬網絡上。5G網絡虛擬化允許將硬件資源劃分為可由軟件控制的功能——網絡功能虛擬化（NFV）。在網絡管理方面，NFV會設法直接優化網絡服務。相關的網絡管理方法，稱為軟件定義網絡（software-defined networking, SDN），是一種有彈性、以編程方式高效率的網絡配置去提高網絡性能和監控的方法，使它更像雲端計算而不是傳統的網絡管理。

由於其可編程特性，SDN和NFV正面對一些新的安全威脅。因此，在虛擬網絡中，需要快速地部署虛擬化保安到幾乎任何網絡位置，並在發現新攻擊時自動回應。自動化是整個策略中重要一環，它可以使用虛擬化來實現。

零信任安全模型

在許多企業的私人網絡中使用的零信任網絡安全概念可用於5G網絡，來解決大部分安全問題。它可以幫助發現用戶並持續監視其行為（網絡內部或外部的人和機器）。

5G物聯網系統會連接大量設備，零信任可以幫助企業驗證和識別所有連接設備並跟蹤這些設備的所有活動，以檢測網絡中的任何不當行為。

與網絡服務商的合作

為了保護用戶免受5G物聯網下可能加劇的DDoS攻擊，企業需要與網絡服務供應商合作應對攻擊。

3.4.2 裝置層面

強密碼和強身份驗證

有些5G物聯網設備可以憑用戶名和密碼，通過互聯網連接。與網絡層面的情況一樣，這些設備用戶應更改默認密碼，並確保他們的密碼夠強。

對於5G物聯網設備製造商，如果設備支持Secure Socket Shell（SSH）密鑰，則應避免在多個物聯網設備上使用相同的SSH密鑰。儘管SSH密鑰被認為是強憑據，但在這種情況下，殭屍網絡很容易發現並利用它們，使用強身份驗證相當重要。此外，製造商可以考慮使用多重要素身份驗證，這能提高安全性。

設備的完整性

確保已啟用安全啟動（Secure Boot）以運行製造商開發的代碼，是非常重要。此外，設備應該能夠檢測到任何攻擊。對於低端設備，這可能具有挑戰性，因為它們需要專用的安全措施來應用在這些設備上。

數據安全與數據保護

無論是通過硬件還是軟件，密鑰都應該安全地儲存在設備上。確保設備上的數據安全儲存以符合通用數據保護條例（GDPR）和其他強力監管法規至為重要。

設備可見性與管理

製造商應確保可以監測實地使用的設備、遠程更新其固件，和安裝修補程式，並最好能自動完成操作。

避免常用帳戶名稱

攻擊者會使用常見的帳戶名稱（如operator和administrator）掃描網絡。因此，用戶不應在物聯網設備上使用這些帳戶名。

[16] Sophos（2022）。Intercept X: Powered by Deep Learning。取自Sophos網址：https://www.sophos.com/en-us/content/deep-learning-cybersecurity
[17] Prisma Cloud（2022）。Threat Detection。取自Prisma Cloud網址：https://www.paloaltonetworks.com/prisma/cloud/cloud-threat-detection#

There are companies such as Sophos[16], and Prisma Cloud [17] that offer such deep learning or machine learning threat detection products. Enterprises can consult their in-house/out-source security experts for the advice of applying this kind of threat detection services.

Network Segmentation

In 5G networks, network segmentation can be used to slice the physical network into different parts for different applications. IoT devices that need to connect directly to the internet should be segmented into their networks and have restricted access to the corporate network. For example, separating Industrial Control Systems (ICS) and corporate networks can improve network security. Network segments should be monitored for abnormal activities. Actions should be taken if a problem is detected.

Security Virtualisation

5G network can be built on a virtual network on top of the physical network. 5G network virtualization will allow the division of hardware resources into functions that can be controlled by software: network functions virtualisation (NFV). In network management, NFV seeks to directly optimize network services. The associated network management approach, called software-defined networking (SDN), is an approach that enables dynamic, programmatically efficient network configuration in order to improve network performance and monitoring, making it more like cloud computing than traditional network management.

Due to their programmable nature, SDN and NFV have a new range of security threats. Therefore, in a virtualised network, it is required to deploy virtualised security rapidly to almost any network location and automatically respond when new attacks are discovered. Automation is a critical component of this strategy and can be achieved by virtualisation.

Zero Trust Security Model

The Zero Trust network security concept, used in many enterprises' private networks, can be used in 5G networks to address most security concerns. It can help to check the presence of users and continuously monitor behaviour (both humans and machines inside or outside the network).

With the vast number of connected devices in 5G, Zero Trust can help businesses authenticate and identify all connected devices and track all activities of those devices to detect any malpractice within the network.

Cooperation with Network Service Providers

To protect users from DDoS attacks that may be exacerbated under 5G, cooperation with network service providers is required to help deal with volumetric attacks.

3.4.2 Device Level

Strong Password and Strong Authentication

Some 5G IoT devices can be accessed over the internet using a username and password. As is the case at the network level, these device users should change the device password from the default and ensure that their passwords are strong enough.

For the 5G IoT device manufacturers, if the device supports Secure Socket Shell (SSH) keys, they should avoid using the same SSH key on multiple IoT devices. Though SSH keys are considered strong credentials, the botnet can easily discover and exploit them in this case. Therefore, it is crucial to use strong authentication. Additionally, manufacturers can consider using multi-factor authentication, which will increase security.

Device Integrity

It is important to ensure that Secure Boot is enabled to run code developed by the manufacturer. Also, the device should be able to detect any attack. For low-end devices, this can be challenging, as it will require something specialized to accommodate those devices.

Data Security and Data Protection

Whether through hardware or software, the keys should be stored securely on the device. Ensuring that data on devices is stored securely to comply with regulations like General Data Protection Regulation (GDPR) and other strong regulations is even more critical.

Visibility and Management

Manufacturers should ensure that devices are visible in the field and firmware can be updated remotely. They should also apply patches. It would be better to do it automatically.

Do Not Use Common Account Name

Attackers will scan the network with common account names such as operator, and administrator. Therefore, users should not use these account names on the IoT devices.

[16] Sophos. (2022). Intercept X: Powered by Deep Learning. Retrieved from Sophos Website: https://www.sophos.com/en-us/content/deep-learning-cybersecurity
[17] Prisma Cloud. (2022). Threat Detection. Retrieved from Prisma Cloud Website: https://www.paloaltonetworks.com/prisma/cloud/cloud-threat-detection#

3.5 區塊鏈簡介

區塊鏈或分散式賬本技術是一種特殊的數據庫，它可能解決上一節中討論的一些物聯網安全挑戰。

- **區塊鏈系統的核心部分是由系統中的持份者共享經加密的安全分散式數碼賬本組成，並允許在他們之間安全地傳輸數據。**
- **驗證後的交易或事件會記錄在帳本後不能被修改或刪除，是不可變的。它為用戶社群提供了一個記錄和共享信息的方式。**
- **在社群中，選定的成員會持有分散式賬本的副本。新交易必須通過在他們之間進行集體驗證的共識過程，才能被接受。如果某成員的賬本經任何方式被更改或損壞，它將被社群的大多數人拒絕。**

區塊鏈的主要特點是：

- **分佈式/去中心化**
- **加密封存**
- **不可篡改數據**

區塊鏈有四種類型：公有、私有、聯盟和混合區塊鏈，下表比較了公有和私有區塊鏈之間的差異。

公有區塊鏈	私有區塊鏈
任何人都可以加入，無需特定許可	只有被允許的人才能加入
任何人的都有讀寫權限	只有授權用戶可以訪問數據
不可篡改和去中心化；一旦條目被驗證，任何人都不能更改它	部分去中心化；條目可以由其擁有者更改
適用於需要匿名的平台	適用於需要知道每個參與者身份的平台； 由於企業通常需要保持一定程度的安全性、隱私性、合規性和性能， 因此私有區塊鏈也被稱為企業區塊鏈

表 3.2公有和私有區塊鏈之間的差異

混合區塊鏈是公有區塊鏈和私有區塊鏈的混合，有些程序是私有的，而有些程序則是公共的。

聯盟區塊鏈是一種由多個組織維護的區塊鏈網絡，它是需要授權並具有去中心化的結構。

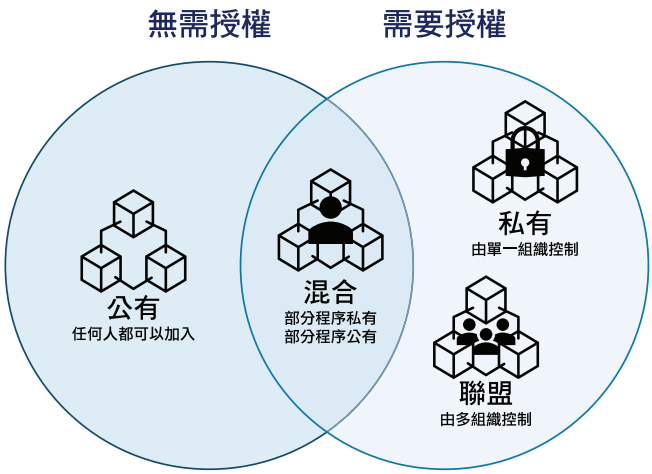


圖 3.4不同類型的區塊鏈

3.5 Brief Introduction of Blockchain

Blockchain or Distributed Ledger Technology (DLT) is a special type of database that potentially helps solve some of the IoT security challenges discussed in the previous section.

- **The core part of a blockchain system consists of a cryptographically secure distributed digital ledger shared among the stakeholders in the system and allows the secure transfer of data between them.**
- **Transactions or events after validation, are recorded in the ledger. The ledger cannot be subsequently modified or deleted, as it is immutable. It provides a way for the user community to record and share information.**
- **In this community, selected members maintain copies of their distributed ledger. When there is a new transaction, it must be collectively validated among them through a consensus process before they are accepted by the ledger. If a member's ledger is altered or corrupted in any way, it will be rejected by the majority of the community.**

The key characteristics of the blockchain are:

- **Distributed/Decentralised**
- **Cryptographically Sealed**
- **Immutable Data**

There are four types of blockchains: public, private, consortium, and hybrid blockchains. The following table compares the differences between public and private blockchains.

Public blockchain	Public blockchain
Anyone can join without specific permission	Only permitted people can join
Read and write access for anyone	Read and write for a single organization
Immutable and decentralized - No one can change an entry once it has been validated	Partially decentralized - The entries can be altered by their owner
Suitable for the platform that needs anonymity	Suitable for the platform that needs to know the identity of each participant. Since enterprises typically need to maintain some level of security, privacy, compliance, and performance, private blockchains are often referred to as enterprise blockchains.

Table 3.2 Differences of Public and Private Blockchain

A hybrid blockchain is a combination of the public and private blockchain. It means that some processes are private while others are public.

A consortium blockchain is a type of blockchain network where multiple organizations maintain the system. It is permissioned and has a decentralized structure.

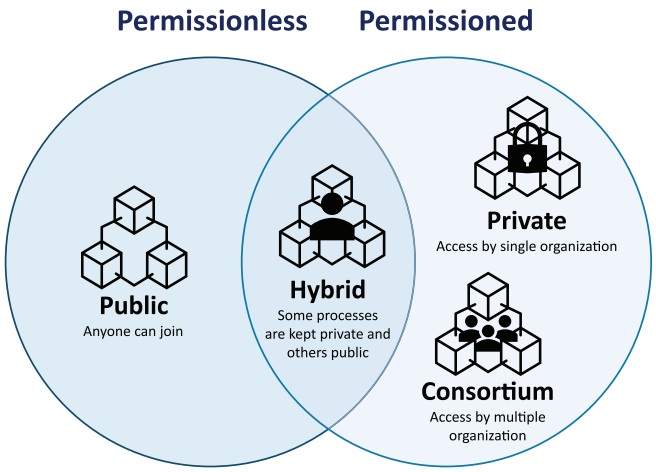


Figure 3.4 Types of Blockchains

3.6 區塊鏈在物聯網中的重要性

調查顯示，68%的受訪者對5G物聯網與區塊鏈的結合略知一二或完全不熟悉，因此應向業界提供更多相關信息，以便他們能夠在其營運的不同層面中，運用區塊鏈技術。

傳統的物聯網系統使用集中式架構。信息會從設備發送到雲端平台，該信息會在平台上作數據分析處理，然後發送回物聯網設備。未來幾年使用物聯網網絡設備的數量可達到數十億，由於這種集中式系統的可擴展性有限，它將出現數十億個危及網絡安全的弱點。不斷檢查和驗證設備之間的每筆微交易的開銷將變得非常大而且緩慢。使用區塊鏈，可使數十億連接設備之間的交易處理和協調變得更快。隨著互連設備數量的上升，分散式賬本技術可以幫助支持對大量交易的操作。

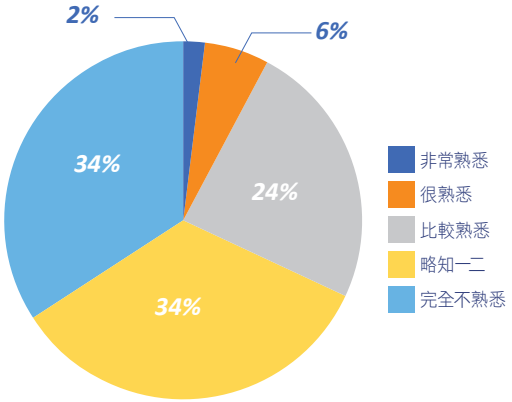


圖 3.5對5G物聯網結合區塊鏈的熟悉度

此外，通過建立持份者之間的信任，區塊鏈可以讓物聯網公司消除與物聯網閘道器相關的處理開銷（如傳統協議、硬件或通信開銷成本）以降低成本。

再者，去中心化的區塊鏈網絡降低了中心化網絡中可能發生單點故障的風險。

在區塊鏈網絡中使用的智能合約，是雙方的協議，它將允許設備在滿足特定要求時安全自主地運行。它們可以是與貨物有關的條件或環境條件。這不僅帶來更高階的自動化、更大的可擴展性和更便宜的傳輸（無需支付中間商和中介費用），而且這些智能合約還可以防止某些人竄改數據以牟利。信息在一個分散的、加密保護的網絡中共享，意味著要破壞網絡安全變得非常困難。

3.7 物聯網結合區塊鏈的主要優勢

建立對物聯網數據的信任

每筆交易都被記錄下來，放入一個數據塊中，並添加到一個安全且不可篡改的賬本中，而該賬本是不能作更改或刪除，只能添加。因此沒有一個組織可以控制物聯網設備產生成的大量數據。

增強安全性

它可以在數據傳輸和儲存時，驗證和允許由受信任方發起的交易和進行加密。區塊鏈允許授權人員訪問 網絡以跟蹤過去發生的交易，提供了透明度和可靠的方法以識別數據洩漏的來源並快速採取補救措施。

此外，它不會有單點故障，並可以快速識別整個網絡中的薄弱環節。

降低成本

通過區塊鏈上的自動化交易驗證和流程，無需付費給中間商和中介機構。

交易快捷

對於與多個供應商、生產商、分銷商和消費者的交易，使用分散式賬本可讓沒有信任關係基礎的各方也 可直接相互交換數據，從而免卻人手流程並提高交易速度。

3.6 Significance of Blockchain in IoT

From the survey, 68% of the respondents are either slightly or not at all familiar with 5G IoT combined with blockchain, therefore more information about it should be given to them so that they can make use of the blockchain technology in different aspects of their operation.

Traditional IoT systems are dependent on a centralized architecture. Information is sent from the device to a cloud platform, where the data is processed using analytics and then sent back to the IoT devices. When the number of devices joining the IoT networks becomes billions in the coming years, due to limited scalability with this centralized system, it will expose billions of weak points that compromise network security. Constantly checking and authenticating every microtransaction between devices would become very expensive and slow. Using blockchain, the processing of transactions and coordination among billions of connected devices can become faster. As the number of interconnected devices grows, distributed ledger technology can help support the manipulation of large numbers of transactions.

Besides, with the enabled trust among the stakeholders, blockchain can allow IoT companies to eliminate the processing overheads related to IoT gateways (such as traditional protocol, hardware, or communication overhead costs) to reduce their costs.

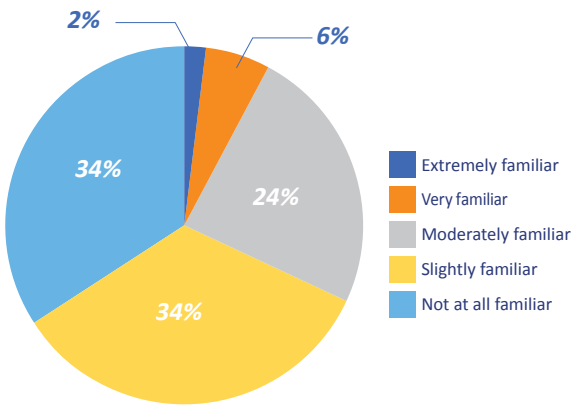


Figure 3.5 Familiarity with 5G IoT Combined with Blockchain

Furthermore, a decentralized blockchain network reduces the risk of a single point of failure that may occur in a centralized network.

Using smart contracts in blockchain networks, which are an agreement between two parties, will allow devices to function securely and autonomously when specific requirements are met. Smart contracts may be related to cargo conditions or environmental conditions. Not only does it allow for greater automation, scalability, and cheaper transfers (without having to pay middlemen and intermediaries), but these smart contracts also prevent overwriting by individuals who want to use the data for their benefit. Information is shared across a decentralized, cryptographically secured network, meaning it becomes very difficult to compromise network security.

3.7 Key Benefits of IoT with Blockchain

Building Trust to The IoT Data

Each transaction is recorded, put into a data block, and added to a secure and immutable ledger that cannot be changed or deleted but only added. No single organisation can control the vast amount of data generated by IoT devices.

Enhanced Security

It can verify and allow transactions originated by trusted parties and encryption while data is being transmitted and stored. A blockchain allows authorized people to access the network to track the transactions that happened in the past. It provides transparency and a reliable way to identify a specific source of any data leakages and take quick remedial action.

Besides, it does not have a single point of failure and can quickly identify the weak link in the entire network.

Reduced Costs

By automating the transaction validation and processes on the blockchain, there is no need to pay for middlemen and intermediaries.

Speed of Transactions

For transactions with multiple suppliers, producers, distributors, and consumers, using a distributed ledger allows parties without a basis for a relationship of trust to exchange data directly with one another, eliminating manual processes and increasing transaction speed.

3.8 採用區塊鏈和物聯網技術需要考慮的事項

網絡隱私和交易保密

在公有區塊鏈上，任何人都可以看到在賬本上的交易歷史。通過分析交易模式，可以推斷出公鑰背後的用戶或設備的身份。因此，無法保證身份的隱私。如果需要考慮隱私，則應使用混合或私有區塊鏈。

可擴展性

隨著物聯網設備產生的數據量增加，要讓設備保存大量數據，但不減慢交易或數據流將會非常困難。以太坊和比特幣等知名區塊鏈長期以來存在可擴展性問題，不適合用於物聯網設備所產生的海量數據。

不同的解決方案可以用作處理擴展性問題，如分片 (Sharding) 和鏈下交易 (off-chain transactions)。

- **分片：**在創建新區塊時，所有在分散式賬本中的交易都需要由區塊鏈節點再次驗證。使用分片，鏈的狀態被分成稱為「分片」的塊。在區塊鏈網絡中並行處理驗證，應該能增加網絡每次可以處理的運算量。
- **鏈下交易：**它們是在區塊鏈之外處理的數值交易，與鏈上交易相比，它們是即時執行的。

3.9 物聯網結合區塊鏈的應用

物聯網結合區塊鏈的一些應用實例：

圖 3.6 物聯網結合區塊鏈的一些應用實例

調查顯示，35.2%的受訪者對物聯網結合區塊鏈應用感興趣。其中，大多數人對「物聯網數據市場」和「醫療保健」應用感興趣。

除了在圖3.7中列出的應用外，其中一位受訪者還對「遊戲和娛樂」感興趣。

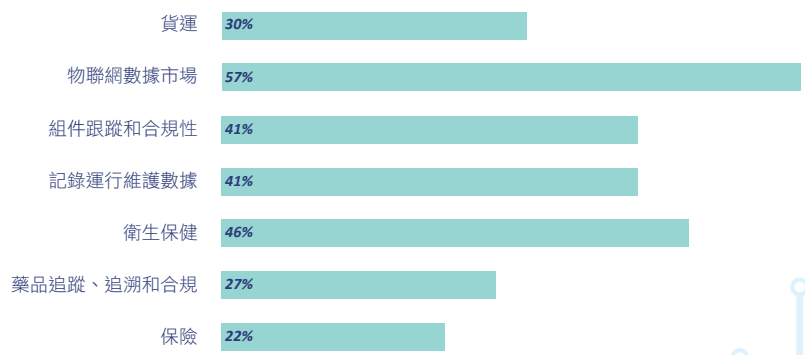


圖 3.7 對物聯網結合區塊鏈應用的興趣

3.8 Considerations for the Adoption of Blockchain and IoT Technologies

Network Privacy and Transaction Confidentiality

On public blockchains, anyone can see transaction history on the ledger. By analysing the transaction pattern, the identities of users or devices behind public keys can be deduced. Therefore, the privacy of the identities cannot be guaranteed.

If privacy is a concern, hybrid or private blockchains should be used.

Scalability

As the volume of data generated by IoT devices increases, it will be challenging for IoT devices to retain large amounts of data without slowing down transactions or data flow. Better-known blockchains such as Ethereum and Bitcoin have long had scalability issues and are unsuitable for the massive amounts of data generated by IoT devices.

In order to solve this scalability issue, there are different solutions like sharding, and off-chain transactions.

- **Sharding:**
  When creating a new block, all transactions in the distributed ledger need to be verified again by the blockchain nodes. With sharding, the state of the chain is divided into chunks called shards. Validation is processed in parallel in the blockchain network. This should increase the amount of computation the network can handle at one time.
- **Off-chain transactions:**
  These are transactions that deal with value outside the blockchain. Compared to on-chain transactions, they are executed immediately.

3.9 Use Cases for IoT with Blockchain

Some of the use cases for IoT with blockchain are:

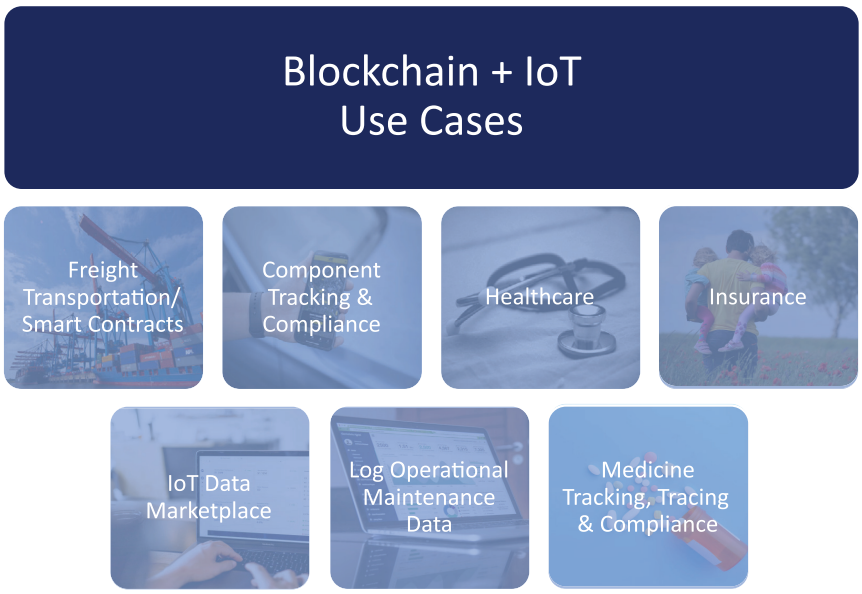


Figure 3.6 Blockchain + IoT Use Cases

From the survey, 35.2% of the respondents have an interest in IoT blockchain applications. Among them, most of them are interested in “IoT data marketplace” and “health care” applications.

Apart from the applications listed in figure 3.7, one of the respondents also interested in “Game and entertainment”.

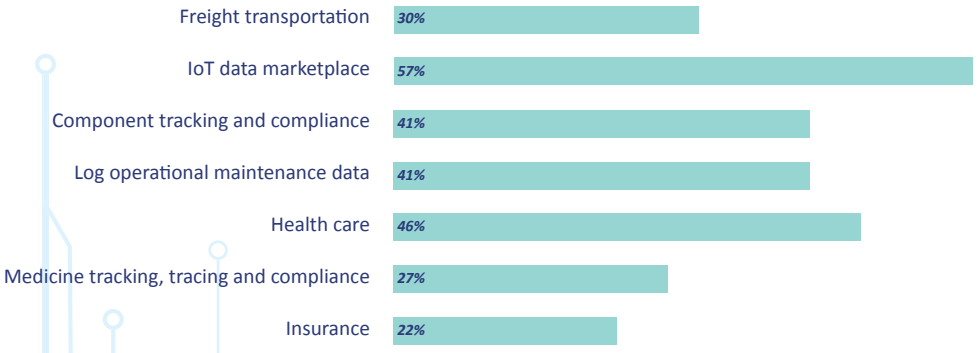


Figure 3.7 Interest in IoT Blockchain Applications

貨運/智能合約

在運輸葡萄酒或其他稀有食品等易腐爛貨物的過程中，貨物需要保持在一定的溫度和光照下。使用物聯網設備可以收集箱子或托板的位置、溫度、到達時間和狀態等數據。這些數據隨後會被放入區塊鏈，從而能夠檢查貨物在運輸過程中的歷史記錄，並在無法滿足協定時拒絕接受產品。由於區塊鏈上的記錄是無法篡改的，因此各方都可以信任數據並作為供應鏈中的質量保證。

此外，公司可以使用智能合約把業務和領域規則編碼。例如，通過不斷地將溫度數據發送到智能合約。當有任何溫度下降時，它可以實時通知持份者。而由於智能合約是在區塊鏈上運行，這些溫度記錄是無法更改。

物聯網數據市場

從物聯網數據中可以獲得有價值的信息。例如，物聯網大數據可以幫助企業了解客戶需求，制定市場策略。物聯網數據市場提供了一個連接數據提供者和消費者的平台，讓他們從具價值的數據中獲利。

使用區塊鏈可以保證數據的完整性，為交易提供保障。

組件跟蹤和合規性

跟蹤飛機、汽車或其他產品中的某些重要組件以符合安全和法規是十分重要。相關的物聯網數據可以儲存在分散式區塊鏈賬本上，讓各方在產品的整個生命週期中都能追蹤組件的來源。這些信息可以透過安全、簡單和經濟的方式與監管機構、托運人和製造商共享。

記錄運行維護數據

對於某些關鍵性機器，如引擎和電梯，使用物聯網設備來跟蹤其安全和保養狀態都是十分重要。它們的運行數據和所產生的維護數據都可以被儲存在區塊鏈上，以防止數據被篡改。第三方保養合作夥伴可以使用區塊鏈來監視機器以進行預防性維護，並將其工作記錄放回區塊鏈上。另外，更可以與政府部門分享運營記錄，以驗證合規性。

衛生保健

使用區塊鏈技術儲存疫苗記錄和電子健康記錄等健康數據，能提高安全性和兼容性。該技術可以接駁到多個數據管理系統，並兼容不同電子健康記錄系統。醫療保健數據可用分散方式儲存，以確保不會被篡改。由於並非儲存在單一個數據庫中，故此不會有單點故障問題。

區塊鏈上的記錄可作為證明資料真確性的憑據，來建立智能和安全的電子保健記錄系統。

藥品追蹤、追溯和合規

藥物的儲存環境會影響其質量和效力，如果保存在不當的溫度下，便需要丟棄。通過使用物聯網設備來紀錄藥物的溫度並將其儲存在區塊鏈上，可以於日後檢查藥物的溫度歷史，以確保其符合規定。

此外，假藥會影響治療結果和造成人命相關的巨大公共衛生問題。區塊鏈可以安全和不可改變的方式，為藥物追溯和產地來源提供有效的解決方案。運用區塊鏈技術建立一個分散式數據共享平台，來儲存和分享供應鏈各持份者之間的交易數據，可確保信息經過加密，保持可以獲得和不可變特性、透明度和安全性，並只有授權方可以獲取信息。它提供了一種主動方法來跟蹤、檢測和管理藥品供應鏈中的假冒產品。

保險

一些物聯網設備（如用於健身的可穿戴設備）可以收集各種與用戶健康相關的數據，如飲食、活動和其他生命表徵。通過將數據儲存在區塊鏈中，保險公司可以評估其客戶的健康狀況並確定客戶要支付的保費。

一些智能家居設備具有監控系統，例如監控攝像鏡頭和智能鎖。通過將設備數據儲存在區塊鏈中，保險公司可以驗證索償並減少欺詐性索償。

客戶的駕駛頻率和行為會影響保費計算，運用安裝在客戶汽車中的傳感器收集數據，可以確定其駕駛態度。保險公司可以將數據儲存在區塊鏈上以確保其完整性，來確定不同駕駛習慣的客戶的保費。

Freight Transportation/Smart Contracts

During the transport of perishable goods such as wine or rare foods, it is important to keep the goods under a certain temperature and light exposure. Location, temperature data, arrival time and status of the case or pallet can be collected using IoT devices. Then the data can be put into the blockchain, enabling the ability to check the history of the good as it goes through the transportation and reject accepting the product if the contract cannot be met. As the records on a blockchain are immutable, all parties can trust the data and act as quality assurance in the supply chain.

Besides, companies can use smart contracts to encode business and domain rules naturally. For example, data collected by a temperature sensor can be continuously sent to a smart contract. When there is any temperature drop, it can inform stakeholders in real-time. Since the smart contract runs on the blockchain, the temperature record cannot be changed.

IoT Data Marketplace

Valuable information can be obtained from IoT data. For example, IoT big data can help companies understand customer needs and formulate market strategies. IoT data marketplaces provide a platform to connect data set providers and consumers to monetize the wealth of information generated by the data.

Using blockchains can guarantee data integrity, providing a secure channel for transactions.

Component Tracking and Compliance

It is critical to track some components inside aeroplanes, automobiles or other products to comply with safety and regulations. Relevant IoT data can be stored on a distributed blockchain ledger, allowing all parties to see the provenance of components throughout the product's lifecycle. This information can be shared with regulators, shippers and manufacturers in a secure, simple, and cost-effective way.

Log Operational Maintenance Data

For some of the critical machines, it is vital to track the state of their safety and maintenance with IoT devices. The operational data and the resulting maintenance data of these machines, from engines to elevators, can be stored on the blockchain to prevent data tampering. Third-party maintenance partners can use the blockchain to monitor machines for preventive maintenance and put records of their work back on the blockchain. Operational records can be shared with government entities to verify compliance.

Healthcare

Using blockchain technology, health data, such as vaccination records and electronic health records, can be stored more securely, increasing security and interoperability. The technology has the potential to connect multiple data management systems working in warehouses and provide potentially connected and interoperable electronic health record systems. Instead of being stored in one database, healthcare data can be stored immutably in a decentralized manner. Therefore, there is no single point of failure.

This blockchain record can be used as proof and confidence to create a smart and secure healthcare ecosystem.

Medicine Tracking, Tracing and Compliance

Storage conditions can affect the quality and potency of medication, which means drugs kept at the wrong temperature need to be disposed of. The temperature of drugs can be tracked and stored on the blockchain using IoT devices. The temperature history of the drugs can then be checked to see if it meets the requirements.

Besides, counterfeit medications create major public health concern that severely impacts human lives and treatment outcomes. Blockchain may provide an efficient solution for drug traceability and provenance in a secure and immutable manner. Blockchain technology can establish a distributed shared data platform for storing and sharing transaction data among various supply chain stakeholders to ensure that information remains accessible, immutable, transparent and secure through cryptographic techniques and only accessible to authorized parties. It provides a proactive approach to track, detect and manage counterfeit products in the pharmaceutical supply chain.

Insurance

Some IoT devices such as fitness wearables can collect various user health-related data, such as diet, activity, and other vital signs. By storing the data in a blockchain, the health insurance company can assess the health of their clients and determine which premiums to give.

Some smart home devices have monitoring systems such as surveillance cameras and smart locks. By storing the device data in a blockchain, the insurance companies can verify claims and reduce instances of fraudulent claims.

The premium rates of insurance can be affected by customers' driving frequency and behaviour. Data can be collected using sensors installed in customers' cars to determine the drivers' driving attitudes. By storing the data on the blockchain to ensure its integrity, insurance companies can use it to determine rates based on the driving habits of different customers.

3.10 現有的物聯網結合區塊鏈應用

在圖3.8中列出了一些現有的物聯網結合區塊鏈應用：

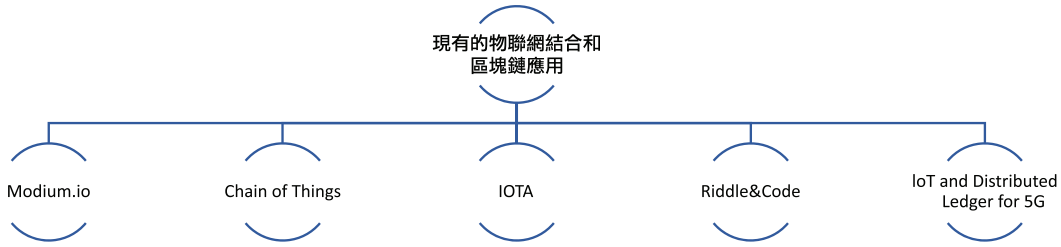


圖 3.8.現有的物聯網結合區塊鏈應用

Modum.io

用於供應鏈中，為涉及實質產品的交易提供完整的數據。

它包含一個帶有物聯網傳感器（有/無蜂窩功能）設備，用於測量貨物在運輸過程中所處的環境狀況，如溫度和濕度。數據通過智能手機應用程式/蜂窩服務上傳到他們的系統平台上。隨後數據會被儲存到區塊鏈上並可顯示在儀表板中。由於數據儲存在區塊鏈上，因此無法更改。該傳感裝置會跟產品一起付運。在運輸過程中，產品可能接觸過會影響其質量的特定狀況。例如當溫度高於某個臨界點，系統會自動要求供應商更換產品。

Chain of Things（CoT）

致力利用區塊鏈和物聯網之間的聯繫，來解決連接設備的基本問題並開發高效率的未來應用。它試圖處理設備的身份問題，以解決安全性和互操作性的系統性問題。它將通過企業合作夥伴關係、合資企業和內部項目，開發和部署工業、環境和人道主義項目[18]。

IOTA

IOTA的Tangle是一個開放、免費且可擴展的分散式賬本，旨在支持無障礙的數據和價值轉移，記錄和執行物聯網生態系統中機器和設備之間的交易。

Tangle是一個用於確認交易的節點系統，其中每筆新交易都會確認之前的兩筆交易。IOTA聲稱它比典型的區塊鏈更快、更高效。

隨著IOTA 2.0開發網絡（DevNet）的推出，正如2015年項目開始時所設想的那樣，他們聲稱這是第一個完全去中心化、可擴展和免費的IOTA網絡。它無需費用、沒有區塊、沒有鏈、沒有礦工、沒有能源浪費、沒有審查、沒有中心化及沒有權限。

Riddle&Code

RIDDLE&CODE建立了實體世界和數位世界之間的可信任連接，為工業代幣經濟奠定了基礎。他們的業務是結合區塊鏈、硬件和軟件[19]。

應科院的物聯網區塊鏈在5G（ASTRI's IoT and Distributed Ledger for 5G）

由香港應用科技研究院（應科院）開發，使用區塊鏈技術的物聯網數據交換系統。它可讓5G物聯網設備所產生的大量數據，能更有效率地流通，這對於智慧城市應用的發展相當重要。

目前的物聯網數據交換由個別數據供應者和消費者進行，這為需要由不同數據源獲得數據的開發人員帶來困難。應科院運用區塊鏈技術解決了上述問題，還解決了單一信任源和單一故障源等固有問題。

應科院的解決方案使用區塊鏈技術作為具透明度和可追溯性的支柱，並解決在實際應用中累積大量物聯網數據時，所面對的可擴展性問題。它使用鏈下方法來減輕大量儲存開銷和加快緩慢的數據存取，同時還使用區塊鏈來解決數據發佈和發現、運用智能合約、提升數據安全和保障私隱。

本應用可以幫助需要作私人數據交換的組織，其中數據提供者和數據消費者也是分散的，如銀行、房地產經紀人、醫院和超市。

另外，它是一個聯盟區塊鏈解決方案，多個組織可以參與該聯盟，並只有經過授權的用戶才可加入網絡。與公有區塊鏈相比，它更適合需要高隱私度的企業使用。

[18] Chain of Things（2020）。取自Chain of Things網址：https://www.chainofthings.com/
[19] Riddle&Code（2022）。The Blockchain Interface Company。取自Riddle&Code網址：https://www.riddleandcode.com/

3.10 Existing IoT and Blockchain Applications

Figure 3.8 shows some of the existing IoT and blockchain applications

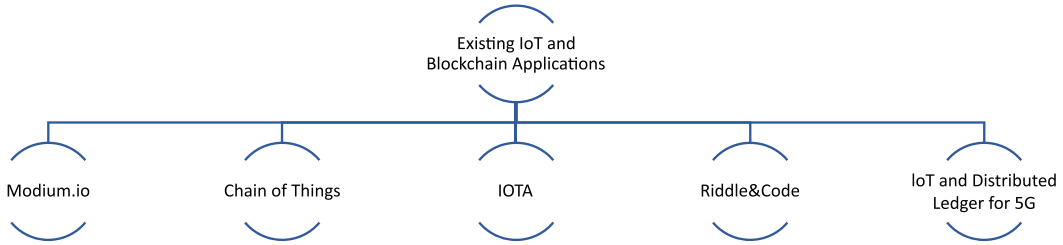


Figure 3.8 Existing IoT and Blockchain Applications

Modum.io

It is an application in the supply chain that provides data integrity for transactions involving physical products.

It consists of a device with IoT sensors (with/without cellular capability) to measure the environmental conditions that the goods are exposed to during transport, such as temperature and humidity. Data is uploaded to their platform via a smartphone app/cellular service. The data will then be stored on a blockchain and visible on their dashboard. Since the data is stored on the blockchain, it cannot be changed.

This sensing device will be delivered with the product. During transport, the product may have been exposed to specific conditions that could affect its quality. If the temperature is above a threshold, the system can automatically ask the supplier for product replacement.

Chain of Things (CoT)

Quoted from their website, "Chain of Things (CoT) is a research lab and venture studio dedicated to leveraging the nexus between blockchain and IoT to solve fundamental problems in the connected devices space and to develop highly efficient futuristic applications. CoT will address the point of device identity from birth to solve for systemic issues of security and interoperability. With this it will develop and deploy industrial, environmental, and humanitarian projects through corporate partnerships, joint ventures, and internal projects."[18]

IOTA

IOTA's Tangle is an open, feeless, and scalable distributed ledger designed to support frictionless data and value transfer. It is designed to record and execute transactions between machines and devices in the IoT ecosystem.

Tangle is a system of nodes used for confirming transactions, in which each new transaction confirms two previous transactions. IOTA claims that it is faster and more efficient than a typical blockchain.

With the launch of the IOTA 2.0 Development Network (DevNet), they claim that it is the first fully decentralized, scalable, and feeless IOTA network, as was envisioned at the inception of the project in 2015. It is no fees, no blocks, no chain, no miners, no wasted energy, no censorship, no centralization, no permissions.

Riddle&Code

Quoted from their website, "RIDDLE&CODE builds the trusted connection between the physical and digital world and creates the basis for the industrial token economy. We combine the highest security standards with the potential of blockchain technology and integrate robust hardware & software stacks into the infrastructure of our global, one-tier clients."[19]

ASTRI's IoT and Distributed Ledger for 5G application

It is an IoT Data Exchange Using Blockchain Technology application developed by ASTRI to make the circulation of huge amounts of data as the next generation of IoT devices connect to the coming 5G networks be more efficient. It is crucial for the development of Smart City applications.

The current IoT data exchange is conducted by individual data providers and consumers, creating a bottleneck for developers who may need data from various sources. ASTRI's solution based on blockchain resolves these problems. Besides, it solves the inherent issues like a single source of trust and a single source of failure.

ASTRI's solution uses blockchain technology as the backbone for transparency and traceability and addresses the scalability issue of accumulated IoT data in real-case applications. It used an off-chain approach to relieve large storage overheads and slow data access, while also using blockchain to address data publication and discovery, smart contracts for transactions, data security and privacy protection.

This invention is also of interest to organisations requiring private data exchange in which data providers and data consumers are in a distributed fashion such as banks, estate agents, hospitals, and supermarkets.

It is a consortium blockchain solution. It is permission, and only authorized users can join the network for enterprises to use with higher privacy requirements compared to a public blockchain. Besides, multiple organizations can take part in the consortium.

[18] Chain of Things. (2020). Retrieved from Chain of Things Website: https://www.chainofthings.com/
[19] Riddle&Code. (2022). The Blockchain Interface Company. Retrieved from Riddle&Code Website: https://www.riddleandcode.com/

4 對5G物聯網技術的評價及可作出的準備

在採用5G物聯網技術前，我們需要了解5G物聯網將帶來的影響，以及企業應如何做好準備。

4.1 5G物聯網的優缺點

優點	缺點
1. 提高效率 2. 提高生產力 3. 節省營運成本 4. 更好的用戶體驗 5. 實現更多創新應用 6. 改善安全條件	1. 5G覆蓋範圍有限 2. 基礎設施成本 3. 網絡安全風險 4. 市場潛力不明確

表4.1 5G物聯網優缺點總結

4.1.1 5G物聯網的優點

提高效率

5G讓企業能夠有效地協調所有設備。智能可穿戴設備可以幫助企業管理人力資源，公司亦可以有效率地開展業務。他們還可以為員工提供結合了不同技術的設備，以簡化管理和營運。例如，倉庫管理員可以通過AR輕鬆查閱倉庫貨架狀態或得知產品位置。

提高生產力

5G物聯網與AR/VR的結合可用於員工培訓。加強持續在職培訓，提升員工解決問題的實際能力，讓他們在新職位或進行新任務時有更好的表現。

另外，通過這種結合，專家和現場工作人員也可以幾乎在任何地方一起協作工作。技術人員亦可以透過AR/VR技術，在檢查中看到肉眼無法檢查的盲點，這比人工檢查更詳細和全面。他們還可以隨時工作，不會耽誤項目進度。因此，5G物聯網能夠提高企業生產力。

此外，銷售人員可以隨時隨地輕鬆了解客戶需要並提供服務。透過AR/VR，商戶可以為客戶提供更加沉浸式的體驗，增加銷售能力和營收。

節省營運成本

5G物聯網可以降低智能工廠的營運成本。通過5G遠程控制、監控和重新配置，機器和設備可以進行自我優化，簡化生產線和整體規劃，還能在虛擬工廠環境中進行培訓和維護。

5G物聯網系統能使供應鏈管理變得更智能和簡化物流流程，從而降低營運成本。它可以實時提供大量數據，包括位置、溫度、濕度、壓力或其他信息。資產跟蹤的加強，可以更好地管理資產及降低管理成本。

5G 網絡在每平方公里內能支援數百萬台連網設備，可以用於改善電網監控，能更準確預測能源需求，更有效管理能源，降低電力峰值和整體能源成本，從而降低營運成本。

此外，5G能顯著地延長物聯網設備的電池壽命，可節省大規模部署物聯網傳感器的成本。

更好的用戶體驗

VR最大的問題是用戶長時間佩戴VR眼鏡會感到頭暈和不適。目前的解析度可能不足，另外當用家改變視角時，影像可能出現延遲。5G的高傳輸速度和低時延可以提高VR螢幕的解析度，降低時延，減少用戶的不適。

此外，5G提升了反應速度和影像解析度，改善了AR的用戶體驗。由於AR應用中有大量數據，5G可以實時提供更好的沉浸式內容。

5G可以提供高質量的可視化、分析和設備控制服務。例如，客戶可以從任何角度虛擬地查看和試用新產品。此外，企業可以通過5G物聯網設備更了解客戶，並提供個性化服務，以提升客戶體驗。

實現更多創新應用

5G 在網絡和設備端提供更高的數據速率、更低時延和能耗，能實現在各個垂直市場中的商業應用。例如，醫療專業人員可以提供更積極主動的救生護理，並使用AI識別在早期階段的疾病。

5G物聯網將帶來更多創新應用，這不僅加速了企業的數字化轉型，還重塑了政府和組織保護，並改善全球公民的生活方式。

4 Evaluation and Preparation for 5G IoT

To adopt 5G IoT technology, it is required to understand what impact 5G IoT will bring and how enterprises can get prepared for it.

4.1 Pros and Cons of 5G IoT

Pros	Cons
1. Increase Efficiency 2. Increase Productivity 3. Save Operating Costs 4. Better User Experience 5. Enable More Innovation 6. Improve Safety Conditions	1. Limited 5G Coverage 2. Infrastructure Costs 3. Security Risks 4. Unclear Market Potential

Table 4.1 Summary of Pros and Cons of 5G IoT

4.1.1 Pros of 5G IoT

Increase Efficiency

5G allows businesses to coordinate all devices efficiently. Smart wearables can also help enterprises manage human resources. Companies can perform operations efficiently. They can also equip employees with devices integrated with other technologies to simplify management and operations. For example, warehouse managers can check the status of warehouse shelves or obtain the location of products easily through AR.

Increase Productivity

The integration of 5G IoT with AR/VR can be applied to train employees. The enhancement in continuous on-the-job training allows the employees to be equipped with practical problem-solving skills and perform their job better at the beginning of a new position or a new task.

Collaborative work between experts and on-site workers can also be carried out almost anywhere with this integration. Technicians can also see the blind spots that cannot be checked by human eyes with AR/VR, making it more detailed and comprehensive than manual inspections. It can be carried out at any time without delaying the progress of the project. Hence, 5G IoT enables businesses to be more productive.

Sales staff can easily understand customers' needs and deliver service anytime, anywhere. It may integrate AR/VR to provide customers with a more immersive experience, increasing sales capabilities and revenue.

Save Operating Costs

5G IoT can reduce operating costs in a smart factory. Through remote control, monitoring, and reconfiguration with 5G, the machinery and equipment can be self-optimized to simplify the production line and overall planning. It can also support training and maintenance in the factory environment.

5G IoT systems can support smarter supply chain management and streamline logistics processes, thereby reducing operating costs. They can provide massive amounts of data in real-time, including location, temperature, humidity, pressure, or other information. It is possible to improve asset tracking, allowing assets to be well-controlled to reduce management costs.

A 5G network can support millions of devices per square kilometre to reduce operating costs. This is because it can improve grid monitoring, make energy demand forecasts more accurate, and make energy management more efficient, reducing power peaks and overall energy costs.

In addition, 5G has significantly extended the battery life of IoT devices. It makes the mass deployment of IoT sensors a more practical solution to reduce costs.

Better User Experience

The biggest problem with VR is that users will feel dizzy and uncomfortable after wearing VR headsets for a long time. The current resolution may not be high enough and the picture may be delayed when users change their angle of view. The high transmission speed and low latency of 5G can improve the resolution of VR screens, reduce latency and reduce user discomfort.

Besides, 5G improves response speed and screen resolution, optimizing the user experience for AR. As there is a large amount of data in AR applications, 5G enables better immersive content in real-time.

5G can provide high-quality visualization, analysis, and device control. For example, customers can view and try the new products virtually from any angle. In addition, enterprises can get to know more about the customers through 5G IoT devices and deliver personalized services to improve customer experience.

Enable More Innovations

5G provides higher data rates, lower latency and energy consumption at the network and device ends. It will unlock potential for many business cases in all vertical markets. For example, medical professionals can provide more proactive life-saving care and use AI to identify disease at the early stages.

5G IoT will release new levels of creativity and use case execution. Not only accelerating the digital transformation of enterprises but also reshaping the way governments and organizations protect and improve the lives of global citizens.

改善安全條件

5G可以加強公共安全機構的運作流程，有更快的反應時間，以便裝置存取重要資料。同時，MEC確保關鍵任務能及時完成，消除在生死關頭下，因通訊障礙或中斷所造成的風險。

此外，機械人能在危險任務中發揮關鍵作用。它們可以監視區域、進入危險環境並執行一些對人類極為危險的任務。5G允許在緊急情況下對機械人進行可靠的遠程控制，並實時讀取得機械人所收集的視頻或傳感器數據。

圖4.1 5G物聯網應用的好處

4.1.2 5G物聯網的缺點

5G覆蓋範圍有限

如第 1.2.3.1 節所述，5G由sub-6和mmWave區域中各種不同的無線電頻率組成。mmWave在下載速度方面有巨大優勢，但不能傳送太遠或穿透室內障礙物。透過安裝更多包括毫微微基站和微微基站的小型基站，可以增強室內覆蓋。它們是低功率基站，主要用於中小型場所。

毫微微基站（家庭基站）是用於家中或辦公室內，由用戶維護，覆蓋範圍約為10米，只能支持少數使用者。它們以低成本改善辦公室、餐館甚至家庭的室內覆蓋範圍。

微微基站是安裝於建築物中的每一層，由移動網絡營運商維護，覆蓋範圍約為200米。營運商通常在一個地點部署多個微微基站，以增加網絡容量和覆蓋範圍，並確保用戶可以從一個接入點無縫切換到另一個接入點。

基礎設施成本

如前所述，5G網絡需要使用更多的小型基站，尤其是在室內環境中。因此，一些營運商會考慮透過分享網絡來共同構建。多家公司可以共享網絡基礎設施和分擔成本，以快速提供服務，實現互惠互利。服務提供商可以將總成本降低多達30%，同時還可以提高網絡質量。

網絡安全風險

連接大量物聯網設備到5G網絡將大大增加企業面臨的網絡威脅。更高的頻寬和更多基於軟件的網絡功能也可能帶來額外的風險。

由於並非所有製造商都優先考慮網絡安全，因此許多物聯網設備在製造時，可能沒有採取足夠的安全措施，例如數據加密、安全更新等。由於5G可以連接更多設備，數十億個具有不同安全級別的設備，意味著數十億個潛在的漏洞。攻擊者可以入侵和控制物聯網終端設備，並利用它們發動攻擊，對網絡和業務造成破壞。物聯網設備缺乏安全標準，可導致廣泛的網絡漏洞和黑客攻擊。

因此，5G物聯網需要採取保護性安全措施來保護網絡的完整性並降低其安全風險。

市場潛力不明確

5G技術處於早期發展和演進階段，而5G生態系統尚未完善。對於企業用戶來說，他們可能並不清楚5G物聯網應用的市場潛力。對於網絡營運商來說，由於市場反饋不足，他們會仔細規劃自己的5G基礎設施和部署策略，以免在升級至5G過程中投資出現虧損。

構建5G生態系統，需要政府支持在不同行業中推廣5G、部署和研發，以建立公眾對 5G 的信心。

從調查所得，大部分受訪者認為5G物聯網應用的弊端主要是在於開發成本、5G覆蓋範圍有限等方面。

除了上述缺點外，一位受訪者指出：「一些持份者可能認為新技術將取代他們的工作，因此他們拒絕採用新技術，例如物聯網報錶。」

Improve Safety Conditions

5G can strengthen the current operating procedures for public safety agencies, and also provides faster response time to allow units to access important information. Meanwhile, MEC ensures critical tasks are completed in time and eliminates risks that may be caused by communication barriers or interruptions under life-and-death situations.

In addition, robots play a key role in dangerous missions. They can monitor areas, enter dangerous environments, and perform tasks that are extremely dangerous to humans. 5G allows reliable remote control of the robot in an emergency and access to the video or sensor data collected by the robot in real-time.

From the survey, a majority of the respondents are positive about the benefits of 5G IoT applications. And most of the respondents think that 5G IoT applications can increase efficiency and productivity. Besides the benefits listed in figure 4.1, another benefit mentioned by a respondent is to "speed up IoT devices response time".

Figure 4.1 The Benefits of 5G IoT Applications

4.1.2 Cons of 5G IoT

Limited 5G Coverage

As described in section 1.2.3.1, 5G consists of a variety of different radio frequencies in sub-6 and mmWave regions. The mmWave has huge advantages in download speeds but cannot travel too far or penetrate obstacles indoors. To enhance the indoor coverage, more small cells can be used. Small cells include femtocells and picocells. They are low-powered base stations and are mainly used in small and medium-sized places.

Femtocells are deployed at home or office and maintained by users. Their range is about 10 meters, and they can only support a few users. They improve indoor coverage in offices, restaurants, and even rural homes at a low cost.

Picocells are deployed on each floor of a building and maintained by mobile network operators. Their range is about 200 meters. Operators usually deploy multiple cells in one location. It increases capacity, improve coverage, and ensures that users can switch from one access point to another seamlessly.

Infrastructure Costs

As mentioned previously, it is required to use more small cells in the 5G network, especially in an indoor environment. Therefore, some operators are considering using network sharing to build networks. Several companies share network infrastructure and costs, provide services quickly, and achieve mutual benefits. Service providers can reduce the total cost of ownership by as much as 30% while also improving network quality.

Cybersecurity Risks

A large number of IoT devices connected to 5G networks will greatly increase threats faced by enterprises. Higher bandwidth and more software-based network functionalities could also pose additional risks.

Since not all manufacturers prioritize cyber security, many IoT devices may not have enough security measures such as data encryption, security update, etc. when they are manufactured. As 5G could connect more devices, billions of devices with different security levels mean billions of possible vulnerabilities. Attackers can invade and control IoT terminal devices, and use them to launch attacks, causing damage to the network and businesses. The lack of security standards for IoT devices means widespread network vulnerabilities and hacker attacks.

Therefore, protective security measures are required for 5G IoT to safeguard networks' integrity and ease their security risks.

Unclear Market Potential

5G technology is in its early stages of development and evolving, the 5G ecosystem has not yet been perfected. For enterprise users, they may not be clear about the market potential of 5G IoT applications. For operators, as the feedback from the market is insufficient, they will plan their 5G infrastructure and deployment strategies carefully, ensuring they do not jeopardize their return on investment during the 5G upgrade.

Building a 5G ecosystem requires government support for 5G promotion, deployment, and R&D activities in different industries to build the public's confidence in 5G.

From the survey, most of the respondents think that the drawbacks of 5G IoT applications are mainly high development costs and limited 5G coverage.

Besides the drawbacks listed above, a respondent points out that "some stakeholder might think new technology will replace their job thus they refuse to adopt new technology, example: IoT metering".

圖 4.2 5G 物聯網應用的弊端

4.1.3 優點與缺點

最終企業將能通過運用先進的5G物聯網的應用而得益。採用5G是勢在必行，它將推動行業的數字化轉型，讓人們的生活變得更輕鬆，造福行業和公眾。

調查顯示，大多數受訪者（51%）同意5G物聯網帶來的好處多於弊端。顯而易見，5G 技術正在進步、克服障礙、改進中以滿足人的需求，並在組建和資源運用上作更好的規劃。

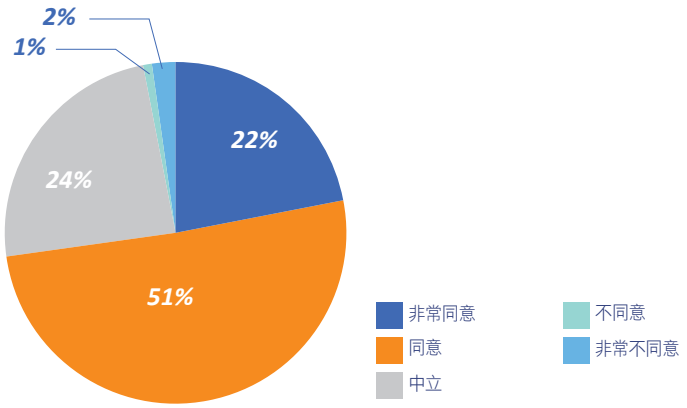


圖 4.3「5G 物聯網利多於弊。」

4.2 企業和 IT 領導者如何為 5G 物聯網做好準備

在部署5G物聯網應用時，企業可能會面對不同類型的潛在障礙。

問卷調查結果顯示，在5G物聯網應用中，不到一半的受訪者（44%）認為存在一些潛在障礙。其中大多數人認為政府支援和發展資源不足。除了列出的潛在障礙外，一些受訪者還指出缺乏人才和難以承受的硬件成本也是潛在障礙。

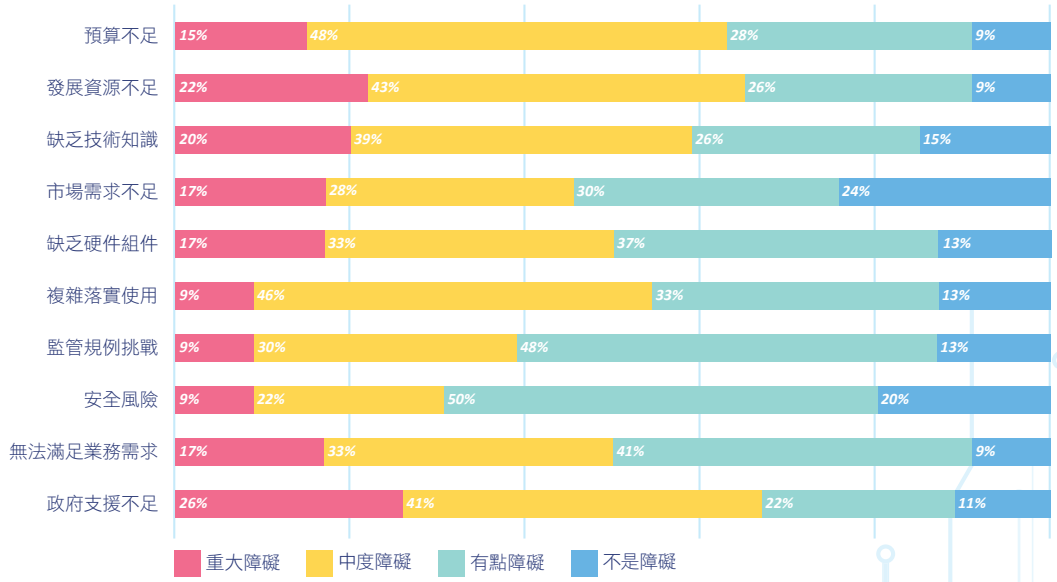


圖4.4 5G物聯網應用中潛在障礙的評級

Figure 4.2 The Drawbacks of 5G IoT Applications

4.1.3 Pros vs. Cons

Ultimately, the businesses will reap the benefit through the advanced applications of 5G IoT. The adoption of 5G is imperative, it will promote the digital transformation of the industry, make people's lives easier and benefit the industry and the public.

From the survey, most of the respondents (51%) agree that 5G IoT brings more benefits than drawbacks. It is crystal clear that 5G technology is advancing, overcoming obstacles, improving to meet human needs, and making better plans for establishment and resource utilization.

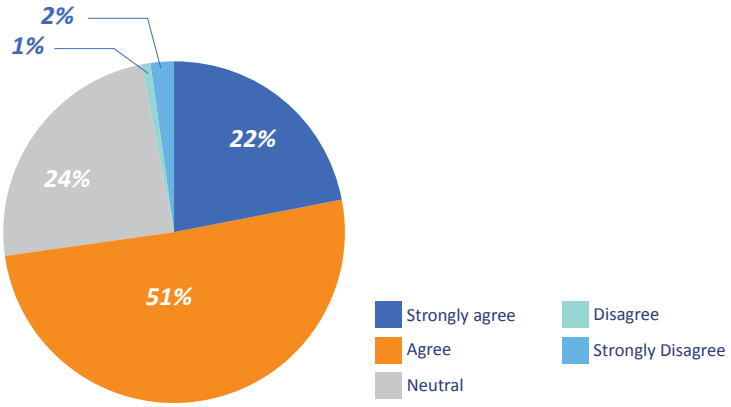


Figure 4.3 "5G IoT brings more benefits than drawbacks"

4.2 How Enterprises and IT Leaders Can Prepare For 5G IoT

When deploying 5G IoT applications, companies may face different kinds of potential barriers.

From the survey, less than half of the respondents (44%) have potential barriers in 5G IoT applications. Most of them think that there are not enough government support and resources for development. Besides the potential barriers listed, a few of them point out some other potential barriers, including a lack of talent and unaffordable hardware costs.

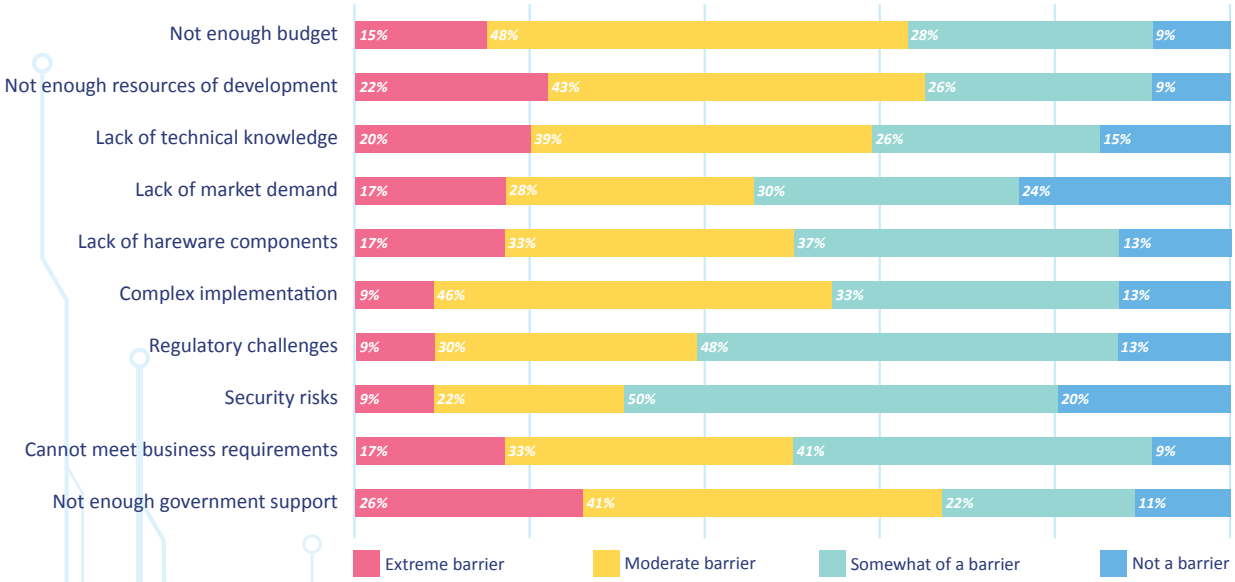


Figure 4.4 The Rating of The Potential Barriers in 5G IoT Applications

為應對5G物聯網發展挑戰，大部分受訪者作出了「尋求政府支持」、「聘請人才」、「加強了解5G物聯網」等應對方法。除了列出的方法外，受訪者還提出了「等待市場增長」。

圖 4.5 應對 5G 物聯網發展挑戰的方法

4.2.1 制定5G策略

公司要有效地利用5G，必須了解5G能帶來什麼機遇，才可說服投資者投資。例如，一些需要快速儲存、訪問和處理數據能力的行業，在規劃如何運用5G新技術時，他們將要研究需要作出那些改變。

此外，企業必須承擔開發或部署5G應用所需的費用。例如，引入邊緣網絡和計算，可能需要更改網絡系統和基礎設施，從而需要培訓員工或採購外判服務。公司應該準備足夠的預算作應對。
再者，企業在採用5G物聯網相關產品和服務時，需要了解5G物聯網系統，並採取有效措施將潛在風險降到最低。如果企業想建設自己的5G專網，就需要遵循相關5G標準。

4.2.2 績效管理

隨著 5G 的興起，網絡中的物聯網數據流量將迎來大幅增長。企業需要工具來收集和解釋數據以查明網絡中的任何問題或其應用效能。應用效能管理（APM）解決方案是了解分散式網絡和應用的有效工具。APM 能揭示在特定使用位置的效能數據，並得知應用或服務所倚賴的各種組件。它可以幫助了解在核心網絡之外的用戶體驗。亦可以偵測資源使用的趨勢，減少在硬體上不必要的投資。

4.2.3 5G網絡部署

企業可以購買公共5G服務、租用5G網絡切片，或建設專用5G網絡。它們應該比較服務的功能和成本，並選擇最合適的服務。它們應該考慮如何建構或使用：

1. 無線電網絡的頻譜
2. 5G基礎設施
3. 小型基站（家庭基站/微微基站）

To cope with the challenges in 5G IoT development, most respondents used the methods such as “seek for government support”, “hired talents”, and “learnt more about 5G IoT”. Besides the methods listed, “waiting for the market to grow” is suggested by the respondents.

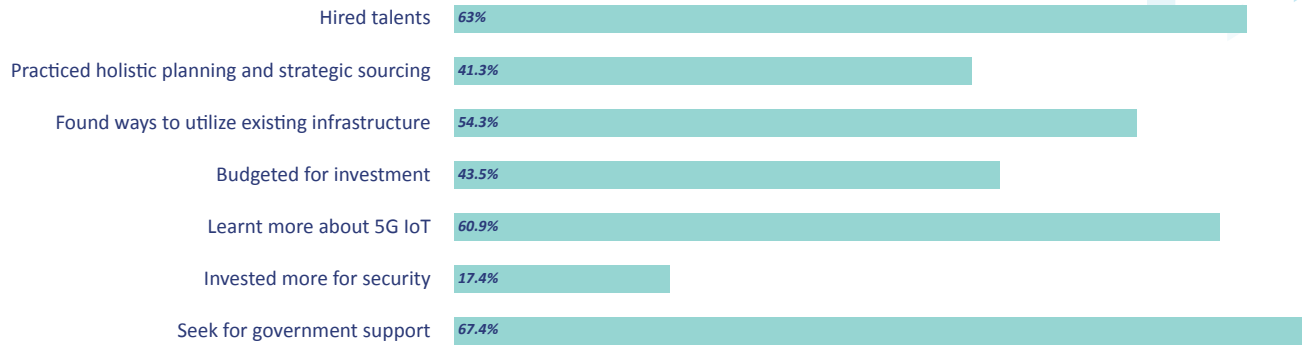


Figure 4.5 Methods to Cope with the Challenges in 5G IoT Development

5G IoT devices generate huge amounts of data that traditional centralized data centres may not have enough resources to handle. In addition, Edge computing can facilitate data collection and processing to ensure lower latency and a better user experience. It could reduce the usage of Wide Area Network (WAN) bandwidth and decentralize computing. Therefore, the system and network infrastructure in the 5G system need to be planned clearly.

4.2.1 Create on 5G Strategy

Companies wishing to take advantage of 5G must understand opportunities that 5G unleashes. It can provide investors with reasons to invest. For example, some industries require the ability to store, access, and process data quickly, they will need to explore what changes are required while planning how to use new technologies with 5G.

Moreover, enterprises must bear some expenses for the development or deploying 5G applications. For example, introducing edge networking and computation could cause the change of system network and infrastructure, and it will require efforts for staff training or outsourcing. Companies should prepare to set aside a sufficient budget.

Moreover, when adopting 5G IoT-related products and services, enterprises need to understand the 5G IoT system and take effective measures to minimize potential risks. If businesses want to build their own 5G private networks, they need to follow the 5G standard.

4.2.2 Performance Management

With the rise of the 5G, the IoT data traffic in the network will be tremendous. A tool that gathers and interprets data to pinpoint any issues within a network’s or application’s performance will be required. Application performance management (APM) solutions are effective tools for understanding decentralized networks and applications. APM can display performance data specific to the user’s location and grant visibility to the various components that an application or service depends on. APM can further understand and provide a consistent user experience outside the core network. It can also detect trends in resource usage and reduce unnecessary investment in hardware.

4.2.3 5G Network Deployment

Companies can purchase public 5G services, lease 5G network slices, or build private 5G networks. They should compare the features and costs of the services and choose the most suitable one. They should consider:

1. The frequency spectrum of the radio network
2. 5G infrastructure
3. Small cells (femtocells/picocells)

4.3 政府在5G物聯網上扮演的角色

智慧城市是指積極將技術應用於不同領域以提高效率、改善市民生活質素、促進可持續發展的城市。根據2021年智慧城市指數調查，新加坡連續第三年成為全球最智慧城市，而香港排名第41位，較去年的第32位下降9位[20]。

儘管香港實施智慧城市發展比世界上許多城市稍晚，但自2017年12月香港政府推出《香港智慧城市藍圖》並致力在五年內把香港建構成一個智慧城市以來，香港已在六大範疇[21]實現階段性發展。例如快速支付系統「轉數快」(FPS)等主要措施已在過去幾年如期推行。

5G 網絡可以幫助和加強智慧城市的基建基礎。一般用戶可能會認為5G 網絡僅旨在為通訊提供更高速度和容量的網絡服務，並在串流媒體內容方面提供更好的用戶體驗。5G技術的低時延、低功耗、多連接等特點，將其用途從手機擴展到了物聯網的應用層面。在未來，不同領域的智慧城市應用會越來越多，並需要強大的5G網絡支持。因此，要保持香港在5G市場的領先地位並加快智慧城市的發展，政府必須系統地完善5G網絡基礎設施，推動香港5G物聯網應用的發展。

為協助業界適應5G物聯網技術，大部分受訪者希望香港政府能夠為研發開支提供稅務優惠、在更多公共服務中採用5G物聯網技術，並推出5G物聯網應用資助計劃。除了圖 4.6 中列出的措施外，受訪者還認為政府可以通過「支持5G物聯網數據中心發展」和「向公眾解釋在智慧城市應用中使用閉路電視的好處」來幫助行業。

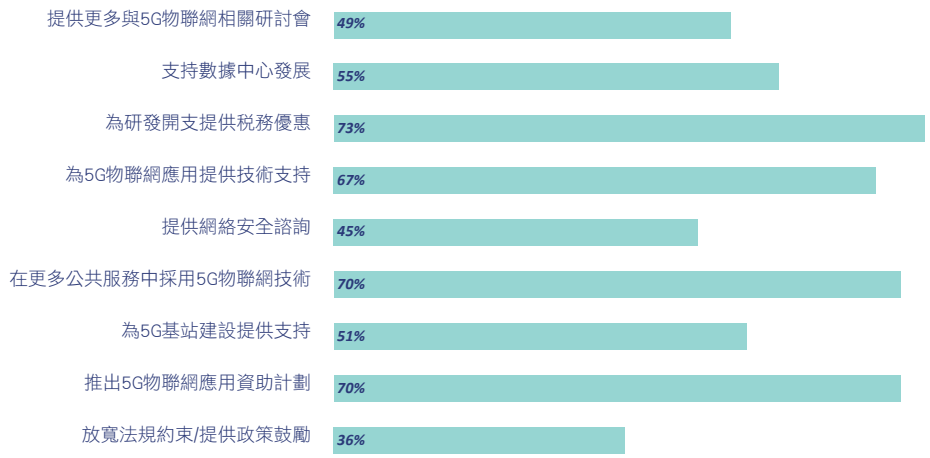


圖 4.6 香港政府可採取的措施以幫助業界採用 5G 物聯網技術

正如施政報告所述，政府將通過多種方式推動5G發展，包括提供更多5G頻譜進行拍賣，以及通過「鼓勵及早使用5G技術資助計劃」資助更多行業採用5G創新應用。為進一步鼓勵公私營機構部署5G技術及推動5G物聯網創新應用的發展，政府將在香港採取更多措施加快建設智慧城市。

[20] 言嘉庸（2021，10月31日）。智慧城市 | 香港全球排名41 多方位推動5G發展。取自當代中國網址：https://www.ourchinastory.com/zh/2745/%E6%99%BA%E6%85%A7%E5%9F%8E%E5%B8%82%EF%BD%9C%E9%A6%99%E6%B8%AF%E5%85%A8%E7%90%83%E6%8E%92%E5%90%8D41%20%E5%A4%9A%E6%96%B9%E4%BD%8D%E6%8E%A8%E5%8B%955G%E7%99%BC%E5%B1%95

[21] 六大範疇包括「智慧出行」、「智慧生活」、「智慧環境」、「智慧市民」、「智慧政府」及「智慧經濟」。

4.3 Government's Role for 5G IoT

A smart city refers to a city that actively applies technology in different fields to increase efficiency, improve citizens' quality of life, and promote sustainable development. According to the Smart City Index 2021 survey, Singapore is the smartest city in the world for the third year running, while Hong Kong ranks 41st , down 9 places from 32nd last year.[20]

Although Hong Kong's implementation of smart city development is a bit later than many cities around the world, it has achieved phased development in 6 smart areas [21] since the Hong Kong government launched the "Smart City Blueprint for Hong Kong" in December 2017 to develop Hong Kong into a smart city within 5 years. Major initiatives, such as the Faster Payment System (FPS), have been implemented as planned in the past few years.

5G network could help and strengthen the foundation of a smart city's infrastructure. General users may think 5G networks only aim at providing higher-speed and high-capacity network services for communications and delivering a better user experience in streaming multimedia content. The low latency, low power consumption, and multiple connections of 5G technology have expanded its use from mobile phones to the application level of IoT. In the future, there are more smart city applications in different areas that will require strong 5G network support. Therefore, to maintain 5G leadership and accelerate the development of the smart city, the government must systematically improve the 5G network infrastructure and promote the development of 5G IoT applications in Hong Kong.

To help the industries in adapting 5G IoT technology, most of the respondents wish the Hong Kong government can offer tax concessions for R&D expenditure, adopt 5G IoT technology in more public services and introduce a 5G IoT application funding scheme. Besides the measures listed in figure 4.6, respondents also think the government can help the industries by "supporting 5G IoT data centre development" and "explaining to the public the benefits of using CCTV in smart city applications".z

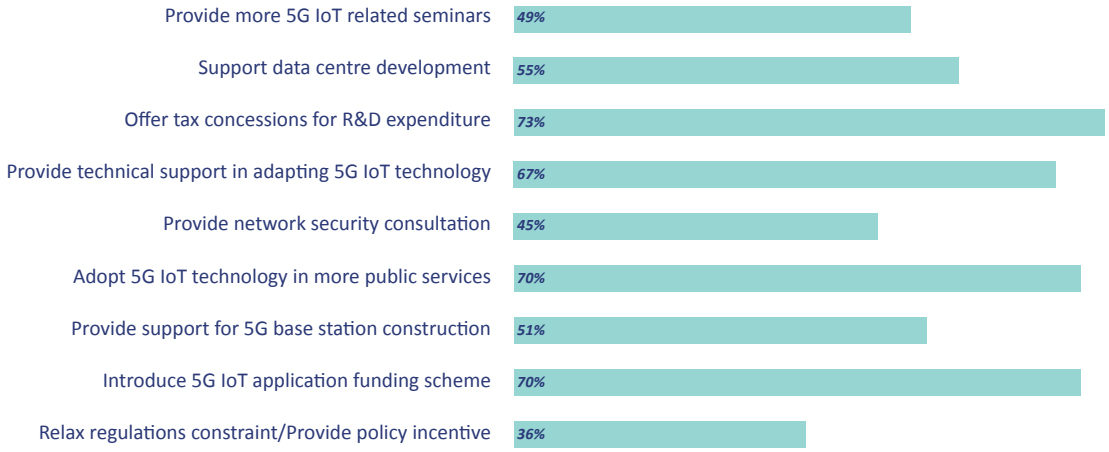


Figure 4.6 Measures that Hong Kong Government can Take to Help the Industries in Adopting 5G IoT Technology

As mentioned in the policy address, the government will promote the development of 5G in various ways, including providing more 5G spectrum for auction and subsidizing more sectors to adopt 5G innovative applications through the Subsidy Scheme for Encouraging Early Deployment of 5G. To further encourage public and private organizations to deploy 5G technology and promote 5G IoT innovation, the government will take more measures into account to build a smart city in Hong Kong.

[20] 言嘉庸. (2021, October 31). 智慧城市 | 香港全球排名41 多方位推動5G發展. Retrieved from Our China Story Website: https://www.ourchinastory.com/zh/2745/%E6%99%BA%E6%85%A7%E5%9F%8E%E5%B8%82%EF%BD%9C%E9%A6%99%E6%B8%AF%E5%85%A8%E7%90%83%E6%8E%92%E5%90%8D41%20%E5%A4%9A%E6%96%B9%E4%BD%8D%E6%8E%A8%E5%8B%955G%E7%99%BC%E5%B1%95

[21] The 6 smart areas include "Smart Mobility", "Smart Living", "Smart Environment", "Smart People", "Smart Government" and "Smart Economy".

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香港科技園	**Hong Kong Science & Technology Parks Corporation**

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Please scan the QR code of 5G Internet of Things (IoT) Applications Survey below:

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