White Paper on 5G City

List of Contents

List of Illustration

List of Tables

Executive Summary

5G City is a city with high efficiency 5G Network, an important infrastructure for developing smart services in various fields. 5G City offers significant advantages to the government, private sector, and people sector, including an extensive coverage network that allows users to have a better connection to high-speed connectivity and enhancing the accessibility of 5G smart services in the city. This also include the adoption of 5G technology to promote energy conservation, which can have a positive impact on the environment and lead to the development of a sustainable 5G City. 5G City is an important foundation for the future development of various technologies and intelligent services, which requires high-quality 5G technology that has high-speed connectivity and the ability to connect massive devices for achieving the development of an efficiency 5G City.

Therefore, the 5G City development plan is important for driving the country's economy and society by enhancing the 5G infrastructure to cover a wide area in the city, which can improve the quality of people's lives and provide maximum benefits to business sector. In driving Thailand to have an efficient 5G City and aiming for the application of modern technology to produce services that can help reduce problems that Thailand faces and meet the needs of all sectors to meet with the goal of using digital technology to drive Thailand to the developed countries, it is necessary to formulate a clear 5G City development plan, which will consist of 4 flagship projects: 1.) The Development of 5G Network criteria for 5G City Certification, to develop 5G network to be more efficient for providing various intelligent services and certify for the city that meets the network criteria to provide a positive image for the 5G city development. 2) The Development of Pilot 5G Livelihood City, focuses on the development of intelligent services for improving the quality of people's lives in the city. 3) The Development of Pilot 5G Governance and Industrial City, enhancing the potential of industrial sector for driving the economic growth. 4) The Development of Long-Term 5G City Plan, which establish the 5G ecosystem alliance to support the development of advanced networks criteria for improving the performance of intelligent services and promoting the sustainable 5G city development. Consequently, Thailand should consider the proposal of the 5G city development plans in the first 3 projects in short-term phase, initiate to be the prototype of 5G city development in 2022, and implement the 4th project in mid-term phase (2023) to continuously develop 5G City in long term.

1. 5G City

1. 5G City

1.1 Definition of 5G City

5G City is a city with high efficiency 5G Network, an important infrastructure for developing intelligent services in various fields. 5G City provides many benefits to the government, the private sector, and the people sector such as an extensive coverage network. It allows the users to have a better connection to high-speed connectivity and it also supports the implementation of 5G intelligent services in the city. Moreover, 5G technology does not only promote energy conservation and green energy but also brings a positive impact on the environment developing a sustainable 5G technology city.

Fifth Generation (5G technology) is a technology that helps to improve the efficiency of telecommunications. It enables the transmission of massive amounts of data in real-time, which is equivalent to fiber optic transmission. As a result, the devices can receive and transmit the data in real-time which leads to more intelligent technologies and services adopted by various industries. Hence, 5G is the origin of the development of 5G City.

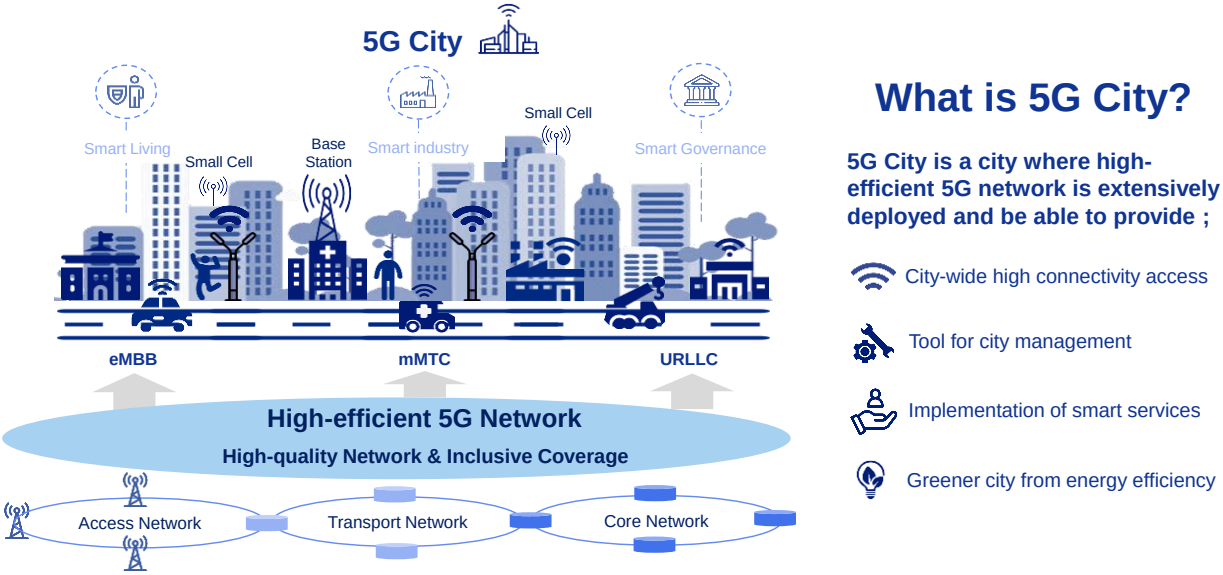


Figure 1-1: Definition of 5G City

In addition, 5G technology promotes the use of green energy and supports the conservation of the natural environment by utilizing renewable clean energy. 5G technology can improve the development of smart services resulting in a reduction of energy consumption in various industries, such as the health industry, where 5G technology is deployed in telemedicine (5G Teleconsultation) to provide a remote medical consultation to hospitals in a remote area. The lower distance in travelling, the lower carbon emissions, and

pollution generated in the city. On the other hand, the manufacturing industry can use 5G technology with AI and IoT to monitor machine operation and energy consumption in real-time to increase production efficiency. Unmanned Aerial Vehicle (5G UAVs) which is used to inspect the gas pipeline as part of the development in the energy industry helps to reduce the number of employees and vehicles required for implementation, including the prevention of hazardous substances and the protection of employee safety. Therefore, 5G technology could promote energy conservation by reducing carbon emissions which developing a 5G city to become an environmentally friendly city and has a sustainable development.

Currently, Thailand has already developed a Smart City in many regions of the country, focusing on utilizing technology and creating innovation to improve the efficiency of smart services and city management with a goal to develop livable cities and promote the quality of people's lives in the city. Importantly, the high-performance of the 5G network is the key enlargement of advanced *5*G services. Hence, the development of 5G needs to be targeted widely on the potential areas, such as smart cities, innovation districts, or other economic areas.

As a result, 5 G city is the first development goal of smart cities improvement to have higher efficiency since 5 G technology networks and infrastructures are the basic requirement of many smart services that rely on high-speed communication and massive connection of 5 G technology devices such as self-driving car service, remote medical consultation service, and intelligent detection service, etc.

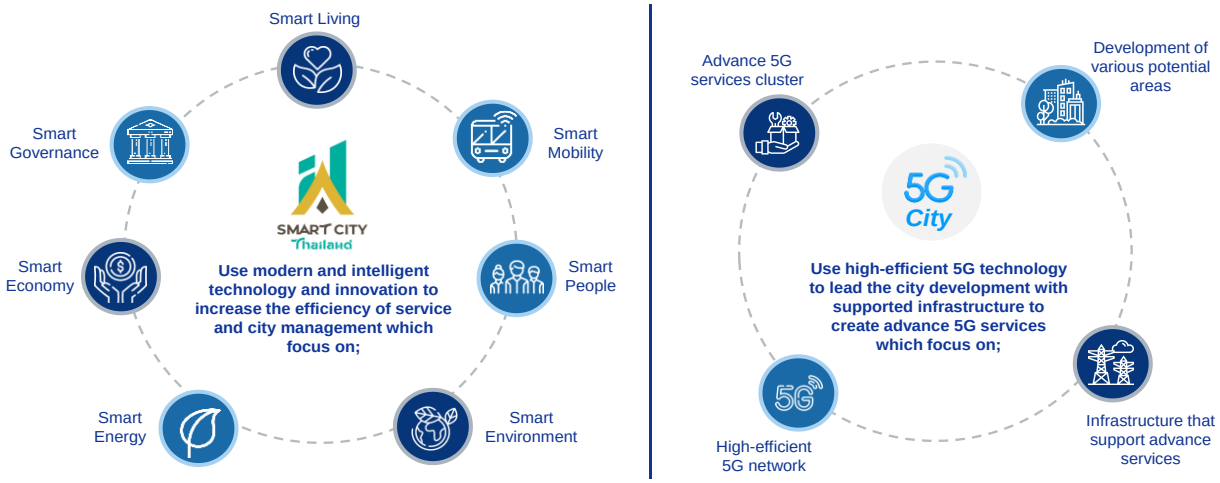


Figure 1-2: Smart City and 5G City

1.2 The Necessity of 5G City Development

5 G City is an important foundation for the future development of technologies and services, especially in the fourth industrial revolution (Industry 4.0) which requires high-speed connectivity and the ability to connect massive devices. 5G City will allow the creation of new intelligent technologies and innovations to accomplish citizen demands.

Technologies and smart services utilize 5 G technology to provide high-speed connectivity and a massive connection of devices. Without 5G technology, providing advanced services in a city will be unable to be successful. An autonomous vehicle is an example of 5G use cases that utilizing high-speed data transmission sending a signal from the vehicle and the control room and vice versa to enable safe automated driving. In addition, high-speed connectivity is required for remote surgery to improve the real-time communication between the control of specialist doctors and various devices in the hospital. As a result, the establishment of a 5G city will directly bring both economic and social benefits to citizens. 5G technology can promote the establishment of various smart services for the business and tourism sectors as well as help to reduce social disparities especially in rural areas of the country in access to education, government services, and business opportunities. 5 G technology in terms of coverage, throughput, capacity, and latency must be capable enough to allow the full implementation of services and technologies in the city in order to unleash the potential of smart services.

Consequently, the 5 G city development plan is significant to the country's economic and social development. High efficiency 5 G infrastructure planning can promote the establishment of many intelligent services that will help to improve the quality of people's lives and business industries. If there is no precise 5 G city development plan, 5G technology would be unable to unleash the potential of services and technologies due to technological limitations and a variety of demands for intelligent technologies and services.

Example of Services in 5G City

5G technology could be used to enhance the efficiency and quality of existing services as well as the development of new services that have been deployed in several countries around the world. The 5 G technology infrastructure is being developed to encourage innovation and the improvement of 5 G intelligent services in the business industries, as well

as the public sector and city residents. According to international case studies, the 5G City concept has been adopted in many countries such as China, Singapore, the United Kingdom, France, Australia, Germany, and Switzerland providing a wide range of services in various industries.[1]

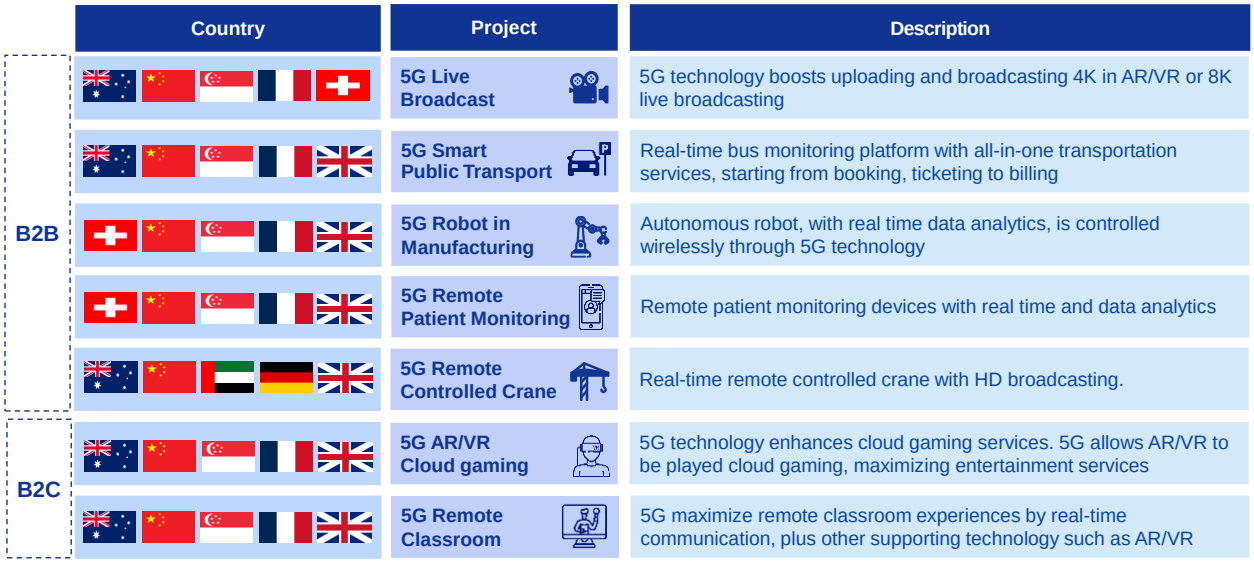


Figure 1-3: Examples of 5G Cities Services Worldwide

In business-to-business (B2B service), many countries throughout the world recognize the importance and necessity of 5G networks to reinforce innovations and improve the efficiency of service in diverse industries. In the media and entertainment business, 5G technology has been introduced to facilitate high-resolution data transmission in 4K live broadcasts to enhance the user experience. In the healthcare industry, there are new types of services utilizing 5G technology such as surgery, follow-up, and teleconsultation for patients in remote areas. It allows the communication experience in different places to be seamless and enables remote medical care in rural area to be executed.

Moreover, 5G technology is used in the government sector to improve public services by providing public transportation services that can be connected to a platform that allows users to track and monitor the real-time status of buses helps the commuters to be able to plan travel time and a booking ticket system for services paying via the platform as well. 5G technology with IoT and AI technology can help to improve production and operation efficiency in the manufacturing and logistics industry. For example, 5G remote-controlled cranes allow the controller to control cranes remotely in real-time from a central control room to increase accuracy and reduce time operation.

[1] Source: Huawei

In a business-to-customer (B2C) service, experience in terms of better well-being and quality of life is directly delivered to a user. By utilizing the capability of 5G technology with Augmented reality (AR) and Virtual reality (VR) technologies, a game business could innovate services and enhance gaming experiences with 360-degree vision systems. Moreover, 5G technology is also used to develop Cloud gaming in the area of higher data transmission and lower latency to provide services seamlessly. Furthermore, 5G technology also developed the quality of education by enabling a remote classroom service through a high-speed 5G network. As a result of real-time communication, it can increase the accessibility of education in the rural area and reduce inequities which is a critical problem in the education system.

Based on the above information, this is only an example of smart services that have been deployed in many countries. Currently, most countries are in the early stage of the development of 5G services. Hence, the 5G technology infrastructure becomes the important key in developing a 5G city so the city could offer high-performance smart services in a 5G city, continuously improve the potential of services with 5G technology, and move towards a sustainable city. This goal could be seen from South Korea that it focuses on the expansion of 5G networks to cover a wide area supporting more number of 5G subscribers and higher data usage. It continuously develops the 5G network's quality to be powerful enough to retain its high performance and allow new intelligent services to be provided through 5G network to both general user and business level.

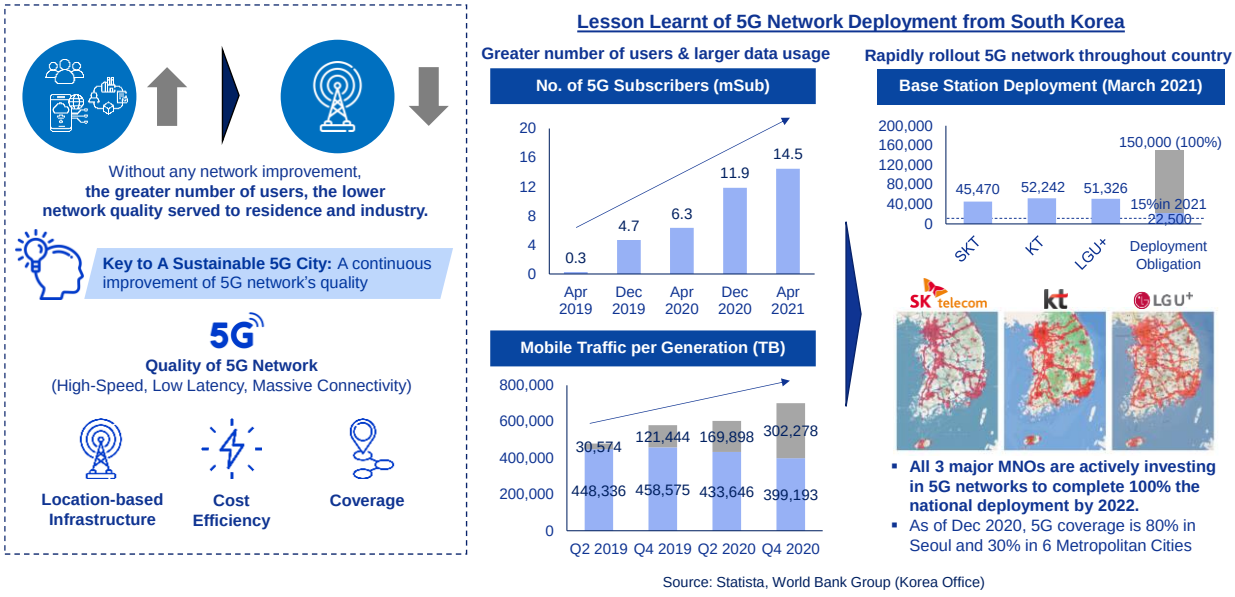


Figure 1-4: Case Study of 5G Network Development in South Korea

1.3 5G City Development Status

1.3.1 Status of 5G Cities Around the World

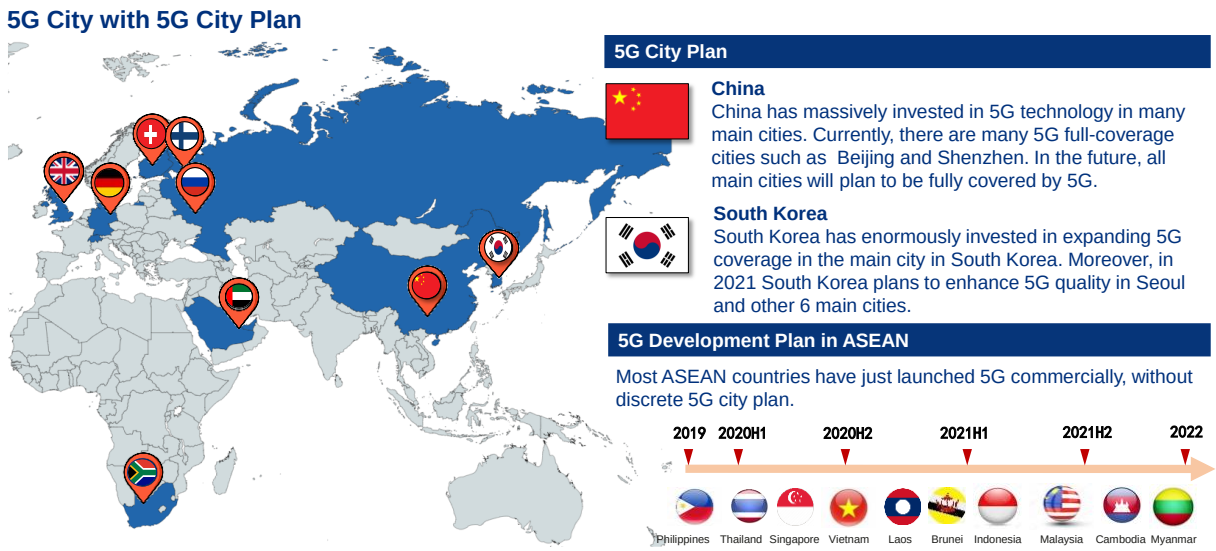


Figure 1-5: Status of 5G Cities Worldwide

The development of 5G cities in other countries is attracting worldwide interest. Each country is trying to have a clear 5G city development plan and establishing its own 5G city to make it ready for providing 5G services, such as London in England, Seoul in South Korea, Beijing in China, Berlin in Germany, and etc. Most of them already have 5G infrastructure for providing 5G services all over the city. On the other hand, the infrastructure of 5G technology is still being installed in some cities. The examples of the area that has completely equipped 5G infrastructure to deliver 5G service across cities are Seoul in South Korea, and Beijing and Shenzhen in China. The development plan of 5G in each city starts from the network expansion in the main cities, such as Hangzhou in China and Incheon in South Korea and the next goal is to roll out 5G infrastructure cover all area of the country.

Considering 5G cities in the Association of Southeast Asian Nations (ASEAN), Singapore is the country with the most developed 5G city in the region while most ASEAN countries are still in the process of preparing to commercialize 5G use cases such as spectrum management and auction, and the installation of equipment to provide 5G technology services. Vietnam, Thailand, and Philippines have already commercially launched their 5G since 2020 but they are still in the process of expanding their 5G network to cover a wide area in the city. On the other hand, 5G in Cambodia and Myanmar is expected to be commercially launched in late of 2021.[2]

[2] Source: Huawei

In addition, many European countries are collaborating with each other to test the pilot of 5G in a large-scale connecting city to become 5G Corridor, especially in the country that its road has high traffic such as

1) The collaboration between Spain and Portugal in developing automated driving technology.[3]
2) The development of corridors from Munich to Bologna in 3 countries: Italy, Austria, and Germany, the deployment of 5G technology along the motorway in the border regions helping the improvement of the safety and environmentally friendly in using autonomous self-driving vehicles in the transport sector.[4]
3) West Midlands region in England, the first large-scale 5G testbed in the country that has developed a project about 5G-connected road sensor network to control transportation management more efficiently.[5]
4) The development of Prague - Munich Corridor in two countries: Czech Republic and Germany to test the smart trams system in a real setting and develop a drone connection system to manage emergency situations.[6]

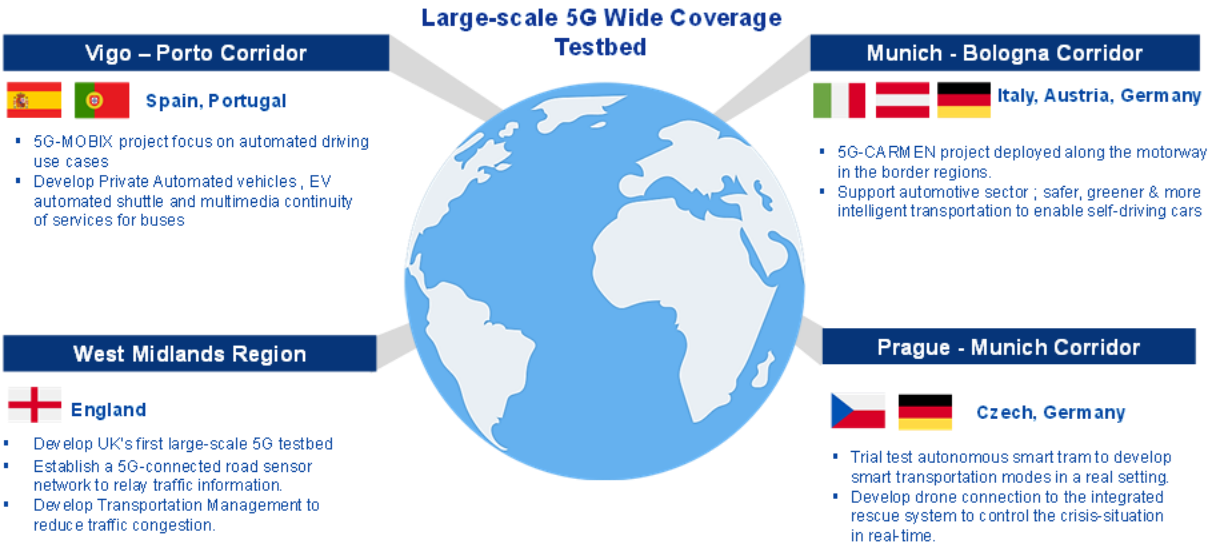


Figure 1-6: 5G Network Testing Project in European Cities

[3] Source: Corridor and Trial Sites Rollout Plan, 5G Mobix (2020)
[4] Source: Objectives Focusing on the Bologna-Munich corridor, 5G CARMEN (2018)
[5] Source: West Midlands to roll out 5G-connected road sensor network, Landmobile (2021)
[6] Source: Pilsen will have its first smart tram, PPF Group (2021)

Development of 5G Technology Infrastructure Around the World

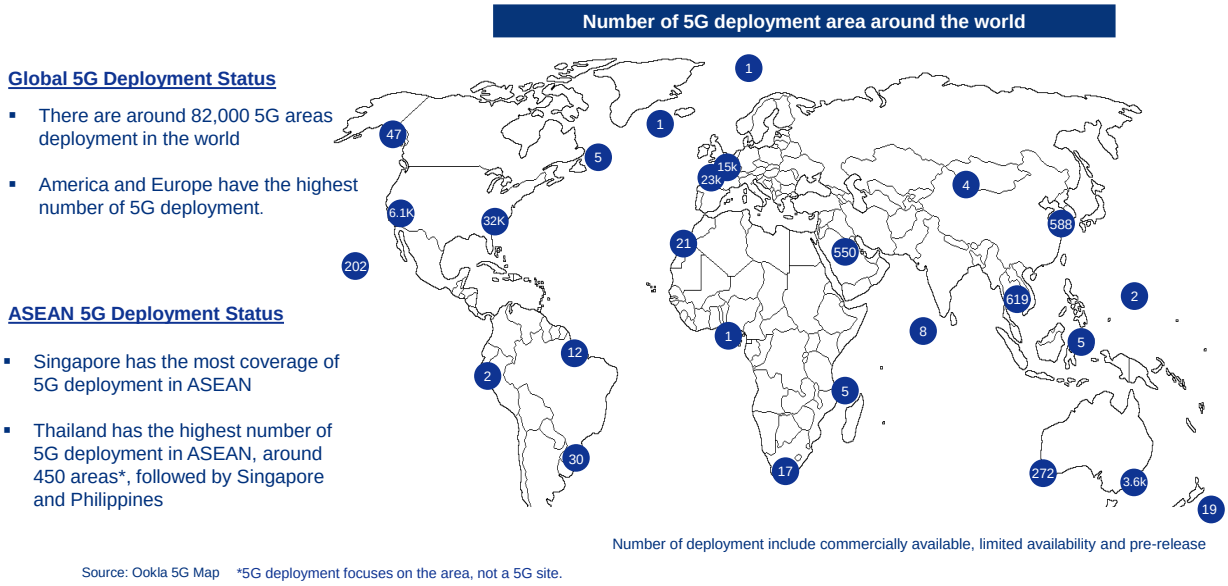


Figure 1-7: Development of 5G Technology Infrastructure Around the World

For the progress in expanding the 5G network, there are over 82,000 areas that have been covered by 5G around the world. [7]Most are commercially launched 5G technology services while Americas and Europe have the most 5G infrastructure installation, especially in the United States. Moreover, China and South Korea are the two Asian countries that have the most progress in the deployment of the 5G network. In ASEAN, Singapore has the widest 5G network coverage in the region. Meanwhile, Thailand already has rolled out 5G network in more than 450 areas in main cities such as Bangkok, Chiang Mai, the Eastern Economic Corridor (EEC), and etc.[8] and it continues to expand 5G network across the country to reach 5G full coverage. Other ASEAN countries such as Philippines have progressed to deploy 5G networks in Manila and other major cities, as well as Jakarta, Indonesia, and Kuala Lumpur, Malaysia.

[7] Source: Ookla 5G Map

[8] As Ookla defines in its 5G infrastructure installation progress, Ookla states that the figure only refers to the area where 5G service is available, which is not the number of base stations.

Example of 5G Cities in China

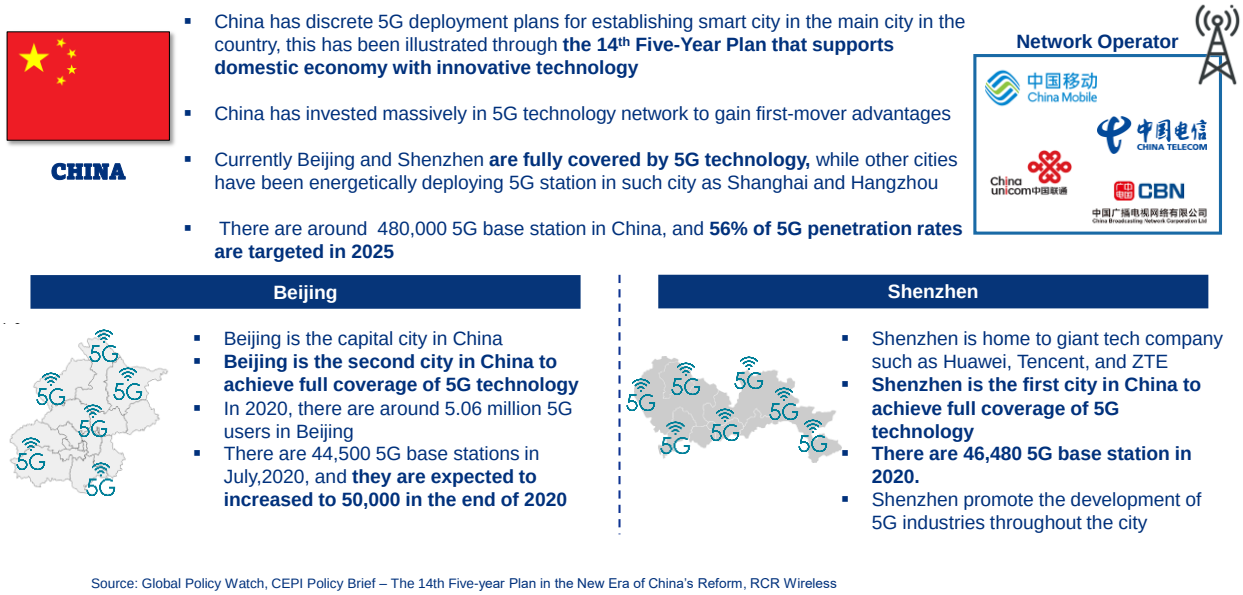


Figure 1-8: Example of 5G Cities in China

China has continued to develop 5G cities by developing a 5G technology infrastructure expansion plan through its 14th Five-Year plan. China has targeted to have a 5G full-coverage so that it could benefit from being the first-mover who provides 5G technology and creating innovative services in the world.[9]

Currently, there are around 480,000 5G base stations in China. It is expected that the 5G penetration rate will reach 56% within 2025 through the cooperation of the main telecom operators such as China Mobile, China Telecom, China Unicom, and CBN. Two cities in China already have 5G full coverage which are Beijing the capital of China and Shenzhen, the main cities in southern China.

Shenzhen where major technology providers in China is located is the first city in China that has a city-wide 5G technology full coverage. In 2020, there are 46,480 5G base stations across the city. On the other hand, Beijing is the second city has a city-wide 5G technology full coverage with more than 50,000 5G base stations across the city. Importantly, there are more than 5 millions of 5G subscribers in Beijing.

[9] Source: Michel, A. Guo, B. & Camille, M. CEPI Policy Brief – The 14th Five-year Plan in the New Era of China's Reform (2021)

Example of 5G Cities in South Korea

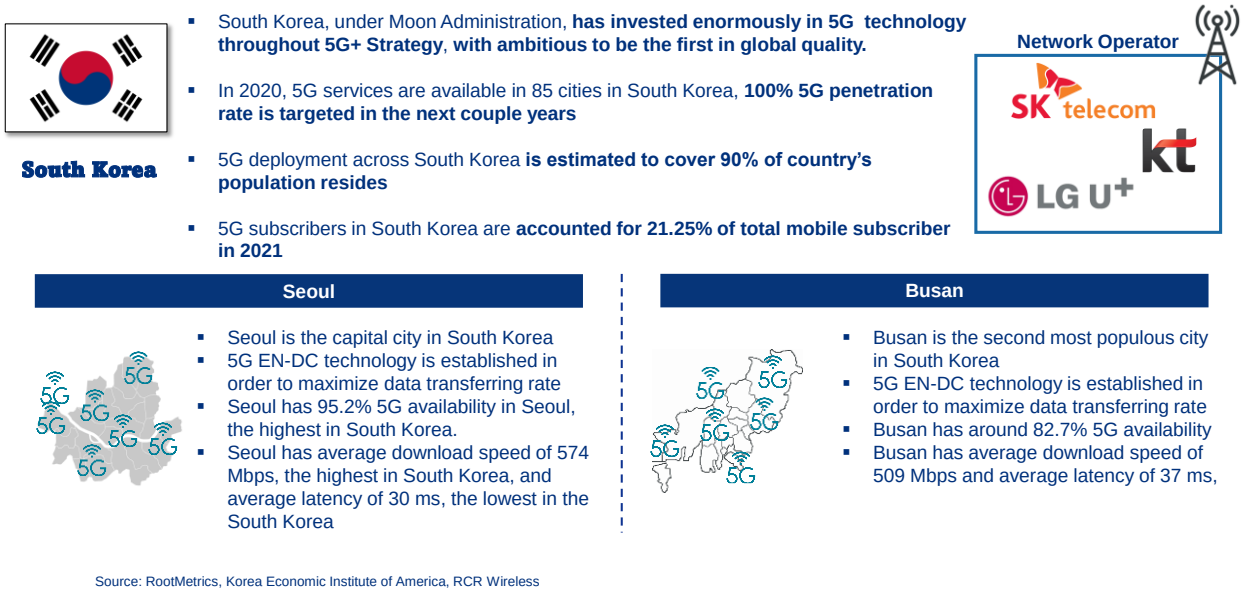


Figure 1-9: Example of 5G Cities in South Korea

South Korea is the first country in the world that commercially launch 5G service. It aims to develop the world's 5G technology standard since 2018. At present, there is 5G coverage in Seoul, South Korea's capital city, as well as other major cities in the country, such as Incheon and Busan, where the development of 5G technology cities is implemented under the country's 5G+ Strategy policy. Currently, 5G already covers 90 percent of area that people are living in South Korea. With the rigorous cooperation of the country's main telecom operators, such as SK Telecom, KT Telecom, and LG U Plus, the full coverage will be reached in the next few years.

Seoul, the capital city of South Korea, has 95.2 percent of 5G network coverage. It could be called the highest 5G coverage city in the country. 5G service in Seoul will have an average download speed and latency of around 690 Mbps and less than 30 milliseconds, respectively. Overall, Seoul is the best 5G city in the country. On the other hand, Busan which has the second largest population in the country has a 5G penetration rate of more than 82.7 percent. 5G service in Busan has an average download speed and latency of 509 Mbps and less than 37 milliseconds, respectively. Hence, it makes South Korea be able to support diverse 5G technology services providing in the country.

Example of 5G Cities in England

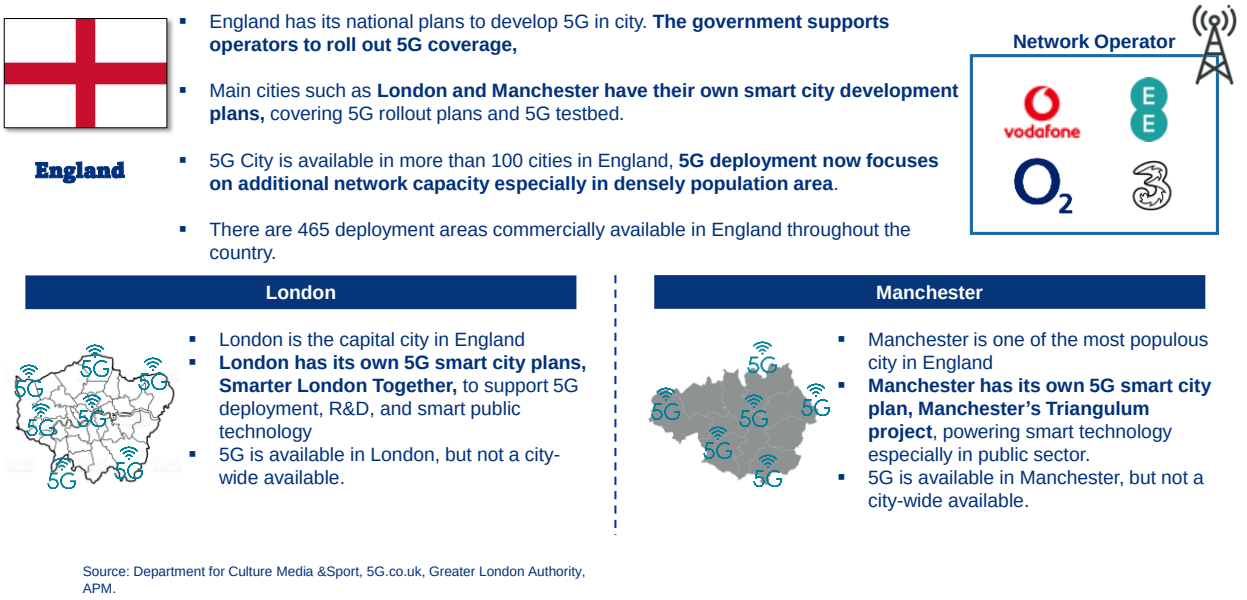


Figure 1-10: Example of 5G Cities in England

England has commercially launched 5G service since 2018. It plans to deploy 5G network across the country based on the 5G National Strategy policy. 5G service is currently available in over 100 cities, including London, Bristol, and Manchester. However, 5G service is still limited in some areas and congested areas like subways. Government and telecommunication operators such as EE, Vodafone, O2, and Three aim to continually expand the 5G network to cover all areas of the city as part of the development policy plan.[10]

London, the capital city of England is the first city where 5G networks have been rolled out. However, 5G service is still limited in only some areas comparing to the service provided in Beijing in China or Seoul in South Korea. London has continuously developed the city to become a 5G city under the Smarter London Together strategy plan by deploying 5G technology and promoting 5G services in the city to make the city have the best 5G network in terms of coverage and quality. On the other hand, 5G network coverage in Manchester, one of the most popular cities in England, is still limited in cities too. However, it is expected that the expansion of 5G network coverage will be accelerated soon due to the 5G city development plan under Manchester's Triangulum Project.

[10] Source: Department for Culture Media &Sport, 5G.co.uk, Greater London Authority, APM.

Example of 5G Cities in United States

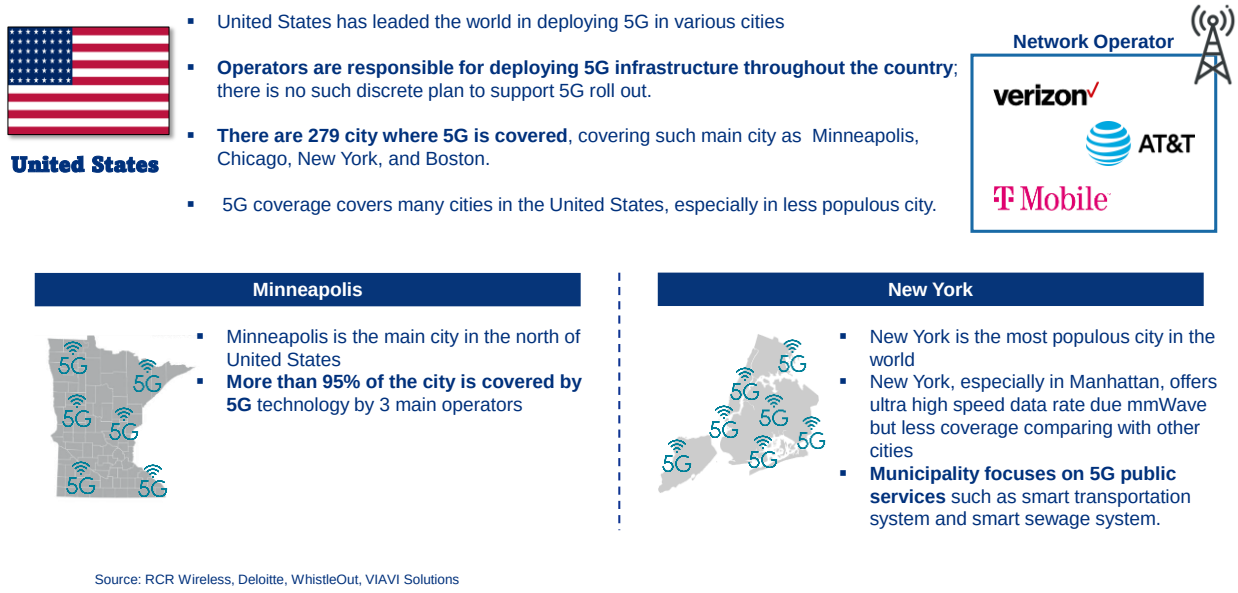


Figure 1-11: Example of 5G Cities in United States

United States is one of the countries that has already rolled out 5G networks and is developing to become a 5G city. Nowadays, more than 270 cities in the United States can access 5G technology, including major cities such as Chicago, Boston, New York, San Francisco, and Minneapolis. However, 5G coverage is still insufficient throughout a city like England. The telecommunication providers, such as T-Mobile, AT&T, and Verizon, are responsible for expanding 5G technology deployments, even though the government does not have any support on 5G deployments like in other countries.[11]

Minneapolis, the largest city in the north of the United States, has 95 percent 5G coverage. However, New York, the largest eastern city in United States with the densest population, has a lower rate of 5G penetration than the other major cities. Even though the telecommunication companies are advertising about 5G technology, but some areas are still inaccessible to 5G technology. However, New York has continuously tried to become a 5G city, as seen by the various available 5G services, such as intelligent traffic analysis and intelligent waste management.

[11] Source: RCR Wireless, Deloitte, WhistleOut, VIAVI Solutions

1.3.2 Status of 5G City in Thailand

Development of 5G Infrastructure in Thailand

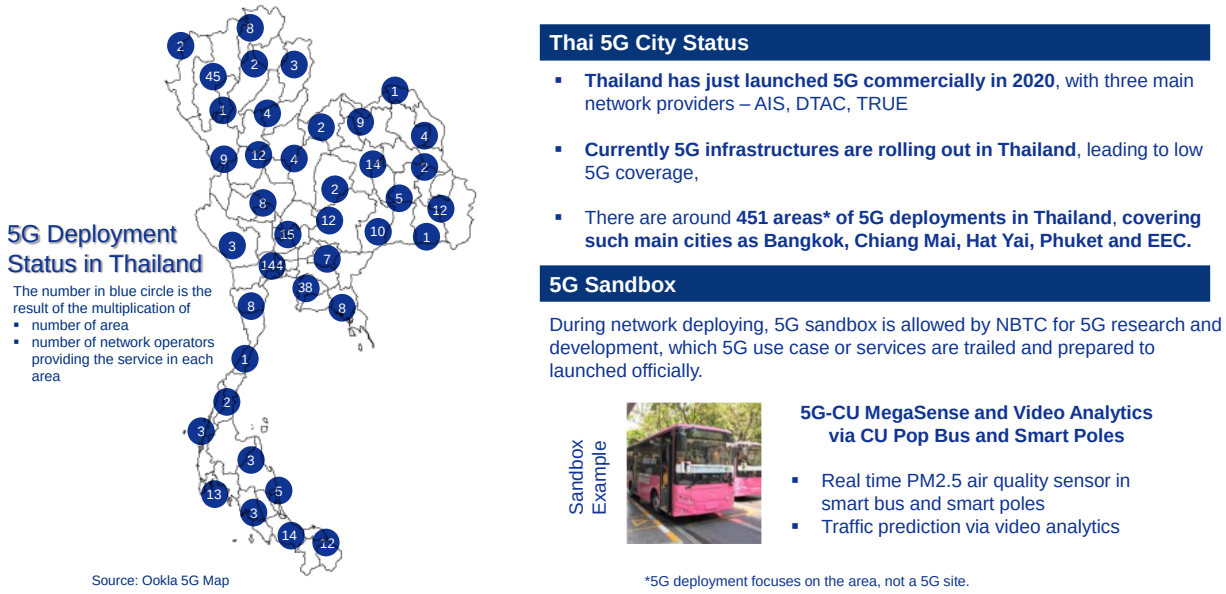


Figure 1-12: Development of 5G Infrastructure in Thailand

5G network expansion after the spectrum auction in 2020 is responsible by three main telecommunication operators, Advanced Wireless Network company (AIS Group), DTAC TriNet company (DTAC Group), and True Move H Universal Communication Company (TRUE Group).

At present, Thailand is still in the process of a 5G network rollout. Approximately 451 areas in Thailand are already covered by 5G technology including major cities[12] such as Bangkok, Chiang Mai, Phuket, Songkhla, and other cities in the Eastern Economic Corridor (EEC). [13]However, 5G coverage in Thailand is still limited unlike South Korea or China that have a full 5G coverage in the major city.

[12] As Ookla defines in its 5G infrastructure installation progress, Ookla states that the figure only refers to the area where 5G service is available, which is not the number of base stations.

[13] Source: Ookla 5G Map

5G Speed and Experience in Thailand

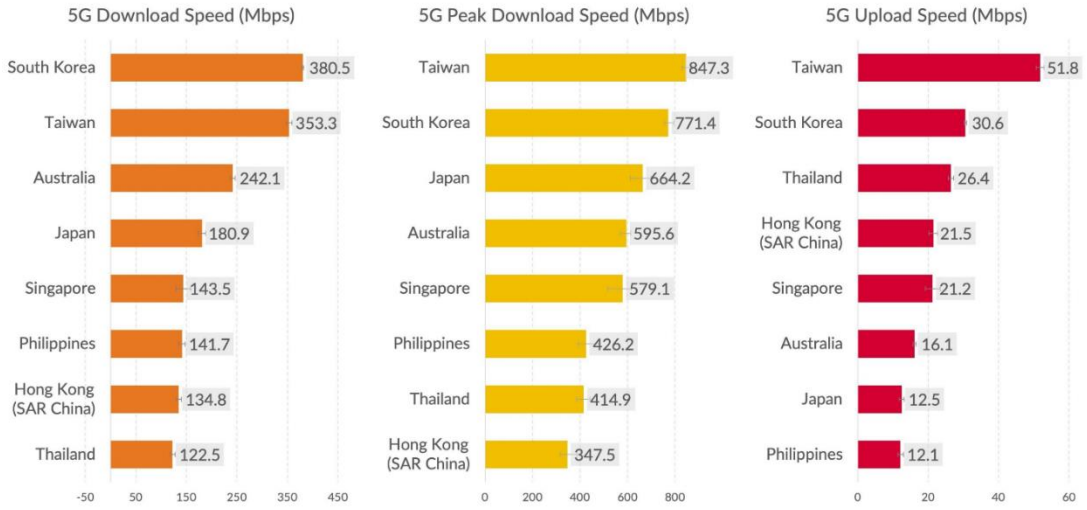


Figure 1-13: 5G Speed in Asia Pacific[14]

Comparing to other countries in the Asia-Pacific region, Thailand's 5G download speed and peak download speed are still low, whereas the upload speed is comparatively high. Thailand still needs to develop a 5G infrastructure to be ready for providing 5G intelligent services. Thailand currently has a low number of 5G subscribers. Therefore, the development of 5G infrastructure is critical to improving stability and support for the applications effectively in the future.

Thailand's 5G experience in terms of video, gaming, and voice application usage is relatively high with a score over 75 in all sectors compared with other countries in the Asia-Pacific region. However, this 5G experience level comparison is in the initial stage. Therefore, the development of the 5G infrastructure and the improvement of service quality is also important to maintain and develop the 5G service experience at a high level until the 5G technology network of Thailand will be completely implement in the future.

[14] Source: OpenSignal: Benchmarking the 5G Experience Asia Pacific - June 2021

Figure 1-14: The 5G Experience in Asia Pacific[15]

Although the development of 5G infrastructure is still in a progress, Thailand has continued to develop 5G city due to the regulation of the National Broadcasting and Telecommunication Commission (NBTC) that allow a trial of 5G technology in a sandbox while waiting for the installation of 5G infrastructure in wide coverage across the country. The sandbox allows the telecommunication operators to test various services as a case study, as well as to prepare the 5G use cases with a fully equipped 5G infrastructure. The example of 5G use cases is 5G-CU MegaSense and Video Analytics via CU Pop Bus and Smart Poles project of Chulalongkorn University. This project will connect PM2.5 pollution detection sensors to the campus bus and it will transfer data to a platform for real-time pollution analysis around the university.[16]

Furthermore, the private sector also has 5G trial project (Testbed) to develop their industries. For instance, the collaboration between AIS Group and the Siam cement group for 5G innovations trial in the industrial sector, the Collaboration of Khon Kaen University and the private sector, such as Charoen Pokphand Group, Siam Kubota Corporation Company, and TRUE Group to establish the True 5G World of Agriculture project for applying 5G technology to improve the potential of the agricultural sector.

However, Thailand has a low number of 5G trial projects and 5G testbed areas comparing to those in other countries. Moreover, 5G use cases are not widely adopted in various industries and areas in Thailand. Hence, the development of 5G city in Thailand in

[15] Source: OpenSignal: Benchmarking the 5G Experience Asia Pacific - June 2021

[16] Source: 5G-CU MegaSense and Video Analytics via CU Pop Buses and Smart Poles, Chula 5G

terms of both 5G network roll out and the adoption of 5G use cases in various industries needs to be continued.

1.4 Service Development of 5G Cities in Thailand

Smart City's Project	Status	Detail
VR Showroom The Loft Asoke	Commercially Launched	A VR Showroom for potential buyers to **enhance purchasing experience** that enables engagement with homes
Sansiri Smart Home	Commercially Launched	**A modern single house with full of technologies** in combination with Google Assistant
Pruksa LivingTech	Commercially Launched	A project that **combines nature and technology** with 4 factors for living: health tech, green tech, safety tech and smart tech.
5G-IoT lighting at Smart Samui	Testing	**Smart Lighting solutions on the NB-IoT network** that will help to increase confidence in safety of tourists and local people.
Rama 4 Model	Testing	**Advanced data-driven solutions** are used to to predict traffic patterns along Rama 4 road
Wangchan Valley Smart City	Testing	A new Smart City in 7 domains for **innovation and technology adoption** which is expected to open in 3Q2021
MR Sales Gallery	MoU Signing	A Mixed Reality Sales Gallery showing a "Complete Living Solution" where they can design and adjust the property
Phuket Smart City Data Platform	MoU Signing	7 Domains of Smart City by **utilizing the IoT to manage based on creating data platform.**

Figure 1-15: Service Development of 5G Cities in Thailand

Currently, Thailand has expanded its 5G network preparing for the development of a 5G city. It already rolled out 5G network in some main cities and began to test the application of 5G services. Most of the 5G trial was demonstrated in the testbed area from the cooperation of the government and the private sector including the telecommunication operators which support 5G network expansion in major cities such as

1. **5G-IoT Smart Lighting Samui Development Project** is the project from the collaboration of Koh Samui Municipality, AIS, and Lighting and Equipment Public Company Limited. 5G has been applied with digital technology such as IoT to make an innovative smart lighting service on public streets for improving the security of the city. In addition, Smart Pole that utilizes 5G technology will make it able to automatically turn the light on-off according to the weather and can have real-time data sharing from CCTV cameras to the control center leading to better security in the city.
2. **Rama4 Model Project** is the project from the cooperation of the Ministry of Transport, Grab Thailand, and Toyota Mobility Foundation in applying 5G technology to Big Data and AI for analysis, planning, and integration from existing data to manage transportation systems by using various measures to solve traffic problems on

Sathorn Road, such as traffic signal control optimization, reversible lanes, smart shuttle bus system, flexible working time, and park & ride measures.

3. **Wangchan Valley Smart City Project** is the project from the collaboration of the National Science and Technology Development Agency (NSTDA) and PTT Public Company Limited. They officially launched the 5G city promotion zone and the development of various 5G smart services which integrate digital technology and innovation to establish a 5G innovation ecosystem for developing the quality of people's life sustainably.
4. **Phuket Smart City Data Platform Project** is the project from the collaboration of the Digital Economy Promotion Agency (Depa) and Phuket City Development Company on the concept of developing Phuket City into a 5G city, including the idea of creating the service innovations by combining digital technology such as IoT, AI, and Robotics technology.

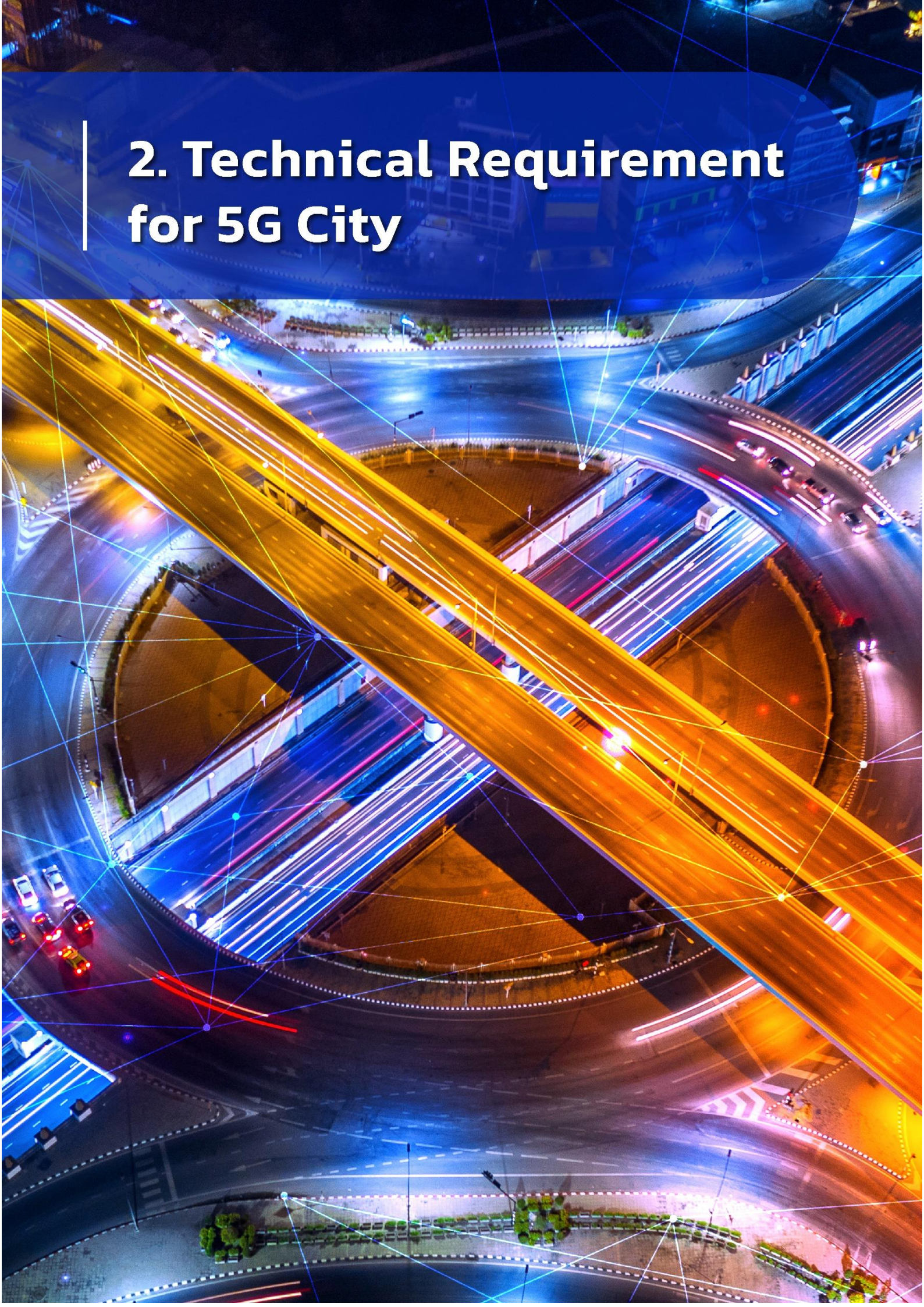
In the business sector, the company has participated in the 5G city development and started to utilize a 5G technology to initial various smart services in several areas. The project is supported by cooperation from both public and private sectors to create innovations from various technologies. The examples are

1. **MR Sales Gallery Project** is an innovation adopted in the real estate business that connects a real world with a virtual world by using Mixed Reality technology. This project is the collaboration between Sansiri Public Company Limited, Microsoft (Thailand), and AIS telecommunication operator by providing AR/VR technology via 5 G technology network to simulate the home environment. It will enhance customer’s experience to create a customized layout with the function of designing and modifying the sample room to meet the customer's requirement.
2. **VR Showroom the Loft Asoke Project** is the project of Cyberrex. It created a showroom to exhibit a sample residence with VR technology deploying through a 5G technology network to improve the customer's homebuying experience.
3. **Sansiri Smart Home Project** utilizes various technologies to create a smart home such as AI, and IoT. A smart home can be controlled by Sansiri Home Service Application with Google Assistant via 5G network giving more convenience for residents.
4. **Pruksa LivingTech Project** promotes the low energy consumption from the adoption of 5G technology. The projects also apply AI and IoT in the Solar Cell

System for wastewater treatment. In addition, Pruksa has developed security management by using door and window magnetic sensor systems with home automation control systems.

The mentioned project is simply the first stage of 5G city development. Overall, the number of 5G services that have been implemented in Thailand is still at a low level. As a result, the government sector, private sector, and other related organizations should be encouraged to develop both 5G technology infrastructure to be more efficient for supporting 5G services and enhance existing services to be 5G intelligent services under the promotion plan for becoming a 5G city.

2. Technical Requirement for 5G City



2. Technical Requirements for 5G City

As a 5G City is necessary to have a significant 5G network infrastructure coverage to provide high-speed connectivity and the ability to connect million devices.

As a result, Thailand's 5G City infrastructure must meet certain standards, such as architectural features that support novel intelligent applications and can provide high-quality 5G services to customers and companies. The important technologies, 5G network capabilities, and 5G technology development trends for the 5G City's infrastructure development are detailed below.

2.1 Infrastructure and Various Key Technologies of 5G City

5G City architecture will combine the concepts of cloud computing system (Cloud Concept) and data processing to generate high-speed results that are closest to the network speed, according to a case study of network characteristics requirements in Europe, where 5G cities are constantly being developed (Edge Concept). There are three stages to the 5G city architecture, which combines two principles and be divided into 3 tiers; 1) Computer Data Centers (DCs) 2) 5G City Multi-Access Edge Computing Nodes, which are access points for processing close to the source (Edge Computing) and will be the closest to the user, and 3) 5G City Small Cells, which are used to disseminate 5G signals across cities.

Furthermore, it can be separated into three layers based on the functional domains of 5G city architecture:

- **Service/ Application Layer** will enable the deployment of end-to-end services at both the individual user and business levels. This layer includes tools and functions that support and generate 5G City services, such as the 5G City Dashboard, which is the start of the 5G City system and includes a 5G city-data display and operation control center for delivering intelligent services to end-users via various technologies and infrastructures to benefit the public, private, and citizen sectors.
- **5G Networks & Technology Layer** is a critical component of the 5G City architecture. It will support 5G smart services in a 5G City to provide the highest level of efficiency to users in the public, private, and citizen sectors, as well as improving data management through related systems and technologies such as

the Cloud, database, and server, which include a variety of technologies that can enhance 5G service functionality more efficiently. Network slicing, edge computing, and big data as examples.

- **Infrastructure layer** is the foundation layer of a 5G City that must be built and developed to enable high-quality 5G services, including supporting various types of technology that will create a city connected to high efficiency on 5G technology and capable of implementing effective 5G services applications. Smart poles, base stations (Cell towers), and sensors are examples of infrastructures.

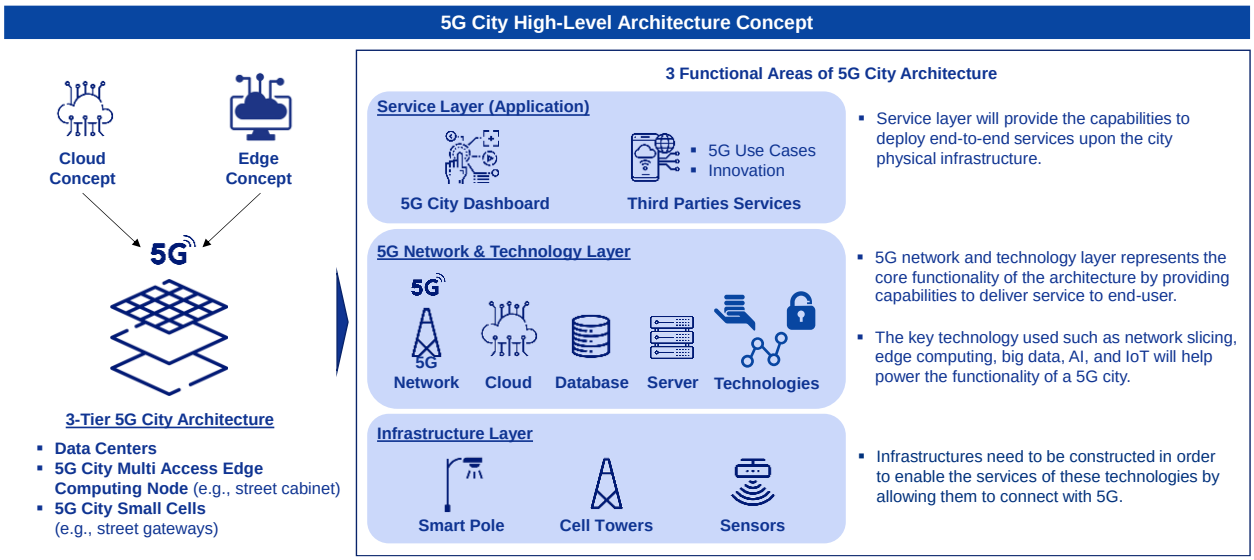


Figure 2-1: Concept of 5G Technology City Architecture

2.2 Technology Adoption in 5G City

As the research of 5G City architecture, it should be considered to apply Dual Giga architecture in combination with various technologies to increase the potential of 5G technology, which will lead to the enhancement of innovative services in 5G cities, driving the development of digital technology in Thailand.

The Adoption of Dual Giga 5G Technology City Architecture Concept

Thailand's 5G City will be more efficient as a result of the creation of the 5G City under the Dual Giga city architecture idea. **Dual Giga architecture is a high-speed communication network that can support high-speed broadband Internet with more than 1000 Megabits**

per second (Mbps) or 1 Gigabit per second (Gbps) in both Wireless and Wireline connections to enable seamless access for communications and services.

High-speed wireless internet via 5G technology and wireline broadband via fiber optic are provided by the Dual Giga city architecture. A Dual Giga architecture must be built in sufficient infrastructure, whether it is a signal tower for installing base stations, 5G base stations, 5G signal transmission points, or fiber optic cables inside the facility or public areas, for a developing city to become a 5G technology city, through the cooperation of mobile operators, technology solution providers, and entrepreneurs in the industrial sphere.

The use of Dual Giga architecture in the building of a 5G metropolis is an idea that has piqued the curiosity of other countries. According to China's concept of applying Dual Giga architecture city to the development of 5G city in 2021, the China's Ministry of Industry and Information Technology (MIIT) has released a Dual Gigabit Network development action plan (2021-2023) to develop the city under Dual Giga architectures concept in more than 20 major cities across the country, with three infrastructure development directions: 1) Infrastructure optimization, 2) Network quality enhancement, and 3) Service improvement are all things that need to be addressed. Furthermore, the following quantitative metrics for network capability evaluation have been considered in China's development plan: 1) Fiber optic network coverage, 2) 10 GPON ratio, 3) 5G network accessibility in a critical area, and 4) the number of 5G base stations per 10,000 people. [17]

Therefore, in China, the adoption of Dual Giga architecture to develop 5G cities can achieve the indicators in terms of the network capacity to be more complete.

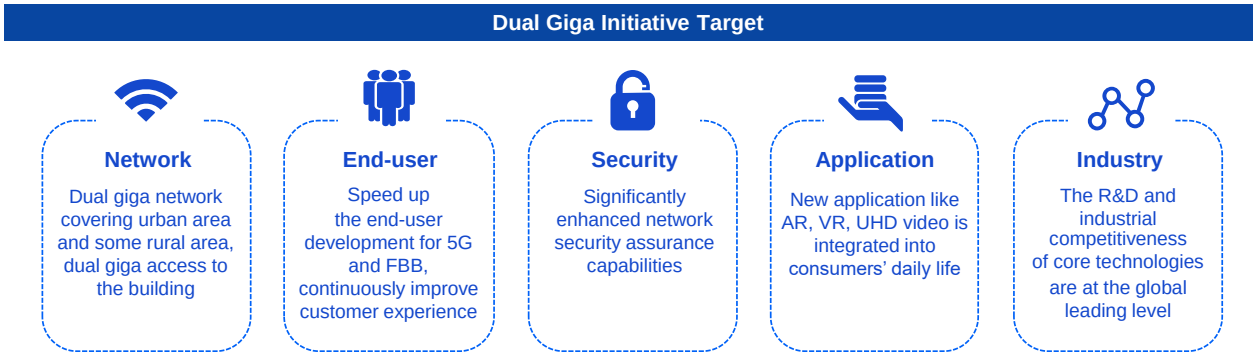


Figure 2-2: Development Dimension of Dual Giga City

[17] Source: China will build more than 20 gigabit cities by the end of 2021, Seetao (2021)

As a result, the development of 5G cities under Dual Giga city architecture concepts will improve the city's 5G services more comprehensively, including network quality, both wireless and wireline broadband, end-user customer experience, network security enhancements, and innovative applications and services that can develop at a high-quality level.

Furthermore, the high efficiency 5G networks will promote industrial research and development in order to contribute to future technologies and service usages.

The Adoption of Various Key Technologies in 5G City

It is necessary to rely on basic technologies for enhancing the potential of services in the city by combining 5G technology with various technologies to create more applications and increase new innovative services for promoting work in efficiency in a variety of industries, as well as to be a foundation of 5G city development by utilizing various key technologies.

For example, Network Slicing, Big Data, Artificial Intelligence, and Internet of Thing, which are details as below:

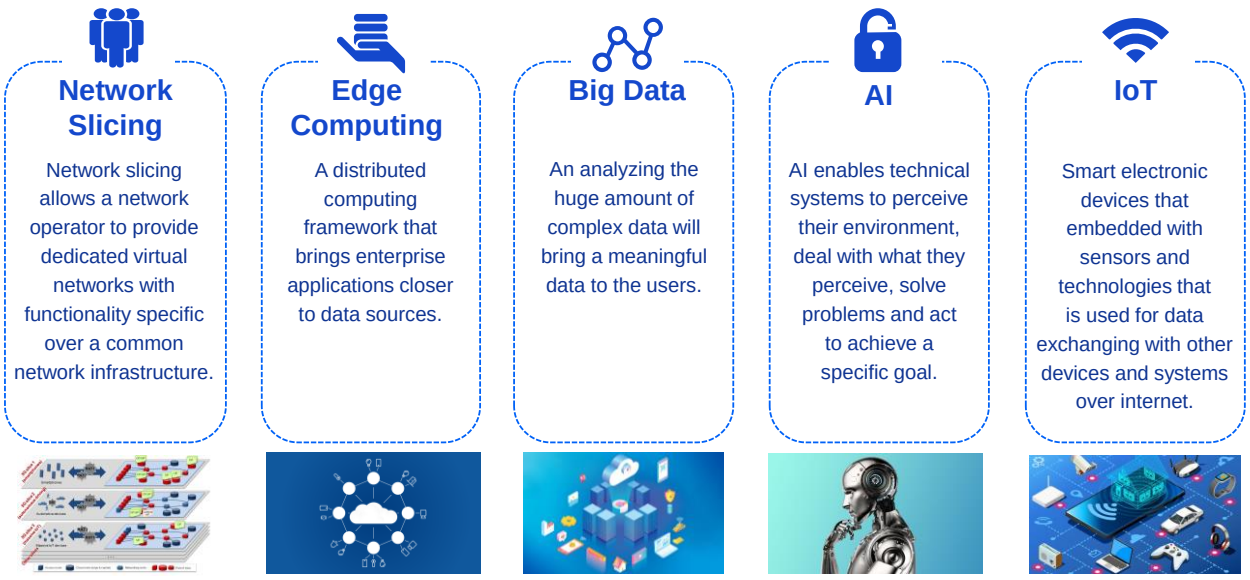


Figure 2-3: Key Technologies in 5G City

1. **Network Slicing**

Network slicing is a common 5G network architecture that enables the creation of virtual networks. Each network slice is isolated from the core network to create an end-to-end network that is tailored to the unique requirements of each application. It can provide in a variety of ways on a variety of parallel structures that the network slicing can categorize

resources and usage properties or customize network functions, in order to create independence for different application scenarios in each industry, providing the following benefits: 1) The network slicing can be used to configure a large broadband network for high-quality live broadcasts, 2) The public wireless networks accessibility through end-to-end networking It is capable of meeting the industry's requirements for high reliability and data privacy as example.

Network slicing facilitates the use of public networks in private network systems for industrial sectors, as well as the development of smart services in vertical industries. Additionally, it establishes a wholesale network service through which telecom-operators can sell sub-networks to corporate clients in order to develop new services, such as healthcare innovation for the establishment of eHealth services or media and entertainment for the use of OTT platforms.

2. **Edge Computing**

Edge computing is a data processing technology that is used to process data in the cloud system that is nearest to the data source in order to process huge amounts of data locally rather than moving them to the main network in order to save bandwidth and reduce data accessibility latency. For the entertainment industry's adoption of OTT platforms. The Edge Computing location can be on the IoT device or on a Local Area Network (LAN), such as a gateway device or central server. Using edge computing to provide services in smart cities results in lower operating costs and faster response times than uploading and processing data on a central server. Initially, data processing and display from various smart devices must be returned to the server, resulting in delayed data activities. Thus, 5G networks and the combined growth of other technologies such as big data, artificial intelligence, the Internet of Things, and cloud computing will aid in the creation of an innovative integrated system with edge computing, data gathering, and data storage, among others.

As a result, Edge Computing technology will enable the development of a highly efficient cloud service system and the potential for smart services to provide business services that require low latency, such as remote control, autonomous driving, and surveillance, as well as business services that require the ability to process large amounts of data, such as real-time video analysis and 4K live broadcasts with augmented and virtual reality technology.

3. **Big Data**

The term "big data technology" refers to the storage of a large amount of data in both detailed and diverse formats, as well as the use of that data to support decision-making through the use of technologies such as data science, artificial intelligence, machine learning, or other technologies that provide benefits in data analysis for the development of the smart city in various dimensions such as trade and economy (Smart Economy), tourism industry (Smart Tourism), public health (Smart Health), and life sciences (Smart Life) (Smart Living). By utilizing Internet of things technology such as sensors and CCTV cameras, smart city management intends to mix data from statistical surveys and real-time data collection.

Big data analytics have the advantages of collecting data and utilizing existing data to make judgments based on a realistic situation, including the use of past data to create forecasts. Additionally, it contributes to data processing and collection via Internet of Things (IoT) technology, which connects and exchanges data with devices and systems via the Internet or other communication networks in order to provide useful analysis results for the development of a smart city in a variety of dimensions, including trade and economics, tourism, public health, and quality of life. By analyzing detailed community data and utilizing sensors to collect data for decision-support purposes, such as collecting traffic survey statistics data to analyze the risk of accidents and traffic congestion management, autonomous vehicles that require high reliability to support artificial intelligence (AI) technology and can utilize Big Data to analyze the automated driving situation can be developed. Additionally, it can connect data between government departments and Open Data platforms to help cities run themselves better.

4. **Artificial Intelligence (AI technology)**

Artificial Intelligence (AI) is a branch of science concerned with developing machines capable of reasoning logically in the same way that humans do. The ability to comprehend knowledge, such as perception, learning, reasoning, and problem-solving, can assist in decision-making, problem-solving, and performing multiple tasks, such as imitating human actions via the process of learning from experience or a new modification via intelligent processing, and can automatically learn from the patterns and characteristics of the data, including the ability to analyze data according to the AI technology's objective.

Artificial intelligence technology is a critical component of the development of 5G cities and has been implemented in smart cities. For instance, the transportation sector is

leveraging AI to develop a time-adjustable traffic signal with real-time data that adapts to changing traffic conditions and optimizes parking finder systems. Additionally, it can assist police in searching for stolen vehicles that are linked to a criminal database. In public security management, the installation of a CCTV camera has been developed to utilize an AI system to detect criminals' faces and video surveillance connected to a control center to assist people in emergency situations immediately. In terms of energy, AI systems assist in managing an intelligent electricity system that can monitor and optimize energy consumption in real time. Additionally, it assists in determining the level of water usage in order to detect leaks.

Additionally, the healthcare sector can leverage AI technology to develop home appliances capable of communicating with the elderly via a computer and an Internet network, which can be used in conjunction with health monitoring devices such as a heart rate monitor and blood oxygen saturation level monitor, among others.

5. **Internet of Things (IoT technology)**

Internet of Things (IoT) technology devices are intelligent electronic devices that connect to the Internet and can communicate with other electronic devices in order to connect and transmit data. It utilizes RFID devices and sensors to create a Wireless Sensor Network (WSN) capable of detecting Physical Phenomena such as light, temperature, and pressure, among others. Additionally, it supports remote access, allowing users to manage and control their devices according to their specifications. The ability to connect a variety of devices enables the measurement and visualization of large amounts of data for analysis and decision-making, which when combined with Big Data technology enables instant analysis of large amounts of complex data.

IoT technology lays the groundwork for connecting devices or other objects to a communication network, including smart urban planning and developing a model for city management, for example: 1) Using a mobile application to control various home devices to improve resident convenience, such as smart lighting systems or automatic electrical equipment. 2) An integrated intelligent power distribution system that aids in the management of electricity consumption. 3) A networked system of city infrastructure, such as a networked traffic light system, through the development of sensors that detect vehicle movement rather than time counting. and 4) Vehicular communication systems (Vehicle-to-Vehicle: V2V), for example, when a vehicle brakes, the vehicle in front alerts the following vehicle for safety, and vehicle-to-infrastructure communication (Vehicle-to-Infrastructure: V2I), for example, a

traffic signal may alert the vehicle to avoid traffic congestion, which can improve transportation management.

2.3 The Capabilities and Key Performance Indicator of 5G Network

5G technology is comprised of several key features that fall into three broad categories: 1) Enhanced Mobile Broadband (eMBB), which has the potential for high-speed data transmission. 2) Massive Machine Type Communications (mMTC), which enables the establishment of large numbers of connections; and 3) Ultra-reliable and Low Latency Communications (URLLC), which enables the establishment of stable and responsive connections. To increase the capacity of the 5G network to be highly efficient, it is necessary to consider three critical factors.[18]

1. **Speed:** Broadband speeds are measured in Megabits per second (Mbps), and the ITU standard requires that 5G support speeds of up to 20 Gigabits per second (Gbps), significantly faster than 4G, which is limited to 1 Gbps. The actual speed usage may be reduced due to interference from other factors, but high-speed internet can meet the requirements for 5G network services in terms of data transmission efficiency.
2. **Availability:** the ability of the 5G signal to cover a large area (Wide Coverage) as measured by the percentage of the population in a target area (% Population Coverage), which is a preliminary criterion for demonstrating that the population can use the 5G network comprehensively in that area, including coverage indoors (Deep Coverage) that can penetrate through obstructions while 5G still have an efficient quality of its service.
3. **Latency:** A measure of network transition time required to transmit data across a network. It is expressed in milliseconds, abbreviated as ms. 5G networks can transmit data with a latency of 1ms, enabling uninterrupted service utilization, despite the fact that each service has varying latency requirements based on its usage.

The aforementioned factors necessitate the definition of clear key performance indicators (KPI) for the 5G network's capacity. A highly efficient 5G network will be critical for maximizing the potential of 5G intelligent services in a variety of fields via the following 5G Network KPIs in 5 as below:

[18] Source: Huawei

1. **Wide Coverage:** Through the use of 5G technology, the population in the area will be able to access a variety of smart services.
2. **Deep Coverage:** 5G networks can transmit signal through obstructions while maintaining network quality, such as indoor buildings, allowing users to access the network effectively regardless of their locations.
3. **Average Speed:** The average speed measured in real-world usage, considering the capability of data transmission at high speeds via a 5G network.
4. **Speed Satisfaction:** The speed at which users are satisfied in actual use is enabled by 5G networks, which can support data transmission services that require a faster network.
5. **Latency:** Low latency enables high-speed connectivity and rapid network response, which has a significant impact on the service potential of 5G networks that require stable data. transmission capabilities.

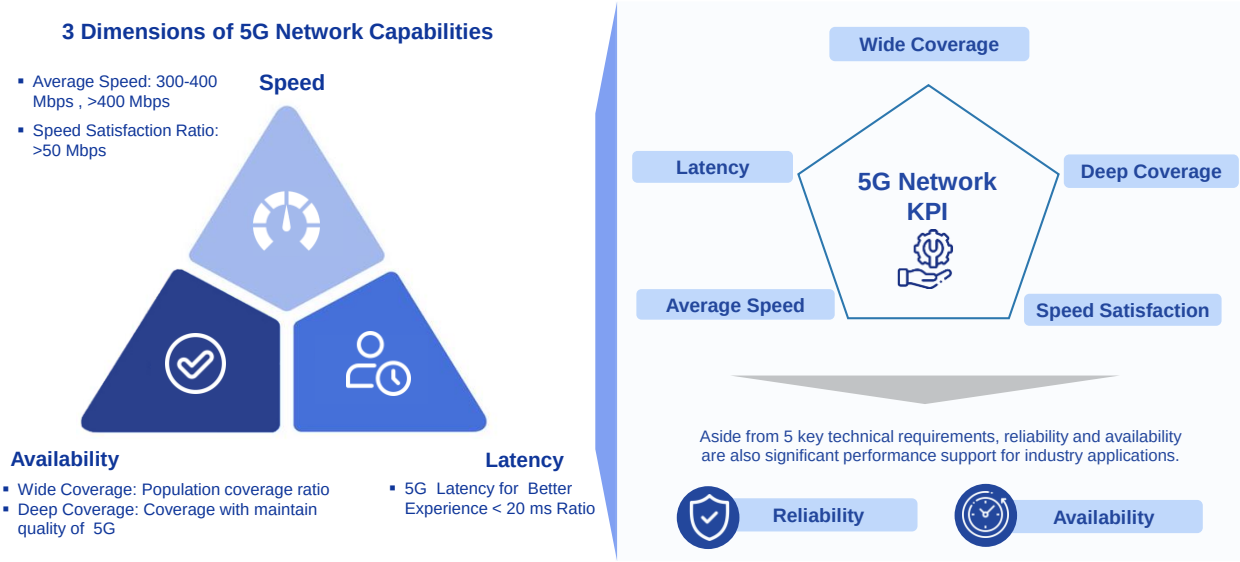


Figure 2-4: Capabilities and Key Performance Indicator of 5G Network

According to the three dimensions of 5G network capabilities and the KPIs that demonstrate the potential for an efficient 5G network, which includes the potential for high-speed data transmission (eMBB), the ability to support mass connections (mMTC), and the potential for stable and responsive connections (URLLC), as well as the performance of technology required in various contexts, it was associated with Reliability and Availability, which is a KPI. These indicators should be used to develop criteria for 5G networks that will apply to the appropriate technical requirements in each 5G service, enabling intelligent services in the 5G City to provide high-quality and efficient services in accordance with established standards.

2.4 5G Technology Development Trend

Currently, the demand for 5G technology is increasing, necessitating the continuous development of 5G technology. 5.5G technology was proposed to improve the evolution of 5G technology in order to maximize the potential of digital technology in order to create a more intelligent world. 5.5G technology's vision is to drive the development of the 5G industry by empowering and creating value for social development and industrial upgrading in various sectors. It has enhanced and expanded the International Telecommunication Union's three standard 5G scenarios (ITU) 1) Enhanced Mobile Broadband (eMBB), which offers the potential for high-speed data transmission; and 2) Massive Machine Type Communications (mMTC). a) the ability to support mass connectivity; and 3) the ability to extend Ultra-reliable and Low Latency Communications (URLLC) in six dimensions[19] for the purpose of optimizing the IoT connection and communication experience. The 5.5G technology enhances the following features in three dimensions:

1. **Uplink Centric Broadband Communication (UCBC):** will expedite the intelligent upgrade of industries built on 5G capabilities, as UCBC enables a tenfold increase in uplink bandwidth. This can be advantageous for manufacturers who require video uploads for machine vision and massive broadband IoT. Additionally, due to its increased coverage and uplink capacity, it can significantly improve the user experience with mobile phones in indoor scenarios.
2. **Real-Time Broadband Communication (RTBC):** will more efficiently deliver an immersive, true-to-life experience via XR technology and hologram services. RTBC can support high bandwidth and low communication latency, with the goal of providing a tenfold increase in bandwidth while maintaining a specified latency and level of reliability. By achieving these goals, the immersive experience for users interacting with the virtual world will be enhanced.
3. **Harmonized Communication and Sensing (HCS):** Increasing the efficiency of autonomous driving. HCS is intended to enable scenarios involving connected cars as well as connected drones. By applying Massive MIMO's beam scanning technology to the sensing domain, HCS can provide both communication and wide-area high-resolution sensing, allowing for more precise location services and thus increasing the safety of self-driving cars.

[19] Source: Defining 5.5G for a Better Intelligent World, Huawei (2020)

Along with enhancing the capabilities of the 5G technology mentioned previously, 5.5G technology will enable the development of innovative applications that expand the potential and add value to a variety of industries. It will take time to prepare the supporting policies and industry for the development of 5.5G technology, which is scheduled to arrive in 2025 and will enable the development of a more intelligent world. Additionally, the sub-100 GHz usage pattern needs to be restructured to maximize the spectrum's value, which includes the adoption of AI technology to enhance capabilities and complete integration with the 5.5G network to enable more efficient improvement, which will result in the development of the world's infinitely digital technology.

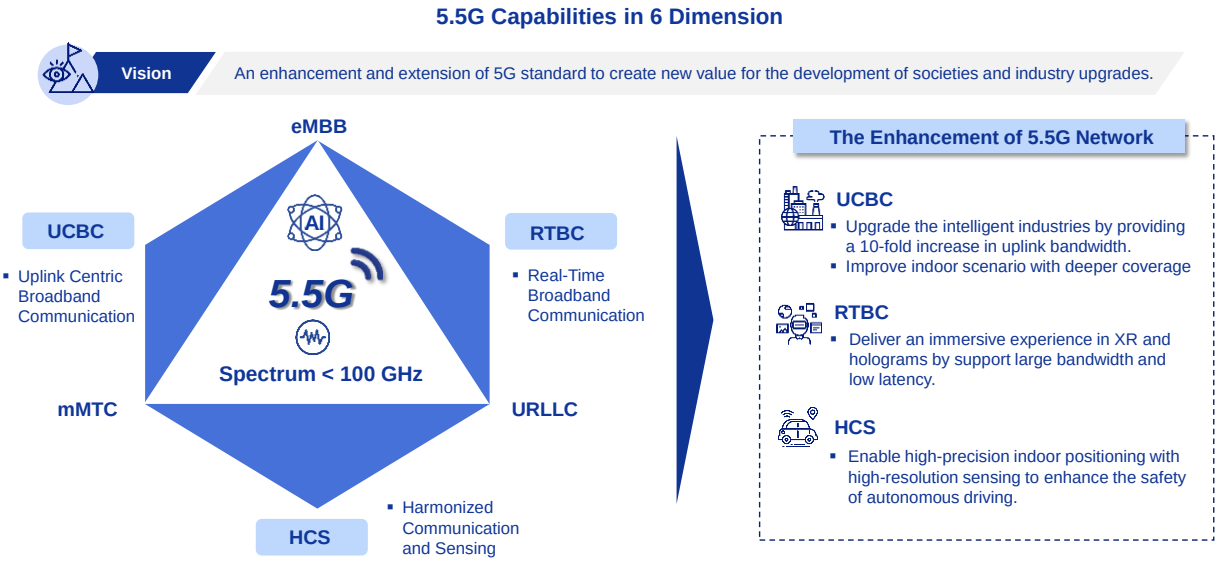


Figure 2-5: 5.5G Network Capabilities

3. Demanded 5G Services for 5G City in Thailand

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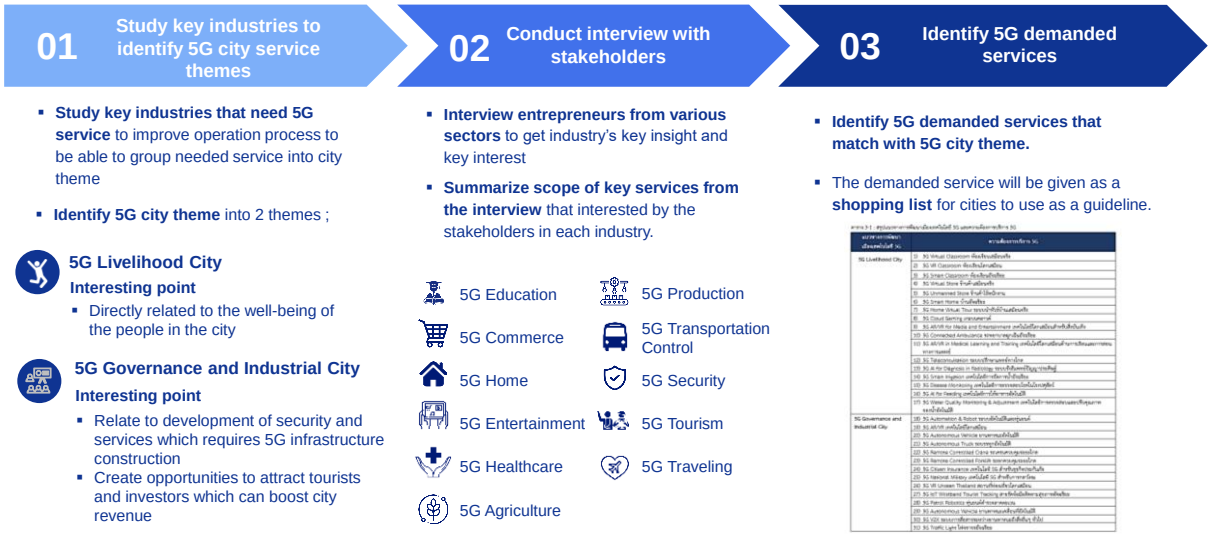


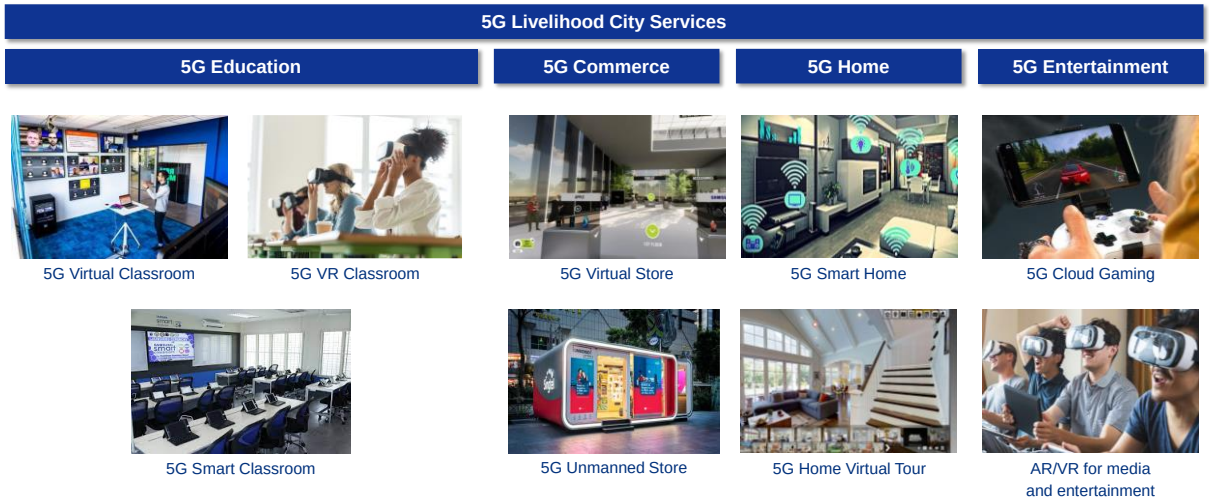
Figure 3-1: Methodology in Identifying Service Needed in 5G City

If various effective infrastructure advancements occur in 5G City, the city will be able to provide a variety of innovative services using the capabilities of 5G technology. As a result, there are three operational processes involved in identifying required services from a wide range of industries:

- **Study the industry to determine the appropriate development strategy for Thailand.** Starting with various industries across the country that have the potential and interest in utilizing 5G technology to improve operational efficiency and require cutting-edge technology to support demand in diverse ways. Afterward, using the obtained information to analyze the most suitable 5G city development plan for Thailand.
- **Interview entrepreneurs from a variety of industries.** After identifying the main potential industries and a suitable 5G city development model for Thailand, key companies in each industry were determined and interviewed to realize about current operations problems, interest in various technologies, and the application of 5G technology in business.
- **Determine the services considered by the business requirement.** The findings of the second step's interviews with enterprises were analyzed to identify the potential services that suitable for the 5G city's development plan. The services identified in this process will be served as models or recommendations for developing to be 5G cities in the future.

According to trend research and discussions with entrepreneurs from a wide range of industries in Thailand, there are several types of smart services that have attracted the interest of diverse stakeholders. The 5G City development models can be classified into two main categories: 1) The Development of 5G Livelihood City and 2) The Development of 5G Governance and Industrial City. The following are the service details for each 5G City development model:

3.1 The Development of 5G Livelihood City



Source: In-depth interview with representative from each industry

Figure 3-2: 5G Livelihood City Services (1)

Source: In-depth interview with representative from each industry

Figure 3-3: 5G Livelihood City Services (2)

The development of 5G Livelihood City is the establishment of services that focus on improving people's lives, both city dwellers and tourists, as well as industrial and commercial groups in the city, which covers service groups in terms of education (5G Education), commerce (5G Commerce), housing (5G Home), entertainment services (5G Entertainment), public health services (5G Healthcare), and agricultural services (5G Agriculture). **The following is a summary of the services that have attracted the interest of each service group, as considered by in-depth interviews with entrepreneurs and industry stakeholders:**

1. Educational Service Group (5G Education)

The education sector is the most important foundation of Thailand's development since it is a process that develops people to have the knowledge and the ability to adapt in the age of globalization. Technologies such as AR, VR, IoT, and Virtual Classroom have been applied with 5G technology to promote and integrate teaching and learning systems in the 4.0 era. Since the Covid-19 situation has affected the education sector, the ministry of education has rolled out online teaching and distance learning via the DLTV satellite system. Improving distance learning at all educational levels increases the technology requirements, according to a statement from the vice president of information departments in private universities

> *"Because the COVID crisis has accelerated distance learning and changing learning patterns, there should be effective technology to support an online feature that allows learners and teachers to communicate as if they were in a real classroom."*
>
> *Vice president of information departments in private universities*

From the interviews with personnel in the education sector and leading universities, founded that there are 3 interesting use cases to support teaching and learning system as follows:

Figure 3-4: 5G Education Use Cases

1) 5G Virtual Classroom: According to interviews with leading private universities, *"Thai education tends to utilize online learning in high demand and the education platform will be offered both online and offline in the future, depending on the suitability of the technology for each content."* Mahidol University has already begun testing services with 5G technology by using virtual classrooms and WebEx, which is a technology that enables teachers and students to communicate with each other on an online platform. The system testing starts in treatment planning for dental implant courses for dental students, which allows the student to ask a question and receive the answer in real-time, including a replay video system as if they were studying in the same room.

2) 5G VR Classroom: According to an interview with an agency in the Ministry of Education, it was said that "A use case that is suitable for applying 5G for educational development is an AR/VR classroom." The founder of the leading English language institute also added that "AR/VR is the next step in the adoption of 5G technology in the education sector." Moreover, leading universities have begun trial testing this service with 5G technology. For example, Chulalongkorn University has collaborated with the Office of the National Broadcasting and Telecommunication Commission (NBTC) in establishing the 5G IT/IOT Innovation Center to study and develop VR technology in the classroom (VR Classroom) with a two-year joint operating period for teaching and learning improvement.

3) 5G Smart Classroom: According to an interview with an agency in the Ministry of Education, it was said that *"Methods of traditional education that focus on assessment, this reduces learners' interest in intelligent learning. Intelligent learning should be planned and applied to create lifelong learning."* Prince Chulabhorn College of Medical Sciences has start trailing 5G Smart Classroom by using 5G technology and other related technologies to support smart classroom, which can increase teaching efficiency and support real-time practice to enhance education in medicine and health sciences in the future.

2. Commercial Service Group (5G Commerce)

Currently, Thailand's trade service sector has a continuous growth rate, especially in the electronic commerce business (E-Commerce) during 2016-2020, approximately 20 percent[20] due to rapid change in technology since the commercial service sector is the top industry facing the digital disruption since consumers are more likely to shop through online channels because there is a better communication channel between sellers and consumers.

[20] E-Commerce business, Electronic Transactions Development Agency (2020)

Many players in the commercial services sector have also shown interest and transformed their business models by adopting digital solutions to meet changing customer needs, according to supply chain managers of Thailand's leading wholesale and retail company that have used technology to improve sale efficiency.

From the interviews with personnel in the commerce sector, founded that there are two interesting use cases to increase efficiency in sale operation and management as follows:

Figure 3-5: 5G Commerce Use Cases

1) 5G Virtual Store: According to an interview with one of the distributors of clothing brands, "The retail and wholesale industries are trending to use 5G AR in the future." The adoption of AR or VR technology will provide more options for customers who want to shop online and try out products before purchasing. The Mall Group Company Limited is example of the main industry that has already adopted technology in their business, which has launched a virtual store platform on Monline.com to transform the traditional retail model into an omnichannel that holistically combine in unified marketing model.

2) 5G Unmanned Store: It's a use case for a smart store that requires network signal stability to connect all systems, which 5G will improve the efficiency of the smart store that uses various technologies such as AI, IoT, and Big Data, etc. According to interviews with major wholesalers and retailers in Thailand, "We have adopted the number-counting software with CCTV in every store to understand customer behavior and improve the store's operational processes, utilize sensors to automatically turn lights on and off in shopping malls to solve the problem of the toilet light that unavailable all time."

3. Housing Service Group (5G Home)

Currently, Thailand must adapt to maintain the competitiveness in the global economy by applying the internet of things (IoT), which is an important technology that will enable the

massive collection of various data types, linking and transmitting data via wireless internet to command and remote control more efficiently. For example, using applications or a voice user interface to control electrical systems, light, temperature, and security systems inside the house. Nowadays, people are tending to use smart devices in the home, which has developed the Smart Home project to enhance the quality of life by focusing on increasing convenience and safety in their lives. From an interview with managers of real estate companies with more than 50 years of experience in their business, smart home projects and the application of 5G technology will solve the problem of latency in the devices and forward into an aging society in Thailand, according to the Department of Mental Health of Thailand, "By 2021, Thailand will completely toward into an aging society with elderly people aged over 60 years more than 20 percent of the country's population[21]." Therefore, the adoption of IoT technology to command or control devices in the smart home will facilitate elderly care, including protecting assets and enhancing the safety of the elderly.

> *"Smart homes will become more popular in the next few years as people need convenience and security in their lives, which the adoption of 5G technology will meet the demands of real-time technology in the smart home."*
>
> *Managers of real estate companies with more than 50 years' experience*

From the interviews with personnel in the real-estate sector, founded that there are two interesting use cases to facilitate residents and support overall real estate industry as follows:

Figure 3-6: 5G Home Use Cases

[21] Source: Elderly Society of Thailand, Department of Mental Health (2020)

1) 5G Smart Home: According to an interview with a mid-sized real estate operator, it was said that *"We have plans to invest in 5G technology for more stable control of smart home systems and real-time data transmission."* Big real estate has also deployed smart home projects **by using technology to develop smart homes** in four aspects: health, environment, safety, and convenience. For example, developing **a smart home with a voice control system via Google Assistant by connecting to smart home devices with AI and IoT technology** to adjust the temperature of the air conditioner. Furthermore, several devices can be controlled simultaneously, such as turning on/off lights and vacuum cleaners, as well as using voice commands to monitor the CCTV camera in the garage.

2) 5G Home Virtual Tour: According to an interview with a mid-sized real estate operator, it was said that *"5G will enable web-based virtual tours to transmit massive of data, such as videos and information about each project's homes more efficiently."* Several real estate companies have already begun to adopt this service in their business. For example, Sammakorn Company Limited has a virtual tour on their website that allows customers to preview the home tour online in a 360-degree virtual environment that can be accessed from anywhere and anytime. In addition, there is staff to assist and answer queries in real time that customers will be able to see the actual rooms inside the project in a 360-degree view of all detail through **a virtual tour on the One Click New Home platform, which can enhance the experience of visiting and booking real estate in the AP group.**

4. Entertainment Service Group (5G Entertainment)

The rapid advancement of technology has a significant impact on Thailand's entertainment services. Thailand spends up to 40% of total internet time on live broadcasts and streaming, as shown in statistics data, with an average daily internet usage of 8 hours 44 minutes and an average daily viewing of broadcasts and streaming of 3 hours and 30 minutes.[22] According to an interview with a former director of a leading Thai movie production company, AR (Augmented Reality) and VR (Virtual Reality) technologies have been introduced for media consumption in the present. However, these technologies have limitations in terms of bandwidth for data transmission, the adoption of 5G technology will provide users with an immersive viewing experience more efficiently.

[22] Source: Market research, OTT Ovum (2021)

Moreover, gaming is also an important activity in the entertainment industry since Thailand has 41% of the total active gamers and 71% of gamers play via mobile/tablet[23]. Nowadays, cloud gaming technology will enable gamers to meet their requirements by being able to play high-quality graphics games via smartphones in real-time without downloading or purchasing high-quality computers.

> *"Virtual reality is a technology that enables viewers to have interesting experiences, especially fantasy movies, ghost movies and horror movies."*
>
> *Former director of a leading film production company in Thailand*

From the interviews with leading company in entertainment sector, founded that there are two interesting use cases to increase the efficiency of data transmission for entertainment services as follows:

Figure 3-7: 5G Entertainment Use Cases

1) AR/VR for media and entertainment: According to an interview with the executive chairman of a content agency, it was said that *"VR is a technology suitable for video content such as travel and game streaming content, and idol shows, while AR is suitable for content marketing applications."*, which can enhance the experience for viewers. **The adoption of 5G technology will allow data transmission to be faster and be able to transmit large amounts of data with high resolution data.**

2) 5G Cloud Gaming: According to an interview with the executive chairman of a game development company, it was said that *"Nowadays, consumers are in great demand and expect cloud service providers or cloud gaming to provide services in Thailand and also bring*

[23] Source: Number of gamers in Thailand, We are social (2019)

high-performance games for users as well." **The cloud technology will allow consumers to be able access to high-performance games without purchasing an expensive equipment.**

5. Healthcare Service Group (5G Healthcare)

Public health or medical services require high-precision services that are directly related to the lives of people. Therefore, modern technology has been used significantly in public health services because technology can enable and facilitate healthcare personnel to perform their duties more efficiently. At present, leading hospitals in both the public and private sectors have introduced technology to improve the efficiency of disease treatment operation, according to the executive assistant of leading private hospital.

> *"We provide telemedicine services, smart ambulances, and autonomous robots to observe diseases and treatment for patient."*
>
> *Executive assistant of leading private hospital*

5G technology is an important factor in improving the potential of various technologies currently supported by 4G technology. Most hospitals are becoming more adoptive of technology in their medical operations. Moreover, Statista and Newsweek collaborated in 2020 to rank the best hospitals in each country based on an in-depth interview with medical professionals, patient surveys, and key medical efficacy indicators as criteria.

From the interviews with agencies in the public health sector and leading hospitals, founded that there are four interesting use cases to support medical services as follows:

Figure 3-8: 5G Healthcare Use Cases

1) 5G Connected Ambulance: Due to the epidemic situation of COVID-19, the Department of Medical Services is aware of the safety of medical personnel and patients to prevent the spread of the virus in the hospitals. The adjustment of the emergency room (ER New Normal) has been proposed and implemented through the 5G MedTech ambulance project, which is a smart emergency ambulance that adopts medical technology and

innovations through the 5G network that can enhance the distance communication between doctors in ambulance and specialists for receiving additional diagnoses to improve the accuracy of patient treatment. In addition, leading private hospitals are also interested in this service, as stated in the interview, *"Our hospital has deployed smart ambulances and we are interested in the adoption of 5G technology to increase the efficiency of the smart ambulance."*

2) 5G AR/VR in Medical Learning and Training: According to an interview with the government organization responsible for the country's public health sector, "*AR and VR would be extremely beneficial in training medical students."* As a result, it is necessary to integrate augmented reality and virtual reality technology into the education of medical students, allowing them to gain an understanding and visualization of the body and organs in more detail.

3) 5G Teleconsultation: Teleconsultation is being used in a variety of healthcare settings as a result of the COVID-19 outbreak. It enables patients to communicate with their doctors in real time, increasing their efficiency and treatment options, which helps save cost and travel time as well as reducing the risk of contracting COVID-19. According to an interview with the director of a medical start-up, "5G is a technology that has the potential to expand the utilization of telemedicine and enable real-time monitoring of symptoms," including improving accessibility to medical services in rural areas as well.

4) 5G AI for Diagnosis in Radiology: According to an interview with the CEO of a leading private hospital that has been in existence for more than 42 years, "Using 5G Technology is very useful for improving accessibility rate of fast diagnosis in areas where fibre optic cables cannot be routed." For example, the usage of CT scans of the lungs on 5G networks to assist hospital medical services that can optimize the data transmission to deliver pictures of the lungs larger than 300 MB in size to be processed promptly. This decreases the working time of healthcare personnel from one hour to 30 seconds.

6. Agricultural Service Group (5G Agriculture)

The agricultural sector plays an important role in Thailand's economy, but in the past, the competitiveness of Thai agricultural products continued to deteriorate. Farmers' occupation is mainly for subsistence and lack of business processes. Agricultural development is therefore an important goal to continuously promote economic growth with the idea of applying technology and innovation to help develop agricultural potential, responding to the entry into Agriculture 4.0, enhancing knowledge and understanding, creating added value to produce products with standard quality as well as increasing competitiveness for sustainable business growth.

> *"IoT and AI technology can assist farmers in monitoring their farm environments, tracking and forecasting animal diseases to reduce losses and disease spread problems."*
>
> *Deputy Managing Director of Thailand's leading agro-industrial and food business*

From the interviews with leading agricultural agencies and agribusiness companies, founded that there are four interesting use cases to increase the efficiency of agricultural business operation as follows:

Figure 3-9: 5G Agriculture Use Cases

1) 5G Smart Irrigation: Currently, Thailand has introduced 5G technology to develop a pilot project for smart irrigation management due to a royal initiative at Huai Khlai Reservoir, Udon Thani Province, in collaboration with the Pidthong Lang Phra Foundation, since **during the dry season, there is a problem that the amount of water storage is insufficient for using including some areas unable to deliver water. Therefore, the idea was to extend the water management service.** Originally, the water flow was controlled by opening and closing the valve by hand, which relied on taking weekly human water stats that caused high data discrepancies and took up a lot of storage time. According to an interview with a committee from a government organization, ***"5G technology will help manage the***

continuous use of water for consumption and agriculture in every season and will reduce the burden of the water user committee." Therefore, the development concept was born using IoT technology to install various sensors, including using Machine Learning and Cloud Computing technologies to develop a digital water meter system, water flow detection system and electronic valve system will make it possible to collect data on water usage. as well as remote command equipment, making it possible to predict the amount of water to be used to allocate water effectively. This will increase the capacity of the water management control center, leading to a model for the development of community irrigation systems and other agricultural projects.

2) 5G Disease Monitoring: According to an interview with an agro-industry business leader, ***"IoT and AI are technologies that assist farmers in monitoring their farm environment and animal health," since farmers who cultivate crops, livestock, and aquaculture sometimes face epidemics that result in massive losses."*** Therefore, the idea was to use technology to help with farm management. For example, the CPF AI FarmLab Powered by Sertis project through the cooperation of the agro-industry company CPF and Sertis company in the development by defining the raising, selling, and housing area within the farm as a separate zone including establishing operational measures in each area by not allowing employees to enter unauthorized areas to prevent the problem of infection and the spread of epidemic disease in the farm by developing a surveillance system through CCTV installation in the area. Moreover, AI technology can be used to detect and analyze data, which will notify the relevant personnel if employees are found roaming in unauthorized areas, enables the farm owner to check historical statistics that are collected in a database displayed on the dashboard to analyze the cause of the problem and improve operations to achieve maximum security to transform into a smart farm development.

3) 5G AI For Feeding: Currently, Thailand has developed the project "Virtual Hackathon by 42 Bangkok X CPF", which has a leading agribusiness company, CPF, cooperate with the Computer Programming Institute to develop the concept of a smart shrimp farm. From an interview with an agro-industry business leader, *"To increase the efficiency and effectiveness of shrimp farming, water, and food monitoring, AI is needed for shrimp farming."* **As farmers are unsure of the appropriate amount of feed for livestock and aquaculture, AI technology was introduced to increase feeding efficiency** by analyzing data collection and making accurate recommendations on required mineral and food intake, as well as estimating the size and weight of animals to help reduce excess waste and costs associated

with overfeeding. This results in cost savings and improved production quality, resulting in more efficient agriculture.

4）5G Water Quality Monitoring & Adjustment: According to an interview with the director of the technology research organization, "Using technology will be beneficial in terms of increasing productivity, reducing costs, and raising agricultural standards that will lead the agricultural sector into the Thailand 4.0 concept." Currently, Thailand has developed the NECTEC FARM series project through the cooperation of NSTDA and the National Electronics and Computer Technology Center, since farmers often face environmental problems that negatively affect aquatic ecosystems such as PH value, oxygen level, and the turbidity of the water including other factors that affect aquaculture. Therefore, AI technology is used to analyze data, including installing sensors to monitor water quality, the amount of oxygen, pesticide residues, and pH conditions to develop the Aqua Grow system, which is an intelligent system that helps farmers monitor water quality in economic aquaculture. It records and collects data in real-time to analyze and provide advice on preliminary pond conditions for farmers. At the same time, the farmer can track the information to manage the farm conveniently via smartphone by focusing on good production management planning, both in terms of the amount of production that comes to the market and reducing production costs.

3.2 The Development of 5G Governance and Industrial City

Figure 3-10: 5G Governance and Industrial City (1)

Figure 3-11: 5G Governance and Industrial City (2)

The development of 5G Governance and Industrial Services is the development of services related to city government and industrial business in various fields. It covers service groups related to the development of government security services, industrial business, and the tourism business, which are the core of driving Thailand's economy sustainably. It includes services such as Production Services (5G Production), Transportation Control Services (5G Transportation Control), Security Services (5G Security), Tourism Services (5G Tourism) and Transportation Services (5G Traveling). **According to in-depth interviews with entrepreneurs and comparative analysis of foreign countries, it can be summarized that the interesting services to each service group are as follows:**

1. Production Service Group (5G Production)

Nowadays, the industrial sector plays a significant role in Thailand's economic growth due to the percentage of industrial output value to total domestic product and industrial product export value to total export value. The rate of expansion has accelerated, particularly for industrial items requiring medium to high technology. However, a significant percentage of imports of parts, components, capital, and technology are also necessary, demonstrating that production in this industry continues to rely primarily on the benefits of utilizing unskilled labor, low wages, and capital.

> *"5G technology is the infrastructure needed to prepare for Industry 4.0."*
>
> *Director of an independent institute of the Ministry of Industry*

From the Thailand 4.0 model, the economy must be restructured from being driven by the development of efficiency in industrial production, towards an economy driven by technology and innovation with smart manufacturing development. The Ministry of Industry has proposed a proposal for 10 targeted industries, which is a mechanism to drive the economy under the concept that Thailand can drive economic growth (S-Curve) in two types: 1) Five industries with potential (First S-Curve) consist of the intelligent electronics industry, the good income tourism industry and health tourism, agro-industry and biotechnology, the food processing industry, and the modern automotive industry. 2) Five future industries (New S-Curve) consist of the integrated medical industry, logistics and aviation industry, digital industry, biofuels and biochemical industries, and industrial robots.[24]

From interviews with those involved in the manufacturing industry both government agencies industrial operators and SI service providers founded that there are three interesting use cases in production sector as follows:

[24] 10 Targeted industries, Office of Industrial Economics (2017)

Figure 3-12: 5G Production Use Cases

1) 5G Automation & Robot: At present, many industrial factories in Thailand have adopted automation systems, automatic machines, and industrial robots to be used to increase production efficiency, especially in the automotive and electronics industry. The interviews with operators shown that the connection of these machines or equipment using a wired connection hinders manufacturing plants that require flexibility in production. An interview with an entrepreneur in the electronics industry said that *"The company is more interested in using a wireless connection than a wired one because it is more convenient to change the production line but at present, there are still problems with stability. If 5G comes in, it will answer this question."*

2) 5G AR/VR: Currently, the utilization of AR/VR technology in the manufacturing business in Thailand is not widespread, but it has begun to be adopted in other countries, such as for maintenance production line simulation or even employee training. According to interviews with production agencies, *"connecting with 5G is a necessity for AR/VR applications, but what we are currently lacking in the creation of AR/VR applications in industry are technological developers."*

3) 5G Autonomous Vehicle: According to interviews with technology and industry research companies in Thailand, "5G would reduce the cost of AGVs by allowing processors to be relocated from embedded AGVs to the cloud and then returned with low latency." 5G technology is being used to control and operate AGVs (Automated Guided Vehicles), which significantly improves factory efficiency.

2. Transportation Control Service Group (5G Transportation Control)

The transport sector is critical to the Thai economy because transportation is a part of every value chain, particularly in freight forwarding. Fast and secure shipment is essential to product quality, as well as any associated costs and expenses. As a result, improving the

quality of transportation will inevitably increase the economy's competitiveness, which will utilize cutting-edge technology to reduce costs. According to regional managers of Thailand's leading transport companies,

> *"Transportation technology will be used more widely in the logistics industry due to an increase in labor costs."*
>
> *Regional managers of Thailand's leading transport company*

From interviews with personnel in leading transport and logistics companies founded that there are four interesting use cases in the adoption of 5G technology to support processes in the logistics industry sector as follows:

Figure 3-13: 5G Transportation Control Use Cases

1) 5G Autonomous Truck: Currently, Singapore has already developed the technologies that enable autonomous vehicles and transport connections. As a result, it shows an opportunity to increase efficiency in both the port and truck delivery industries. In the future, Thailand sees the importance of adopting such technology. This technology for self-driving trucks and trains will become even more influential in the market. Although self-driving trucks are difficult to develop, in the long run they can solve problems in the logistics industry, such as preventing accidents since the self-driving car uses light detection and remote sensing technology to connect to the steering and brake systems to avoid obstacles. and help to solve the shortage of long-distance drivers, etc.

2) 5G Remote Controlled Crane: Nowadays, Thailand has begun to test the application of 5G technology in the port business, which allows operators to **remotely control container cranes via a 5G network** at Hutchison Port Thailand Terminal, Laem Chabang Port, Sriracha District, Chonburi Province. This will play an important role in helping management of transport cargo in commercial ports to be more efficient. It is one of the digital infrastructure

development projects and this 5G technology has contributed to **supporting the Eastern Economic Corridor Project (EEC) in pushing Laem Chabang Port to be the gateway of Thailand and is the center of logistics for trade and investment in ASEAN countries in the future.**

3) 5G Remote Controlled Forklift: At the present, Thailand is in the process of developing a long-distance forklift with 5G technology in a factory in Saraburi by bringing a 5G network that is fast to respond in real-time and the transmission accuracy required for advanced automation. This benefits in terms of productivity because employees can control the car from anywhere. Therefore, it is considered a model for various industries in Thailand to be applied further.

3. Security Service Group (5G Security)

Currently, the government sector is accelerating the development and initiating the adoption of 5G technology in services to improve national security and people's safety, which can be divided into three services as follows:

Figure 3-14: 5G Security Use Cases

1) 5G Citizen Insurance: The safety of people's lives is crucial from the current situation of the COVID-19 epidemic the health insurance business is another important help in protecting the safety of people's lives. The Insurance Commissioner (OIC) revealed that *"5G technology will play a greater role in the New Normal lifestyle, especially in the insurance business where 5G technology will be involved from the beginning to the end of the process resulting in driving various industries to have to adjust from the process of developing insurance products and issuing insurance policies to customers"*[25] **Whereas 5G technology will increase the use of measuring devices such as sensor systems, GPS systems, and**

[25] Source: Prachachat Business, 5G technology and the Thai insurance industry (2020)

various IoT devices that receive a greater amount of data all the time at a much lower cost, allowing information about the customer's risks and protection needs to be quickly transmitted to the insurance company. Therefore, **insurance firms may evaluate and create solutions that are precisely tailored to the demands of their clients, and they can do it more rapidly and automatically.**

2) 5G National Military: The security of the nation is the primary duty of the Ministry of Defense, which is responsible for protecting the nation from various international threats. 5G technology is considered another important aid in driving the country's defense operations, such as **robotic pilots, robot warships, and small unmanned aircraft. It is already deployed in the United States, which 5G technology can improve the operation more precisely and more quickly.** As a result, territorial preservation and national security protection can be carried out more efficiently.

3) 5G Patrol Robotics: From the interview with the board of the Thai Tourism Association, it is said that *"Welcome robots will be used to optimize hospitality services and create a better customer experience."* Currently, the tourism sector in Thailand has several companies that are using robots during the COVID-19 outbreak by applying robots to 5G technology to provide hygiene services for hotels and retail businesses which consists of robots that help measure temperature and screen people at risk of COVID-19 (Temi Thermal ScanBot), security robots that help inspect indoor and outdoor areas (PatrolBot), and smart robots that help maintain cleanliness in the area. area (HygienicBot).

4. Tourism Service Group (5G Tourism)

The changing trend of technology and government policy on Thailand 4.0 and marketing 4.0 affects the policy of the tourism industry in Thailand to tourism that emphasizes innovation, technology, and creativity in tourism management. As a result, entrepreneurs are increasingly using technology in tourism, such as AR/VR for tourism, the application that combines all travel activities in one app, and robots to welcome in hotels, etc. There is also a group of tourists called So Lo Mo, which comes from the words "social, location, and mobile phone," that use technology to travel by themselves. This makes accessing information

convenient and fast. Therefore, the Thai tourism sector has grown more and more continuously.

> *"In the future, the Thai tourism sector will expand and entrepreneurs will use more technology in tourism business, especially AR/VR, a platform that integrates all-in-one attractions and welcome robots in the hotel business."*
>
> *Board of Directors of the Association of Tourism*

From interviews with personnel of agencies in the tourism sector two interesting use cases were found to support the tourism industry as follows:

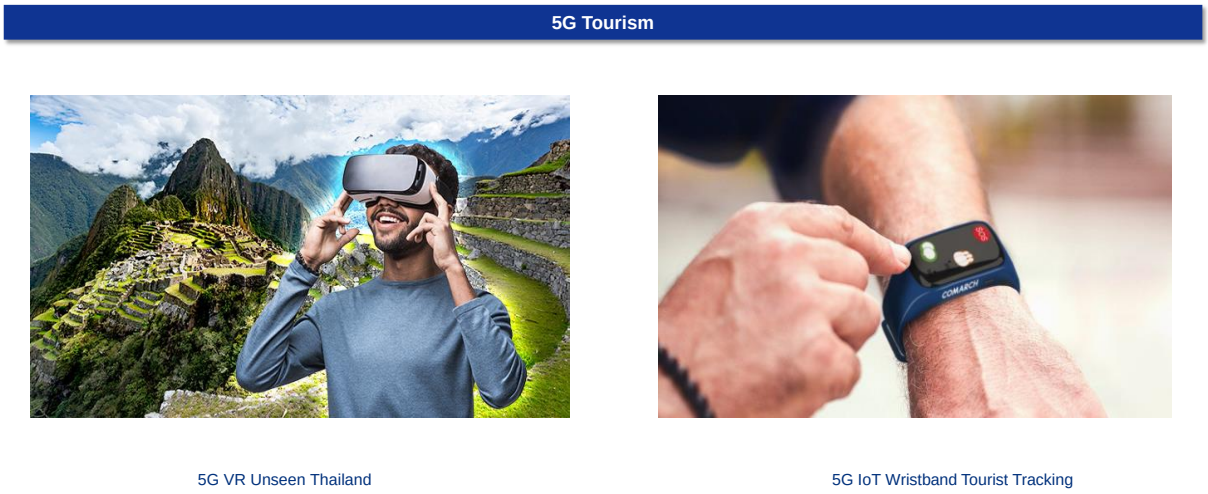


Figure 3-15: 5G Tourism Use Cases

1) 5G VR Unseen Thailand: From an interview with a travel agency that has been in business for more than 20 years, *"Using AR/VR technology in tourism will encourage tourism to recover faster after travel restrictions have been eased."* At present, AIS is collaborating with the Tourism Authority of Thailand to **bring 5G and VR technologies to create a new way of travel experience for tourists to attract both Thai and foreign tourists.** This will help stimulate tourism income, which is an important factor in driving Thailand's economy. In addition, **the technology is used to demonstrate virtual environment of rooms and various locations within the hotel to help customers for booking decisions.** According to interviews with executives of large hotels that have branches both in Thailand and abroad, said "The company plans to apply 5G technology to VR technology for virtual room bookings to create a unique experience for customers after the COVID-19 epidemic improves.

2) 5G IoT Wristband Tourist Tracking: An innovative smart health wristband platform is used in the Digital Yacht Quarantine project in Phuket, where the wristband will track health data including body temperature, heart rate, and pulse signal, including the location of tourists. The information will be forwarded to doctors and relevant authorities for analysis of the traveler's health risks in real-time during the 14-day quarantine on board before coming to Thailand.

5. Travel Service Group (5G Traveling)

Traveling by car, bicycle, or footpath is a daily action that all humans need. At the present, 5G technology is contributing to the development of a more efficient and secure way of living, which can be divided into three categories:

Figure 3-16: 5G Traveling Use Cases

1) 5G Autonomous Vehicle: Self-driving cars are the introduction of technology and innovation to change the way people's lives. **The operation of an autonomous vehicle consists of a key device, computer vision** that allows the car to perceive its surroundings using surround-view camera technology, laser, and radar as well as a navigation system to analyze various environments. **Then processed at the central processing unit (Deep Learning) with AI technology, which requires the shortest time for analysis to send commands to the robotic control system with precision** so that the autonomous vehicle can work in the safest and most efficient way.

2) 5G V2X: V2X or Vehicle-to-everything is a system that uses 5G communication from the car to exchange information between each other back and forth so that the car and the device that communicates with each other can know each other's information to notify and prepare for an incident that will happen within a fraction of a second. V2X can connect to **1) Vehicle-to-Vehicle (V2V) communication system in which each vehicle collects driving data** such as speed level, vehicle position, driver's brake pressure level, etc. to enhance driving safety. **2) Vehicle-to-Infrastructure (V2I) is a system that exchanges data between vehicles**

and infrastructure devices such as surveillance cameras, traffic lights, and traffic lines located on opposite sides of the road. **3) A vehicle-to-pedestrian (V2P) communication system between vehicles and pedestrians** that aids in the reduction of traffic accidents. **4) Vehicle-to-Network (V2N) system for exchanging data between a car and a large network** by linking data from the vehicle and transferring it to a data center to process journeys for the passenger to arrive on time.

3) 5G Traffic Light: Smart Traffic Light is a **camera integration that uses computer vision processing to scan the crossing area to see if anyone is crossing the road. When pedestrians are in the proper position at the crosswalk to cross the road, the AI system analyzes and evaluates the trend of crossing** intentions before sending a signal to the traffic lights. **The Smart Traffic Light system is also regarded as an important aid in reducing accidents for commuters.**

3.3 Summary of Guidelines for the Development of Services in 5G City

Services in 5G City

From the study of the demand for services in Thailand's 5G City, it was found that service groups can be divided into two categories: 1) The Development of 5G Livelihood Cities, and 2) The Development of 5G Governance and Industrial Cities. There are 31 services of demand from various sectors in the 5G City development in different areas of Thailand, the details of which can be summarized as follows:

Table 3-1 : Summary of 5G City Development Guidelines

Guidelines for the Development of 5G City	5G Service Requirements
5G Livelihood City	1) 5G Virtual Classroom
	2) 5G VR Classroom
	3) 5G Smart Classroom
	4) 5G Virtual Store
	5) 5G Unmanned Store
	6) 5G Smart Home
	7) 5G Home Virtual Tour
	8) 5G Cloud Gaming
	9) 5G AR/VR for Media and Entertainment
	10) 5G Connected Ambulance
	11) 5G AR/VR in Medical Learning and Training

Guidelines for the Development of 5G City	5G Service Requirements
	12) 5G Teleconsultation
	13) 5G AI for Diagnosis in Radiology
	14) 5G Smart Irrigation
	15) 5G Disease Monitoring
	16) 5G AI for Feeding
	17) 5G Water Quality Monitoring & Adjustment
5G Governance and Industrial City	18) 5G Automation & Robot
	19) 5G AR/VR
	20) 5G Autonomous Vehicle
	21) 5G Autonomous Truck
	22) 5G Remote Controlled Crane
	23) 5G Remote Controlled Forklift
	24) 5G Citizen Insurance
	25) 5G National Military
	26) 5G VR Unseen Thailand
	27) 5G IoT Wristband Tourist Tracking
	28) 5G Patrol Robotics
	29) 5G Autonomous Vehicle
	30) 5G V2X
	31) 5G Traffic Light

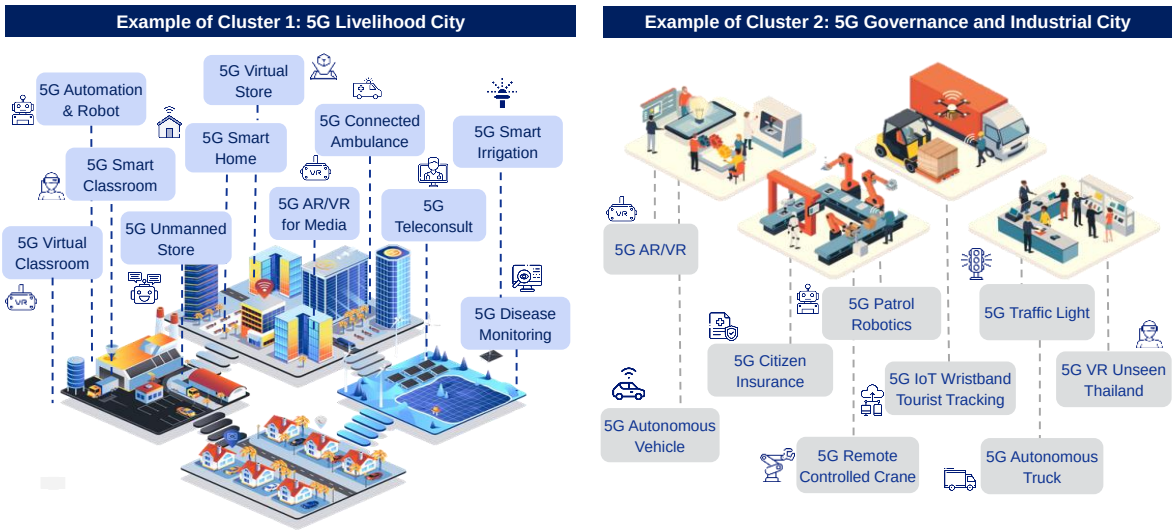
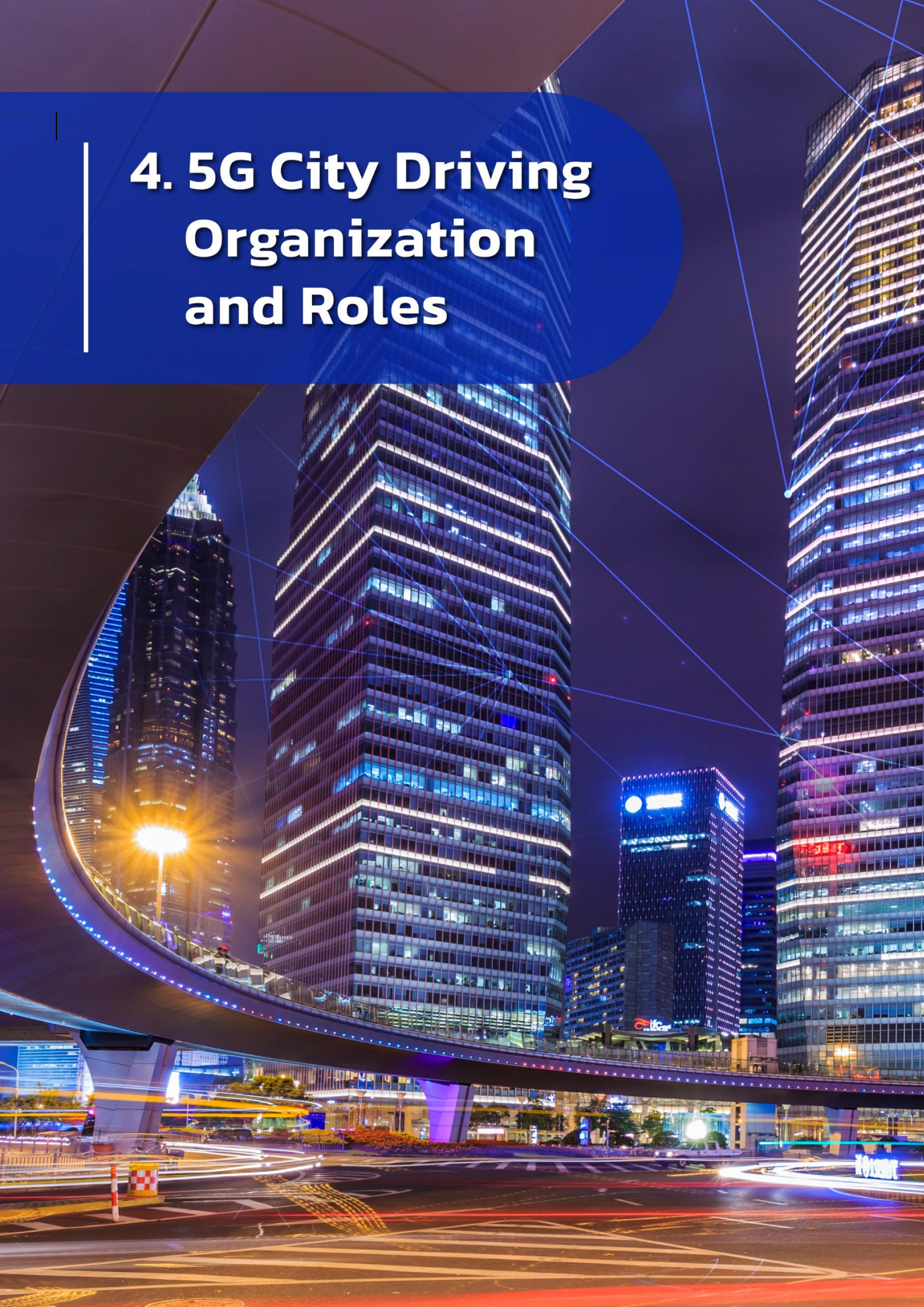


Figure 3-17: Example of Services Group

4. 5G City Driving Organization and Roles



4. 5G City's Promotors and Roles

It is critical to receive cooperation and support from many parties in driving cities to become 5G cities, including the government, private sector, education sector, and people sector, to drive and push both the 5G technology infrastructure and the application of 5G technology to create innovative 5G services. **The following agencies are involved in the development of Thailand's 5G City, with details of roles and responsibilities.**

01 **Governance Sector**

Governance Sector is the main sector that monitors, regulates and push a 5G city development from the beginning by planning the 5G infrastructure as well as the application of public usage.

02 **Private Sector**

Private Sector is the main sector that provides 5G network service. Moreover, Private Sector has an important role on developing more efficient device to support 5G usage and informing the users for both manufacturing sector and public sector.

03 **Academic Sector**

Academic Sector is the main sector that educates, develops, and initiates the idea of 5G implementation that can make further use in other industries which 5G is expected to increase learning potential.

04 **People Sector (Consumer)**

Public Sector mainly provides feedback and which helps identifying the issues to the 5G operators so that the related sectors can solve the issues and develop service quality.

Figure 4-1: 5G City's Promotors and Roles

4.1 Government Agencies

Government agencies have a key role in driving 5G City both at the national level, which are regulated by ministries or main agencies. At the provincial level, governed by district offices or municipal offices, etc. **The role and responsibilities of the government in driving and developing 5G City are necessary to promote and push 5G technology infrastructure development and the application of 5G technology in public services.** The main agencies involved in the development of 5G City are as shown in the following:

	Roles and Responsibilities	Recommendations to Support 5G city
NBTC	➢ Encourage the **development of 5G infrastructure** ➢ Prepare a master plan for **spectrum management** and establish the distribution of frequencies	➢ Accelerate the **allocation of spectrum** to telecom operators ➢ Set **clear standards** for the technical requirements of 5G infrastructure construction
ONDE	➢ Develop **national policies and digital master plans** ➢ Drive innovation of 5G technology to be able to compete commercially ➢ **Regulate digital development fund**	➢ Promote and develop 5G technology by **publishing designating urban areas** to be developing into 5G cities ➢ Support **investment budgets** to facilitate urgent development
DEPA	➢ Promote and develop the adoption of digital technology that applied to business side ➢ Open 5G **Regulatory Sandbox** testing areas ➢ Create Thailand **5G Ecosystem Innovation Center**	➢ **Encourage and promote** the development of 5G use cases including standard and high quality 5G-based services to be employed in smart city areas
NIA	➢ **Enhance national innovation system** towards sustainable value ➢ **Support financial and knowledge** to assist R&D phase of development projects	➢ **Encourage the development and integration of 5G technology** into innovation-based districts, which is currently supported by NIA
Provincial Administrative Organization	➢ Drive 5G technology development of **private and public sector in their own area** ➢ **Establish utility system** that apply 5G technology to provide to the public	➢ Support d**evelopment of 5G technology at the provincial level or urban level under their area** for small agencies, including both public and private sectors

Figure 4-2: Role of Government Agencies in Driving 5G City (1)

Industrial Sector	Tourism Sector	Transport Sector	Trade Sector	Education Sector	Health Sector	Agricultural Sector	Governance Sector
MOI and DIPROM are responsible for ▪ **Formulate policies** and strategies to develop Thai industry ▪ **Promote and support industrial business** to have higher capabilities through the application of 5G technology	**MOTS and TAT** are responsible for ▪ **Develop a complete system** and promote information for tourism sector ▪ **Apply the use of 5G technology to various part of tourism** ecosystem such	**MOT and OTP** are responsible for ▪ **Upgrade infrastructure** to support public transportation service ▪ Drive the development of 5G technology to apply in the field of **intelligent transportation**	**MOC and DIT** are responsible for ▪ **Promote the use of innovations** to enhance the country's trade competitiveness ▪ **Create opportunities** in international market for local business	**MOE and MHESI** are responsible for ▪ **Promote good teaching and learning** environment to the public ▪ Rollout policy to support the cultivation of **5G digital learning** ▪ **Apply digital transformation through 5G** for education system	**Ministry and Department of Health** are responsible for ▪ **Supervise the health system** ▪ **Support the operation** of public health agencies ▪ Promote the **development of 5G to adapt in medical technology**	**MOAC and DOAE** are responsible for ▪ Promote and **develop agricultural ecosystem** ▪ Study, research and **transfer 5G technology** that related to agriculture to stakeholders	**Ministry of Interior and CDD** are responsible for ▪ **Oversee provincial government agencies** ▪ **Provides basic services** such as utility ▪ **Encourage the use of 5G** that can adapt to community development

Figure 4-3: Role of Government Agencies in Driving 5G City (2)

Table 4-1 : Roles and Responsibilities of Government Agencies

Government Agencies	Roles and Responsibilities
1) Office of The National Broadcasting and Telecommunications Commission (Office of the NBTC)	It is the primary unit responsible for supporting and operating in the field of building a 5G technology infrastructure by developing a spectrum management master plan and determining the allocation of spectrum used in the telecommunications industry, including the establishment of standards for using radio frequency, methods of use or connection, and rules and procedures for determining the rate of use or interconnection fees in the broadcasting industry to be fair to service users, service providers, and investors.
2) Office of the National Digital Economy and Society Commission (ONDE)	It is an agency responsible for formulating national policies and master plans on digital and driving innovations in 5G technology to make the country's economic competitiveness as well as improve the quality of life and reduce social gaps. It is also a regulator of the fund in the allocation of the digital development budget (DE Fund).
3) Digital Economy Promotion Agency (DEPA)	The main agency for promoting and developing the adoption of digital technology applied to business, as well as being the main unit in the opening of 5G Regulatory Sandbox testing areas, developing the area to become a service center for industrial development and innovation of 5G technology. Creating a Thailand 5G Ecosystem Innovation Center (5G EIC) to drive innovative development of 5G technology through cooperation of the entire ecosystem.
4) National Innovation Agency (NIA)	It is responsible for enhancing technological and innovation capabilities, especially in the strategic industrial fields of the country, as well as providing academic and financial support to assist in the development of post-research projects and manage working capital for technology research and development.
5) Provincial Administrative Organization (PAO)	It is an agency that supports and promotes its own 5G network development areas within their provinces throughout the country. It is considered as the main intermediary in driving the development of 5G technology with the government and private sectors in their own urban areas, as well as establishing utilities to provide public services by applying 5G technology.

Government Agencies	Roles and Responsibilities
6) Industrial Sector: Ministry of Industry (MOI) and Department of Industrial Promotion (DIPROM)	The Ministry of Industry is responsible for formulating policies and strategies for developing Thai industry as well as promoting and developing the potential of small and medium enterprises and community enterprises to be strong and able to compete in the world market by taking benefits from 5G technology. The Department of Industrial Promotion is an agency that plays a role in promoting, supporting, and developing small and medium-sized enterprises (SMEs), community enterprises, entrepreneurs, and industrial business service providers to have higher capabilities by utilizing the application of 5G technology and strengthening industrial business service agencies to be more efficient.
7) Tourism Sector: Ministry of Tourism and Sports (MOTS) and Tourism Authority of Thailand (TAT)	It is an agency that is responsible for promoting marketing and public relations in expanding the quality market base and creating quality tourism products to increase the value of tourists' spending, as well as developing systems and marketing information technology and marketing information services to meet the needs of tourists and stakeholders.
8) Transport Sector: Ministry of Transport) (MOT) and Office of Transport and Traffic Policy and Planning (OTP)	It is responsible for upgrading the public service infrastructure system and transportation services to be worthwhile and thorough, enabling the transportation system to be safe and promoting the quality of life to integrate and connect the mass transit network with the public transport system, both people and goods, as well as expand the opportunity to travel equally and thoroughly.
9) Commerce Sector: Ministry of Commerce (MOC) and Department of Internal Trade of Thailand (DIT)	The Ministry of Commerce is the main agency responsible for promoting the utilization of innovations to enhance the country's trade competitiveness and upgrade the trade infrastructure to be efficient, standardized, and fair, as well as to promote trade and develop international cooperation. The Department of Internal Trade plays an important role in promoting and developing products, marketing systems and mechanisms that create opportunities and enhance the competitiveness of farmers, farmer's institute, community enterprises, and entrepreneurs.

Government Agencies	Roles and Responsibilities
10) Education Sector: Ministry of Education (MOE) and Office of the Permanent Secretary	It is responsible for upgrading the quality of education and promoting effective teaching and learning systems for the public widely. It is also responsible for supporting other agencies participating in education by creating educational opportunities and vocational education for youth, as well as supporting the cultivation of digital skills learning development.
11) Education Sector: Ministry of Higher Education, Science, Research and Innovation and Office of the Permanent Secretary	It is responsible for promoting, supporting, and supervising higher education to keep up with global changes with academic and administrative independence to develop manpower according to the needs of the country. Also, to conduct research and create innovations to develop communities, society, and countries in the fields of science, technology, social sciences, humanities.
12) Public Health Sector: Ministry of Public Health (MOPH) and Department of Health	It is responsible for promoting public health, supervising, developing, and supervising the health system, preventing, controlling, and treating disease, as well as the rehabilitation of people's abilities and supporting the operation of public health agencies. There is also the development of knowledge and technology of health promotion services to manage health risk factors and environmental health management.
13) Agricultural Sector: Ministry of Agriculture and Cooperatives (MOAC) and Department of Agricultural Extension (MOAE)	It is responsible for overseeing agriculture, providing water resources, and developing irrigation systems, promoting and developing farmers, promoting and developing cooperative systems, as well as the production process and agricultural products, determining measures and guidelines for agricultural promotion, and transferring agricultural technology.
14) Administrative Sector: Ministry of Interior (MOI) and Community Development Department	Responsible for promoting local governance, promoting occupation and the livelihood of people, including community arrangement, land management and public utility services in urban areas. In addition, the Department of Community Development is responsible for formulating policies on community development and community information systems.

Recommendations on the Role of Government Agencies in Driving 5G City

There are proposals and guidelines for the implementation of relevant agencies to expand the development limit as well as its application in public service based on a study of the roles and duties of government agencies engaged in driving 5G City. The main agencies involved in the development of 5G cities are as follows:

Table 4-2 : Recommendations on the Role of Government Agencies in Driving 5G City

Government Agencies	Recommendations to Support 5G City
1) Office of The National Broadcasting and Telecommunications Commission (Office of the NBTC)	Should accelerate the spectrum allocation to telecom operators and set clear standards as well as technical requirements for 5G infrastructure to facilitate the future development of 5G technology in many cities.
2) Office of the National Digital Economy and Society Commission (ONDE)	Should promote and support the development of 5G technology by issuing announcements on the area that has potential to develop into 5G City as a model for 5G technology infrastructure, as well as supporting investment budgets to facilitate urgent development.
3) Digital Economy Promotion Agency (DEPA)	Should promote and encourage the development of 5G technology by supporting 5G service trials in the city. Also, concretely set technical standards of 5G technology for the needed services to be a model for other cities.
4) National Innovation Agency (NIA)	Should promote the development and integration of 5G technology into the innovation development areas that are currently supported by NIA to build a 5G city and provide funding to support its development.
5) Provincial Administrative Organization (PAO)	Should help as an intermediary in supporting the development of 5G technology at the provincial level or the urban level within their responsible areas, encouraging small agencies, both public and private sectors, to collaborate for 5G city development more efficiently.
6) Industrial Sector: Ministry of Industry (MOI) and Department of Industrial Promotion (DIPROM)	Should apply the benefits of 5G technology to promote and develop the potential of operators, small and medium enterprises, and community enterprises to be more competitive in the world market by educating and publicizing information about 5G technology to them.
7) Tourism Sector: Ministry of Tourism and Sports (MOTS) and	Should apply the use of 5G technology to enhance the presentation of attractions through AR/VR technology to attract tourists as well as

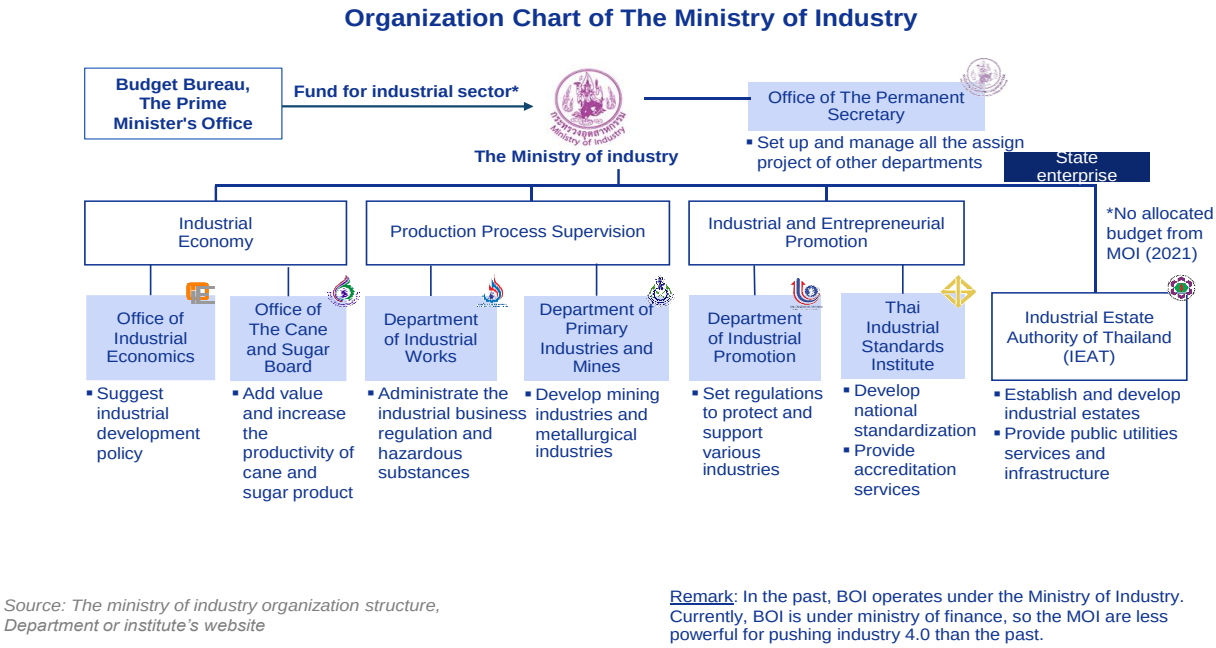
Government Agencies	Recommendations to Support 5G City
Tourism Authority of Thailand (TAT)	promote the communication system for tourists to facilitate better communication.
8) Transport Sector: Ministry of Transport) (MOT) and Office of Transport and Traffic Policy and Planning (OTP)	Should push the development of 5G technology by applying 5G services in the field of smart transportation by developing a GPS system to help track transportation effectively and be able to cover all service areas in real-time.
9) Commerce Sector: Ministry of Commerce (MOC) and Department of Internal Trade of Thailand (DIT)	Should be a continuous push for the adoption of 5G technology in the people's sector as well as to enhance the country's competitiveness in trade and upgrade the commercial infrastructure to be more effective.
10) Education Sector: Ministry of Education (MOE) and Office of the Permanent Secretary	Should consider the importance of upgrading Thailand's education to digital transformation through 5G technology for education, such as 5G Smart Classroom or 5G VR Classroom for students so they can access teaching quickly and efficiently.
11) Education Sector: Ministry of Higher Education, Science, Research and Innovation and Office of the Permanent Secretary	Should be developed to apply 5G technology to higher education teaching, as well as support research and development related to 5G technology for research cooperation between universities and other sectors.
12) Public Health Sector: Ministry of Public Health (MOPH) and Department of Health	Should consider promoting the development of 5G technology for use in medical technology to achieve greater accuracy and speed, such as transmitting massive data, AI-powered rapid diagnosis analysis, and remote treatment development through AR/VR technology.
13) Agricultural Sector: Ministry of Agriculture and Cooperatives (MOAC) and Department of Agricultural Extension (MOAE)	Should be pushing to bring 5G technology to be used in both agriculture and cultivation, irrigation, and processing of agricultural products in the community to create added value for the agricultural sector.
14) Administrative Sector: Ministry of Interior (MOI) and Community Development Department	Should consider integrating the 5G technology with existing local utilities, as well as applying it in other areas to strengthen community development strategies.

Departments Involved in Supporting 5G City

Industrial Sector

The government agency that plays an important role in supporting and regulating the industrial sector of Thailand is the Ministry of Industry (MOT), which is divided into sub-units related to three main groups: 1) The Industrial Economy Mission Group is in charge of recommending economic and industrial policies as well as developing industrial development plans. 2) Monitoring the production process group that is responsible for supervising and supporting industrial business operations, including the promotion of safety in production areas, and 3) Industries and entrepreneurs' promotion group, which has to promote, support, and develop domestic industries and entrepreneurs.

The service in the technology city related to the industrial sector is a service group under the development of 5G Governance and Industrial City that is related to the governance and development of the industrial sector, such as the 5G Automation Robot service or the 5G Remote Controlled Forklift service. The main department under MOT whose main function is to support the development of this field is **the Department of Industrial Promotion,** which has the authority to present opinions to formulate policies and measures to promote and develop the industry, including the implementation of promotional measures that aid in the development of the industry, with a focus on small and medium-sized enterprises, community enterprises, and industrial business service providers**.**



Source: The ministry of industry organization structure, Department or institute's website

Remark: In the past, BOI operates under the Ministry of Industry. Currently, BOI is under ministry of finance, so the MOI are less powerful for pushing industry 4.0 than the past.

Figure 4-4: Organization Chart, Ministry of Industry

Tourism Sector

The government agency that plays an important role in supporting and regulating the tourism sector in Thailand is the Ministry of Tourism and Sports, which is divided into departments of central administration and departments of the overall tourism sector that are responsible for the promotion and development of the tourism industry. The sports section is responsible for the promotion of sports, including sports education. For tourism support, three main organizations are responsible for supporting and promoting tourism.

5G tourism services under the development of 5G Governance and Industrial City are related to the development of governance services and industrial economic development and tourism in the city, such as 5G VR Unseen Thailand or 5G IoT Wristband Tourist Tracking. An agency under the Ministry of Tourism and Sports that has a main duty to support the development of this field is the Tourism Authority of Thailand (TAT), which is primarily responsible for promoting tourism and the tourism industry, as well as for the occupation of Thai people in the tourism industry and public relations for international tourism. This is in line with the main objective of 5G Governance and Industrial City development that wants to develop tourism through 5G technology to attract and promote tourism with both domestic and foreign tourists.

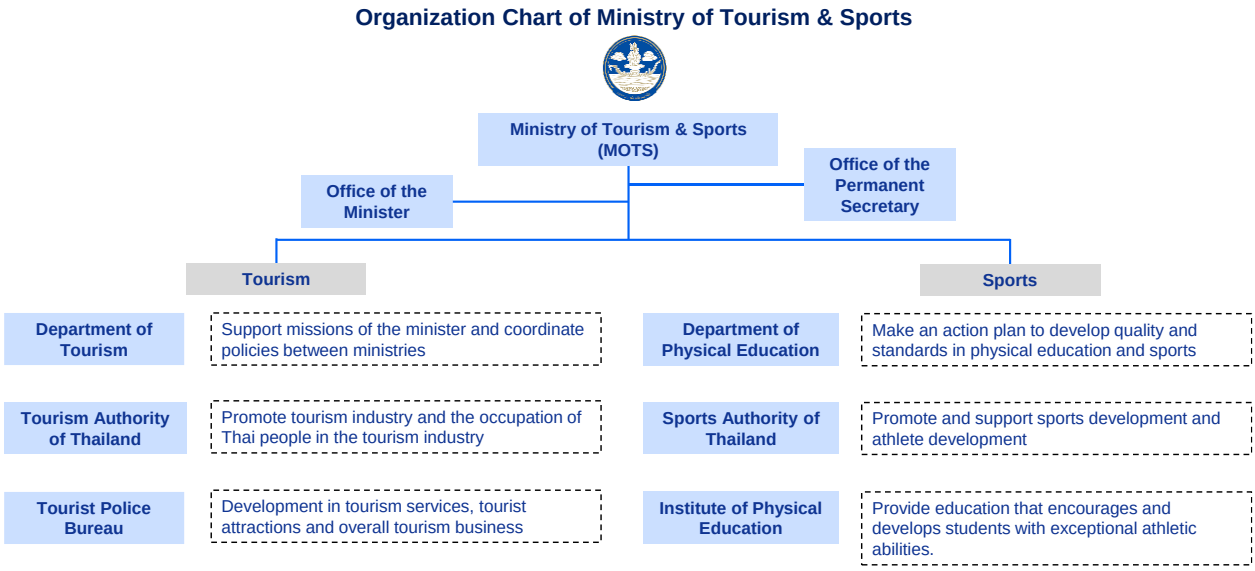


Figure 4-5: Organization Chart, Ministry of Tourism and Sports

Transport Sector

The government agency that plays an important role in supporting and regulating the transport sector in Thailand is the Ministry of Transport. Under this ministry, there is the Office of Transport and Traffic Policy and Planning (OTP) as the main agency for recommending policies and setting standard measures on traffic management, as well as developing intelligent traffic and transportation technologies. In addition, under the ministry, there will be other relevant agencies to supervise the overview of each mode of transport that can be grouped into 4 areas: road transport, rail transport, water transport, and air transport.

5G services for the transport sector are a group of services under the development of 5G Governance and Industrial City related to the development of administrative services and industrial economic development, such as 5G Autonomous Vehicle services or 5G V2X services. The agency under the Ministry of Transport that has the main duty to support development in this area is **the Office of Transport and Traffic Policy and Planning (OTP),** which has the main duty to prepare master plans, investment plans for transport and traffic at the national level and develop intelligent traffic and transportation technology. This is in line with the development of the 5G Governance and Industrial City, which supports autonomous vehicles to increase the convenience of traveling within the city for both tourists and residents.

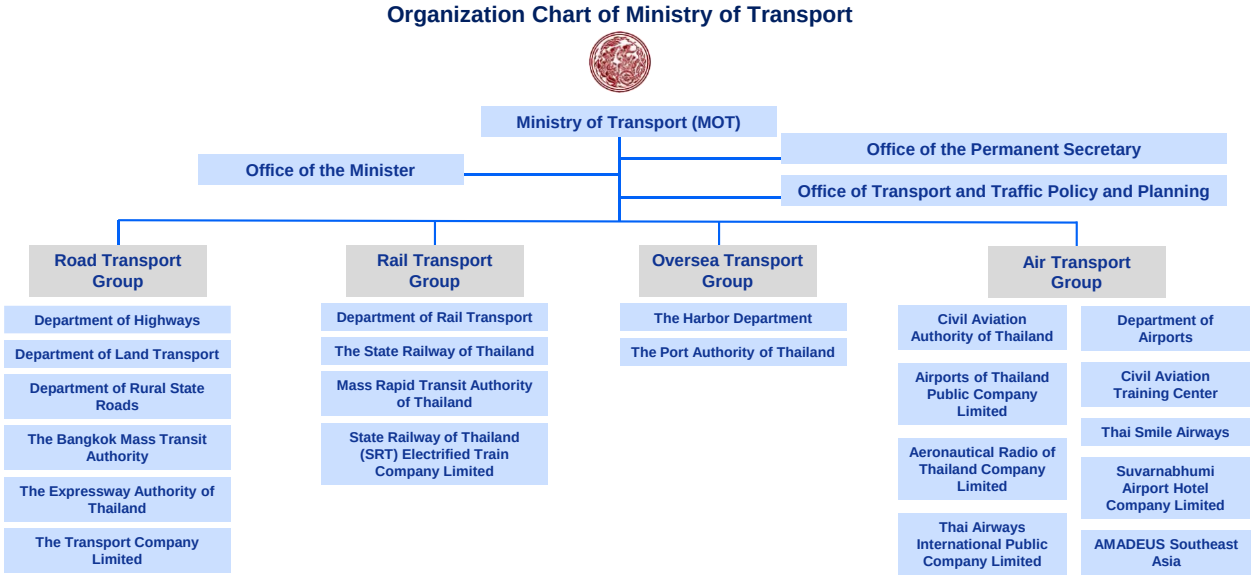


Figure 4-6: Organization Chart, Ministry of Transport

Commerce Sector

The government agency that plays an important role in supporting and regulating the transport sector in Thailand is the Ministry of Commerce. It has powers and duties related to trade, service business, and intellectual property, both domestically and internationally. The departments under the jurisdiction can be divided according to the tasks that govern or support them, including central administration, the domestic trade mission group, the foreign trade mission group, which focuses on international trade negotiations and import-export management, state enterprises related to warehouse management services, and other state enterprises related to the support and development of trade.

5G Services for commerce sector is a group of services under 5G Livelihood City development related to service development, improving people's quality of life. This includes commercial services (5G Commerce), such as 5G Virtual Store services or 5G Unmanned Store services. Agencies under the Ministry of Commerce whose main duties are to support development in this area, such as the **Department of Internal Trade**, have the authority to supervise, promote and develop domestic trade and market efficiency. According to the duties of the Department of Internal Trade, it is consistent with the efforts to develop trade and marketing in 5G Livelihood City by applying technology to solve problems for operators, such as unmanned shops to solve employee shortages or a virtual store to expand sales channels for entrepreneurs.

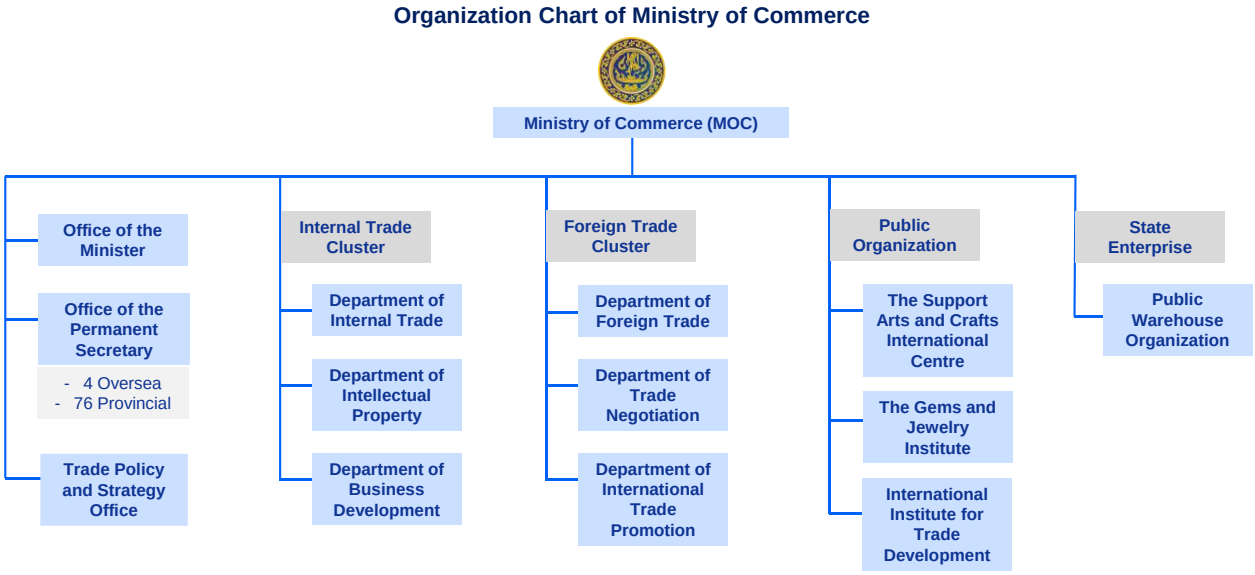


Figure 4-7: Organization Chart, Ministry of Commerce

Education Sector

The government agency that plays an important role in supporting and regulating the education sector in Thailand is the Ministry of Education. It is responsible for promoting education for all people thoroughly and equally, as well as creating equality and educational opportunities. Under the Ministry of Education, can be divided into 5 main sections, namely 1) Office of the Permanent Secretary 2) the Secretariat Office, which is responsible for overall education policies and research for the development of education. 3) The Office of Basic Education is in charge of primary and secondary education. 4) the Office of the Vocational Education Commission, which supervises the education of vocational institutions, and 5) the Office of the Private Education Commission and the Ministry of Higher Education, Science, Research and Innovation, which have duties in relation to the promotion, support, and supervision of higher education.

5G services for the education sector is a service group under the 5G Livelihood City development that is related to the development of services to improve people's quality of life, including educational services (5G Education) such as 5G Virtual Classroom services or 5G Smart Classroom services. the departments under the Ministry of Education that have the main duty to support this development is **the Office of the Permanent Secretary of the Ministry of Education** which has the power and duty to convert the ministry's policies into action plans and prepare budgets of the ministry which will cover all sectors of education, including the Office of Education in all 77 provinces and non-formal education. Also, under the Office of the Permanent Secretary, Ministry of Education, there is an Information and Communication Technology Center that responsible for promoting research and development of information technology for administration and education and **the Office of the Permanent Secretary of the Ministry of Higher Education** which has the power and duty to support the drive for reform of higher education, science, research and innovation, including the establishment of higher education standards.

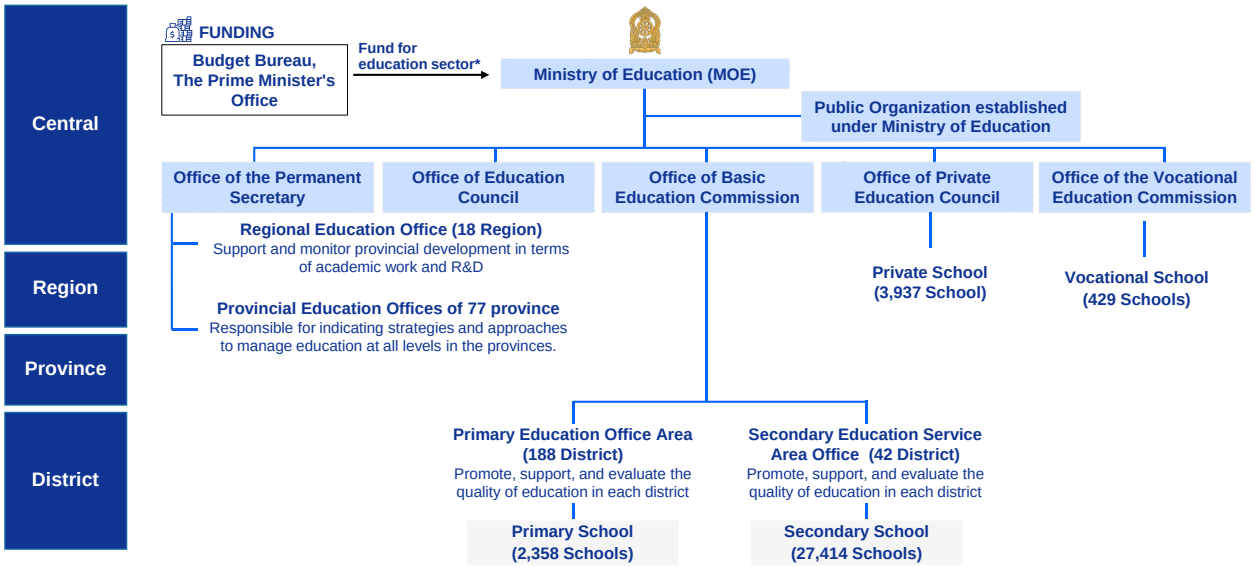


Figure 4-8: Organization Chart, Ministry of Education

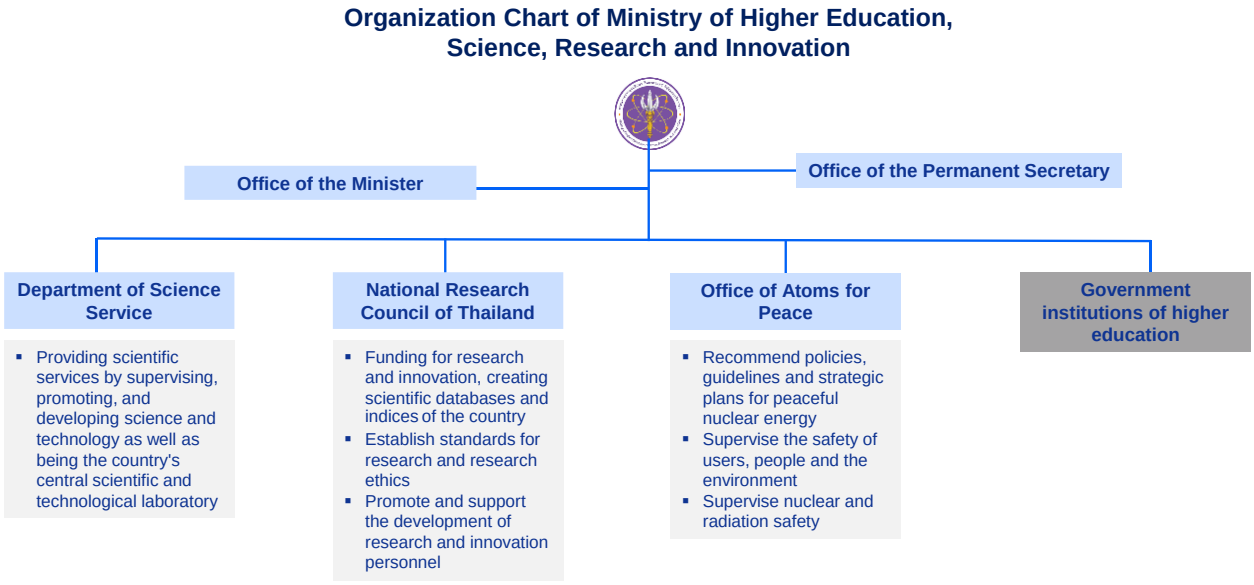


Figure 4-9 Organization Chart, Ministry of Higher Education, Science, Research and Innovation

Public Health Sector

Government agencies that play an important role in supporting and regulating the public health sector in Thailand is the Ministry of Public Health with the powers and duties relating to health promotion, prevention, control, and treatment of disease, which will divide the structure of care agencies at the provincial level such as Provincial Public Health Office down to the sub-district level such as Subdistrict Health Promotion Hospital.

5G Services for the health sector is a service group under the 5G Livelihood City development that is concerned with the development of services to improve people's quality of life. This includes public health services (5G Healthcare), such as 5G Connected Ambulance services or 5G Teleconsultation services. The department under the Ministry of Health that is primarily responsible for supporting the development of this area is the **Department of Health,** which is the main agency for formulating and maintaining medical standards for affiliated organizations, formulating, and developing policies for health promotion for the country. This is in line with the guidelines of 5G Healthcare, which will bring 5G technology into the public health sector to make people in remote areas more accessible to treatment. It also increases the convenience of treatment in 5G cities that may be in border areas as well.

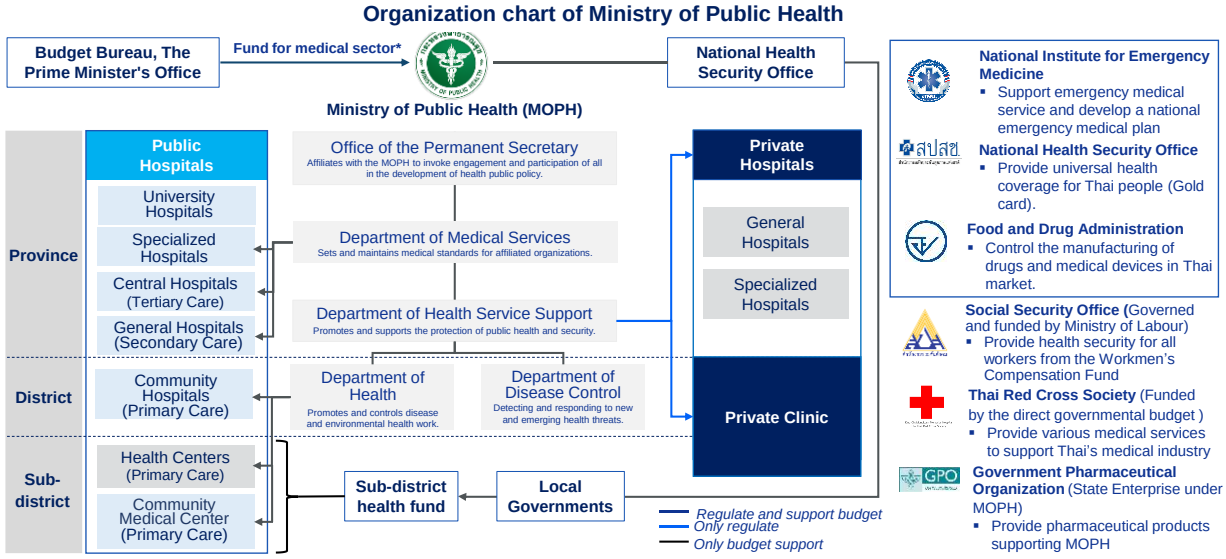


Figure 4-10: Organization Chart, Ministry of Healthcare

Agricultural Sector

Government agencies that play an important role in supporting and regulating the agricultural sector of Thailand is The Ministry of Agriculture and Cooperatives that has the powers and duties related to agriculture, irrigation system development and the promotion of farmers development, including cooperative systems. Government agencies under the ministry can be divided into 4 groups according to various missions, namely 1) central government agency 2) production development mission group 3) production resource management group and 4) promotion and development for agriculture and cooperative systems group.

5G Services for the agricultural sector is a service group under the 5G Livelihood City development of services related to improving the quality's life of residents, tourists, or industrial groups, which include services that related to the improvement of people's quality of life covering the establishment and development of a better irrigation system to develop urban agriculture by the department under the Ministry of Agriculture and Cooperatives whose main duties are to support development in this area such as **Department of Agricultural Extension** with the authority to study, research and develop agricultural extension by focusing on promoting the use of technology and innovations to increase competitiveness in the agricultural sector and vocational training technology transfer as well as providing agricultural services to farmers, community enterprises and related industry groups.

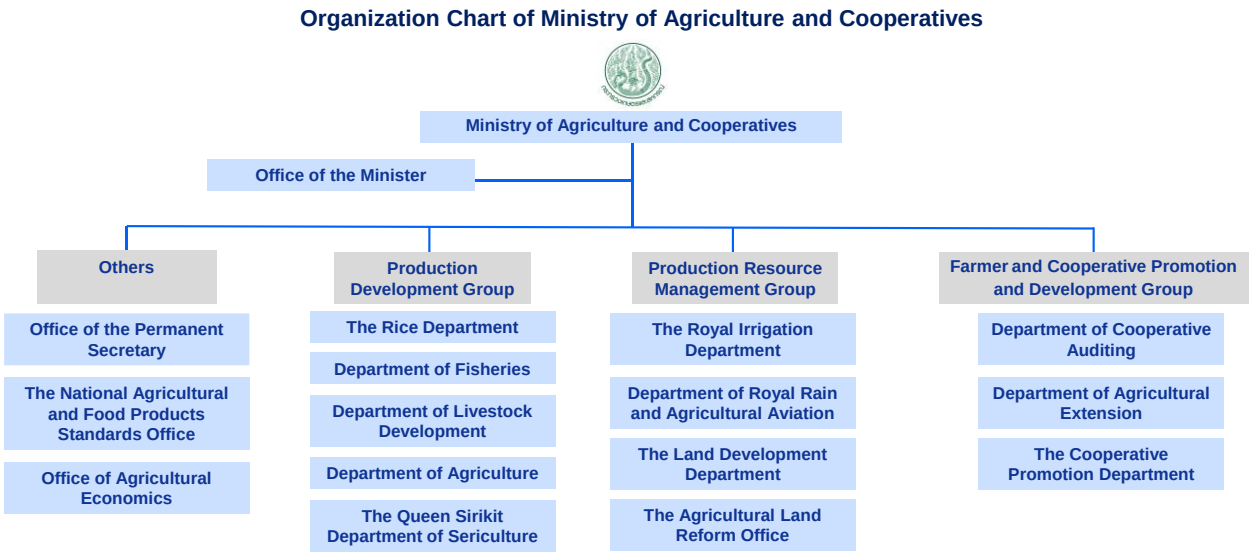


Figure 4-11: Organization Chart, Ministry of Agriculture and Cooperatives

Administrative Sector

Government agencies that play an important role in supporting and supervising the administrative sector of Thailand is the Ministry of the Interior that responsible for the treatment of people's well-being, maintaining public order, promotion and development of politics and administration, development of provincial administration, promotion of local governance and internal stability. Under the Ministry of Interior, there are departments within the jurisdiction that have different responsibilities for each work group, including state enterprises responsible for utilities as well.

5G City services related to the administrative sector are a group of services under the development of 5G Governance and Industrial City related to the development of government services and the governance of urban citizens, such as surveillance services (5G Surveillance) or security services (5G Security). Organizations under the Ministry of Interior that have the primary responsibility to support development in this area, such as the Department of Community Development, have the authority and responsibility to formulate policies to lay down guidelines for community development at the national level for government agencies, the private sector, and those involved in community development to use as a framework for working together. This is in line with the 5G City development approach that wants to promote communities in 5G City to have a better quality of life in terms of effective governance by applying 5G technology.

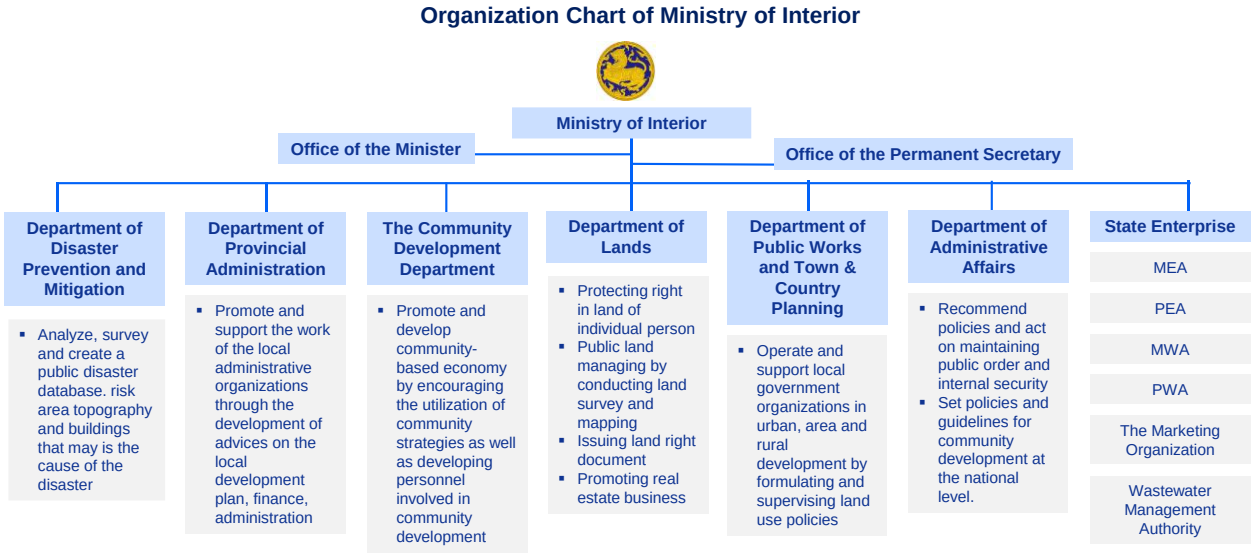


Figure 4-12: Organization Chart, Ministry of Interior

4.2 Private Sector

The private sector is an essential unit in advancing the adoption of 5G technology since it has a role and duty in **delivering 5G network services, as well as improving service users' knowledge and understanding in both the industrial and public sectors**. Furthermore, the private sector is responsible for **developing and manufacturing tools or devices that can support the use of 5G technology, as well as improving the performance of equipment and tools to make them more stable to promote accessibility and widespread use of technology.** the major agencies involved, such as

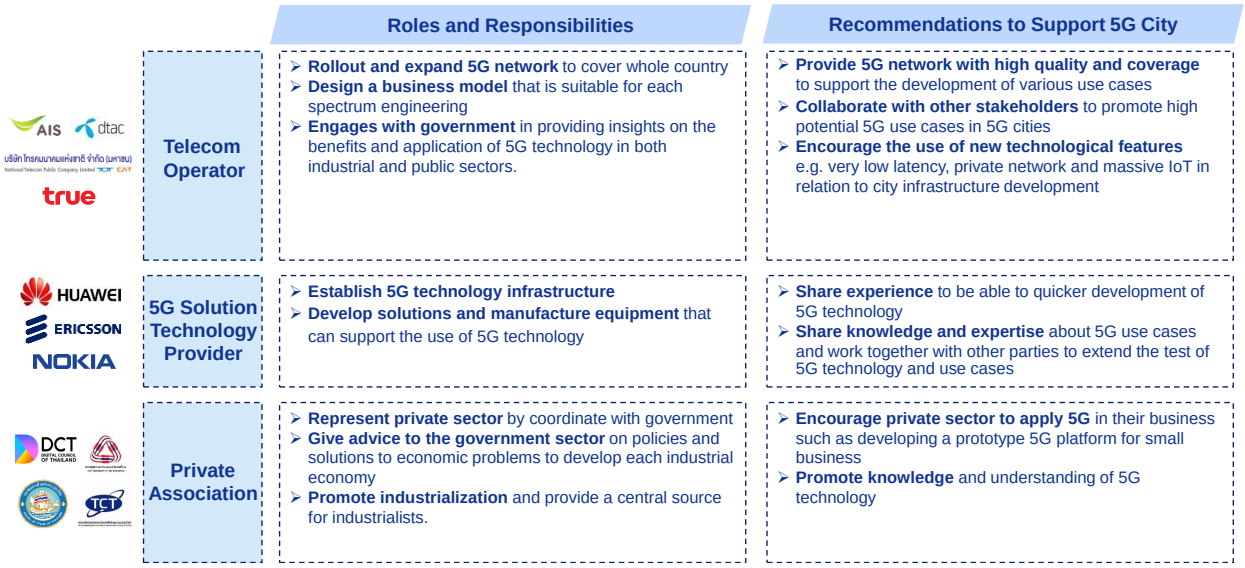


Figure 4-13: Roles and Duties of Private Sector in Driving 5G City

Table 4-3 : Roles and Responsibility of Private Sector

Private Sector	Roles and Responsibilities
1) Telecom Service Provider e.g., AIS, TRUE, DTAC and NT	It is responsible for networking 5G technology areas and is a key player in expanding the 5G network to be used across the country as well as developing a business model suitable for spectrum engineering use. It also works with government agencies to educate them on the advantages and applications of 5G technology in both the industrial and public sectors.
2) 5G Technology Solution Provider	It is primarily responsible for laying the groundwork for 5 G technology, as well as developing solutions and producing equipment that can support the use of 5G technology in various services to promote access to 5G technology.

Private Sector	Roles and Responsibilities
3) Private Association e.g., Telecommunications Association, Digital Council, The Federation of Thai Industries, Chamber of Commerce of Thailand	Have a duty to represent the private sector in coordinating policies and operations between the private sector and the government by giving advice to the government sector and various government agencies regarding policies and solutions to economic problems, for example, the Thai Chamber of Commerce has a role in supporting and promoting the country's exports together with the government sector. The industry council is responsible for providing advice and recommendations to the government to develop the industrial economy, promote industrialists and provide a central source for industrialists.
4) Financial Service Provider	It plays an important role in funding and allocating resources in the economy by acting as the largest and most important source of savings and lending in the financial system, as well as providing services such as domestic and international money transfers that are fast, convenient, safe, and charge a low transfer fee, including collecting payments such as payments for water, electricity, telephone bills, stock trading services, etc.
5) Entertainment Service Group	Play a role in providing entertainment, enjoyment, and fun for the audience to cause relaxation, such as listening to music, watching movies, dramas, and cartoons, as well as playing games. The entertainment service group is one of the main groups that will help drive the development of 5G technology.
6.) Retail Business Operators	The retail business is an important business group that facilitates the purchaser's confidence in the product's quality, helps expand purchasing power for consumers, and performs sales promotion and warehousing to provide the convenience for customer shopping.

Recommendations on the Role of Private Sector in Driving 5G City

Since the private sector is one of the main factors driving the country's development towards Technology City. Therefore, there are recommendations to further the work of the private sector to prepare for developments in the 5G technology era as follows:

Table 4-4 : Recommendations on the Role of Private Sector in Driving 5G City

Private Sector	Recommendations to Support 5G City
1) Telecom Service Provider e.g., AIS, TRUE, DTAC and NT	Provides high-quality 5G network coverage in many areas and cooperates with other sectors to support services that require the use of 5G networks and should promote 5G technology features such as low latency that will comply with infrastructure development.
2) 5G Technology Solution Provider	Sharing experience and collaborating with other sectors in the development of 5G services eliminates the need for each party to initiate the process of innovation or new technologies but can bring the experiences that have been gathered to develop further and move forward faster.
3) Private Association e.g., Telecommunications Association, Digital Council, The Federation of Thai Industries, Chamber of Commerce of Thailand	Should encourage the entrepreneurs to apply 5G technology to their businesses for promoting knowledge, understanding, and capabilities in businesses such as developing a prototype 5G platform for small operators.
4) Financial Service Provider	Apply 5G technology in banking, such as account opening, deposit withdrawals, and payments through artificial intelligence (AI) systems to save time for service users and reduce the cost for service providers as well.
5) Entertainment Service Group	Adapting the technology to help reduce media production costs and save time. This also allows viewers to watch entertainment more quickly and with more virtual reality.
6.) Retail Business Operators	Develop and use 5G technology to increase the efficiency of marketing channels as the quality of the Internet becomes faster compared to 4G technology, retail business operators can manage their marketing channels faster because they can monitor the market condition of the product in real time.

4.3 Educational Institution

Educational institutions are one of the most important sectors in driving 5G adoption because they **serve as a medium for educating, training, developing, and initiating ideas to apply 5G technology, as well as using 5G to achieve educational efficiency that will be extended to other sectors.** It also expands learning opportunities, such as long-distance learning via 5G technology, virtual reality, VR, and AR technologies that can be applied to education or courses that require experimentation. Furthermore, educational institutions are important as a center for research and study of various technical technologies. To drive a comprehensive 5G ecosystem, leading educational institutions that have the potential are listed below.

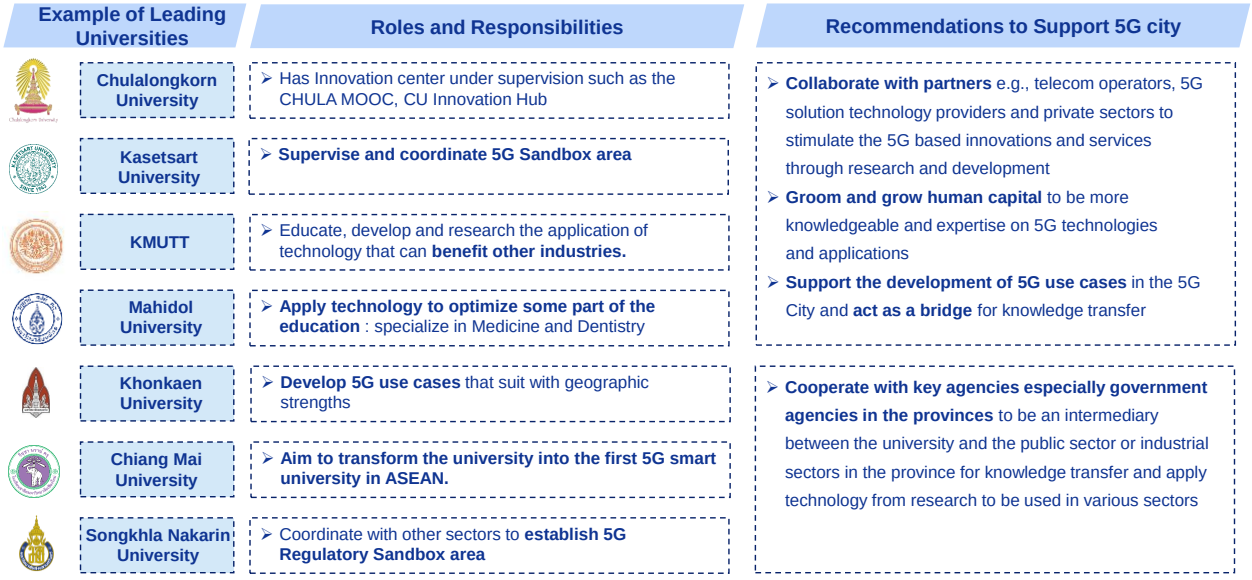


Figure 4-14: Roles and Duties of Educational Institution in Driving 5G City

Table 4-5 : Roles and Responsibility of Educational Institution

Educational Institution	Roles and Responsibilities
1) Chulalongkorn University	There are various innovation centres under its supervision, such as the Learning Innovation Centre (CHULA MOOC), Chulalongkorn University Innovation Centre Project (CU Innovation Hub), etc., which act as supportive agencies to operate and develop teaching and learning for personnel, students, and guests to create innovations that are beneficial to the public.
2) Kasetsart University	Licensed as a coordinator for a specific regulatory area, known as the 5G Sandbox, to develop areas related to the management of 5G technology to pave the way for the development of new innovations.

Educational Institution	Roles and Responsibilities
3) **Khon Kaen University** 	The use case has been developed to suit the geographic strengths, where the university will act as an intermediary in bringing smart agriculture to control precise agricultural production that will be a highlight in 5G trials.
4) **Chiang Mai University** 	An important university of the north that aims to transform the university into the first 5G smart university in ASEAN. The university has conducted teaching and learning to train and develop experts, students, and personnel in ICT through cooperation with various agencies in both public and private sectors, such as the Huawei ICT Academy, etc. In addition, the university has been selected and cooperated with the NBTC as one of the region's 5G testing centers.
5) **King Mongkut's University of Technology Thonburi** 	Committed to education, development, and research, especially the application of technology that can benefit other industries, for example, has signed a cooperation agreement with TOT to jointly develop a prototype of a robot for use in the field to enhance its performance in industrial estates in the EEC and the Special Development Zones to develop into Industry 4.0.
6) **Mahidol University** 	Specializing in medicine and dentistry, including having a hospital under the university, which are Siriraj Hospital and Ramathibodi Hospital, the university has already applied technology to enhance some of the education system, such as real-time remote teaching. In addition to driving the education sector to upgrade Thailand to the Medical Hub of the region, the university has collaborated with various sectors, such as collaborating with the Thonburi Hospital Group to establish a research and development center for innovative medical equipment to become a smart hospital.
7) **Prince of Songkla University** 	A leading university in the south where the Faculty of Engineering has collaborated with the government to establish a 5G telecommunication network test center and prepare the infrastructure for the base station installation by specifying the scope of regulatory areas specifically. The regulatory sandbox for testing 5 G will benefit entrepreneurs and serve people throughout the southern region.

Recommendations on the Role of Educational Institution in Driving 5G City

From the study and data collection in educational institutions, it is found that 5G technology plays an important role in raising the level of education in Thailand to be comprehensive, inclusive, and effective. If the technology that is suitable for each part is applied with the following suggestions:

Table 4-6 : Recommendations on the Role of Educational Institution in Driving 5G City

Educational Institution	Recommendations to Support 5G City
1. Leading educational institutions in each region such as Chiang Mai University and Khon Kaen University, etc.	These universities should cooperate with important agencies, especially government agencies in the province, to act as an intermediary between the university and the public or industry sector in the province for knowledge transfer and application of research technologies in the sector which will accelerate the dissemination of ICT knowledge to other provinces in the region.
2. Thailand's leading educational institutions	Educational institutions should work with partners such as telecommunication providers, 5G solution technology providers, and other private sectors to stimulate innovation and 5G services through research and development of human resources to increase knowledge and expertise in 5G technology for supporting the development of use cases in 5G City and transferring knowledge.

4.4 People Sector

The public sector is a group of users who have contributed to driving the adoption of 5G technology in the field of development from post-implementation feedback that service providers or government agencies can be used to improve, fix, and develop more quality services, which the main group involved are as follow:

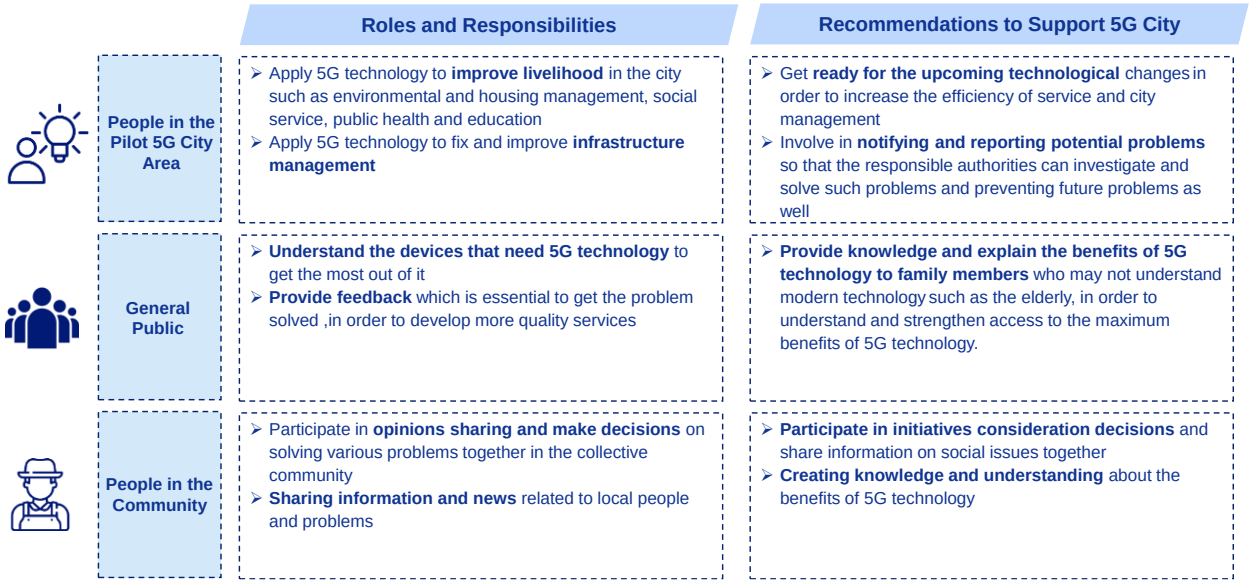


Figure 4-15: Roles and Duties of People Sector in Driving 5G City

Table 4-7 : Roles and Responsibility of People Sector

People Sector	Roles and Responsibility
People in the Pilot 5G City Area	Apply 5G technology to improve quality living by modifying and improving the management of basic utilities, environmental and housing management, social and public health services, as well as education services.
General Public	Understand the devices that use 5G technology to get the most out of it. In addition, if a problem is encountered during use, providing feedback is essential to get the problem solved to develop more quality services.
People in the Community	Participate in opinion sharing and collaborate to make decisions on solving various problems, including a collective community, and sharing information related to local people.

Recommendations on the Role of People Sector in Driving 5G City

Cooperation from the public sector is an important factor in the development and driving of 5G technology to meet the needs and achieve maximum benefits. There are recommendations for the most efficient operation to drive 5G City as follows:

Table 4-8 : Recommendations on the Role of People Sector in Driving 5G City

People Sector	Recommendations to Support 5G City
People in the Pilot 5G City Area	Get ready for the upcoming technological changes to increase service efficiency and city management, reduce the cost, and use of the city's resources. In addition, people in the pilot area should participate in informing and reporting problems that may arise so that the responsible agencies can come to investigate and fix such problems to prevent future problems.
General Public	Should provide knowledge, explain the benefits, methods for using each device, and the mechanisms of 5G technology to family members who may not understand modern technology, such as the elderly, to understand and strengthen access to the maximum benefits of 5G technology.
People in the Community	Provide opportunities for people to collaborate on initiatives, make decisions, and share information on social issues, as well as practice and share responsibility for a variety of issues affecting individuals, such as increasing awareness and understanding about the benefits of technology.

5. Development Plan for 5G City Promotion in Thailand

5. Development Plan for 5G City Promotion in Thailand

5.1 Vision and Goals for the Development of 5G City

The development of 5G City is the enhancement of 5G technology adoption to develop cities and society by using advanced 5G network capabilities to meet various demands. In the development of 5G City, there are visions, goals, and strategies for development as follows:

Vision: Thailand becomes a digital hub of the region supported by development of 5G City and to lead the digital economy with 5G technology.

Mission:

- Promote the establishment of 5G city criteria and support its application in the private and public sectors.
- Develop a 5G city model to promote better living of people in the city.
- Develop a 5G city model to promote trade and investment in the private sector's strategic areas.
- Set long-term development plan of 5G city that in line with digital development for a national economic and social development plan.

Strategy:

- Develop a national criterion for high quality 5G City.
- Build a 5G City models that embrace quality of life.
- Build a 5G City model that refine governance and Industrial sector.
- Develop advanced criteria to support a long-term sustainable and inclusive 5G City plan.

Based on the 5 G City development goals, 4 key development projects that complement each other have been identified. These flagship projects will pave the way for Thailand to have an effective 5G City that can satisfy the demand of the public and private sectors. The following are the 4 flagship projects:

- Flagship Project 1: The Development of Criteria for 5G Network for 5G City Certification
- Flagship Project 2: The Development of Pilot 5G Livelihood City

- Flagship Project 3: The Development of Pilot 5G Governance and Industrial City)
- Flagship Project 4: The Development of Long-Term 5G City Plan

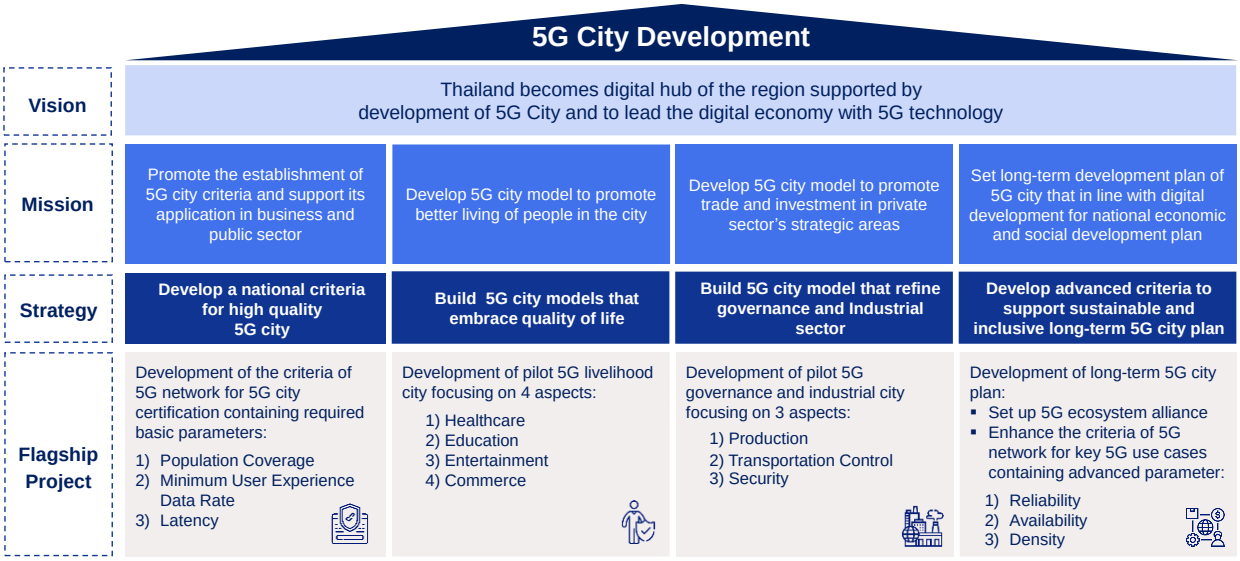


Figure 5-1: Overview of the Development of 5G City

5.2 Scope of 5G City Development

The scope of 5G city development is divided into three dimensions: 1) Network: the network should cover 5G City area and capable in supporting fundamental determinants of Basic and Advanced parameter of use cases 2) Area: the development of 5G city should considering strategic areas in the first step 3) Service: 5G city requires to have intelligent services to be able to support the demand of various industries which will unlock the growth of the city.

Figure 5-2: Scope of 5G City Development

5.2.1 Strategic Areas for 5G City Development

Areas in Thailand that have the potential to develop into a 5G city in the future can be divided into 5 areas as follows:

1. **Bangkok** is the capital of Thailand with a total area of 1,568.74 square kilometers and has a population registered as of December 2020, at about 6 million.[26] At present, most of the area have already been covered with commercial 5G signal services by many telecommunication operators such as TRUE and AIS. Designating Bangkok as the main area for 5G city development is in line with the NBTC's announcement on criteria and methods for licensing spectrum for international mobile telecommunication services that requires the licensee who use the 2600 MHz spectrum to establish a network to provide a telecommunications network for business and telecommunications services covering the economic center city, such as Bangkok and other important areas. Therefore, Bangkok is considered an economic center area that is ready for further development as a pilot area to develop a 5G city as an example for other areas that want to develop into a 5G City as well.

2. **Eastern Economic Corridor (EEC)** is a special economic zone located in the eastern seaboard of the Gulf of Thailand, which is considered an important economic area of the country. It covers an area of three provinces, namely Chachoengsao, Chonburi, and Rayong, totaling an area of 13,266 square kilometers, where more

[26] Source: Office of the Board of Investment

than 80 percent of the 5G base station has been installed.[27] The EEC area will be the focus for developing a smart city, which is a city that uses information technology systems, both IoT and innovation, to manage the city to increase the efficiency of urban development and boots the digitalization for the social economy by driving the use of 5G technology both in business sectors such as the industrial, hotels, government agencies, and communities to apply advantage of 5G technology. It is considered an important area in the development of 5G cities.

3. **Smart City** is a city that uses cutting-edge, smart technology and innovation to improve the efficiency of city services and management, as supported by the Digital Economy Promotion Agency (DEPA), which requires cities with the goal of building smart city to make a proposal to the Smart City Office so that the city can be identified as a smart city promotion zone. As of August 2021, there are a total of 47 smart cities in 30 provinces which consists of 1) 42 smart city promotion zones and 2) 5 smart cities as follows:
    - **Mae Moh Smart City** by Electricity Generating Authority of Thailand (EGAT) in Mae Moh District, Lampang Province, covering an area of 860 square kilometers.
    - **Phuket Smart City** by Phuket provincial office covering all areas of the province to develop into a sustainable tourism city.
    - **Khon Kaen Smart City** by Khon Kaen provincial office covering all areas of the province, focuses on making Khon Kaen a smart livable city.
    - **Sam Yan Smart City** by the Property Management Office Chulalongkorn University covering an area of approximately 0.7 square kilometers in Suan Luang-Samyan, National Stadium, Siam Square and Chamchuri Square.
    - **Wangchan Valley Smart City** by PTT Public Company Limited in Pa Yup Subdistrict Wang Chan District, Rayong Province, which has a total area of 3,454 rai, has the goal of becoming the Eastern Economic Corridor Innovation Zone or EECi.

Therefore, the development of 5G City is comparable to a goal that builds on the development of smart cities as 5G network and infrastructure are the foundation of smart city services.

[27] Source: News Release, Eastern Economic Corridor Development Project

4. **Innovation City** is an innovation-intensive district sponsored by the National Innovation Agency (NIA) as an innovation-intensive area with innovative contributors focused on the demands of local people to create added value, allocate resources, and increase the participation of local. NIA has partnered with the area, businesses, and local people to create the participant of every sector in the area to drive innovation-related business development. This is in line with the goal of developing 5G City, which is the introduction of 5G technology into cities to improve the living and economy of the area and meet the needs of residents. Therefore, it is another suitable area to be developed as a 5G city. NIA has classified spatial innovation into 3 levels as follows:
    - **Innovation District** is an area/community that can easily travel to each other and operates business in the same group. At present, there are 6 innovation districts in Bangkok, 4 innovation districts in the EEC area, and 3 innovation districts in Phuket, Khon Kaen, and Chiang Mai.
    - **Innovation City** is an area where many districts come together to form a unique urban identity. Currently, NIA supports two major innovation cities: Bangkok and Chiang Mai.
    - **Innovation Corridor** will cover many innovation cities that Thailand is trying to make the EEC area an innovation corridor. In addition, NIA plans to expand innovation corridor to the northern region (from Chiang Mai to Phitsanulok) and in Northeast region (from Khon Kaen to Nakhon Ratchasima).

    These innovative cities are already included in other strategic areas that have the potential to develop a 5G city, such as Bangkok or the EEC.

5. **Special Economic Zone (SEZ)** is an economic area on the border under the strategy to promote the utilization of the Economic Corridor Project to transform the transport corridor into the Economic Corridor by emphasizing border areas that have trade contacts with neighboring countries to spread prosperity throughout the region and improve people's income and quality of life as well as increase regional competitiveness. The implementation of this technology at the border will result in increased communication capabilities in remote areas, which will make trade more secure using automated surveillance and other related technologies. As a result, this special economic development zone can be considered another important area in the

development of the border region to become a 5G city to support trade with neighboring countries and improve the livelihood of people in the border area. The SEZ zone has been established in 10 provinces, with a total area of 6,220 square kilometers namely,

- **Tak Special Economic Zone**: 14 sub-districts in 3 border districts, namely Mae Sot District, Phop Phra District, and Mae Ranat District.
- **Mukdahan Special Economic Zone**: 11 sub-districts in 3 border districts, namely Muang District, Wan Yai District, and Don Tan District.
- **Sa Kaeo Special Economic Zone:** 4 sub-districts in 2 border districts, namely Aranyaprathet and Watthana Nakhon
- **Trat Special Economic Zone:** 3 border area sub-districts in Khlong Yai District
- **Songkhla Special Economic Zone:** 4 border area sub-districts in Sadao District
- **Nong Khai Special Economic Zone:** 13 sub-districts in 2 border districts, namely Mueang District and Sa Krai District
- **Narathiwat Special Economic Zone:** 5 sub-districts in 5 border districts, namely Muang District, Tak Bai District, Yi Ngo District, Waeng District and Su-ngai Kolok District
- **Chiang Rai Special Economic Zone:** 21 sub-districts in 3 border districts, namely Mae Sai District, Chiang Saen District and Chiang Khong District
- **Nakhon Phanom Special Economic Zone:** 13 sub-districts in 2 border districts, namely Mueang District and Tha Uthen District.
- **Kanchanaburi Special Economic Zone:** 2 sub-districts in Mueang District.

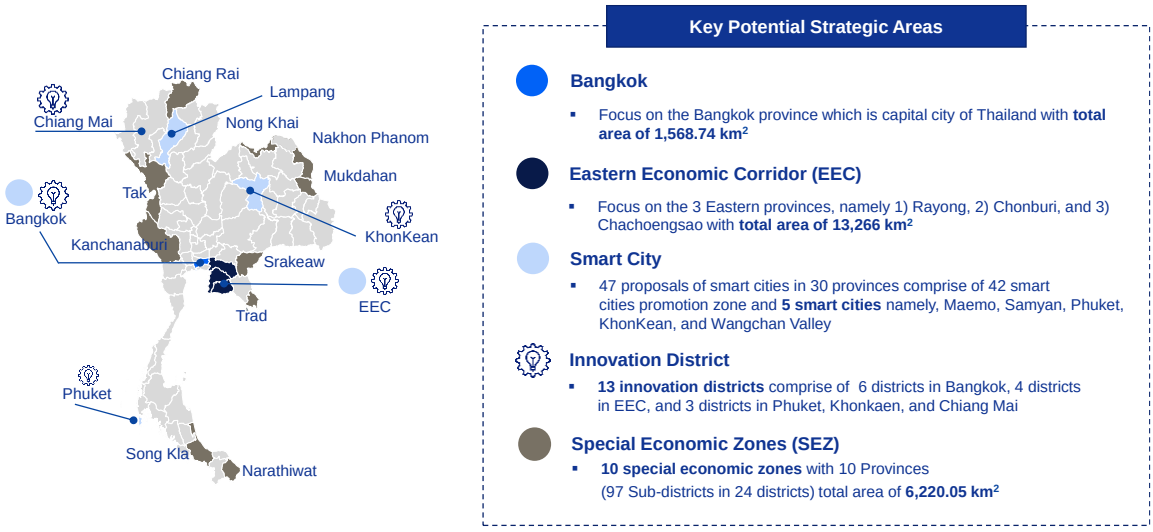


Figure 5-3: Key Potential Strategic Areas for 5G City

5.2.2 Services in 5G City

The services that have gained traction and should be developed in 5G City are those that are in accordance with the city's development guidelines and objectives. However, in each city development model there are use cases that have different demands from different sectors to use as an example of 5G City development which can be divided into 2 groups:

- **5G Livelihood City** focuses on developing services related to improving the lives of people in the city, tourist, and industrial groups covering various service groups related to improving people's quality of life, such as education services (5G Education), commercial services (5G Commerce), housing services (5G Home), entertainment services (5G Entertainment), public health services (5G Healthcare), and agriculture service (5G Agriculture).
- **5G Governance and Industrial City** focus on the development of services related to government services for residents, tourist, and industrial groups covering various service groups related to the development of government and industrial security, such as production services (5G Production), transportation control services (5G Transportation Control), security services (5G Security), tourism services (5G Tourism), and travel services (5G Traveling).

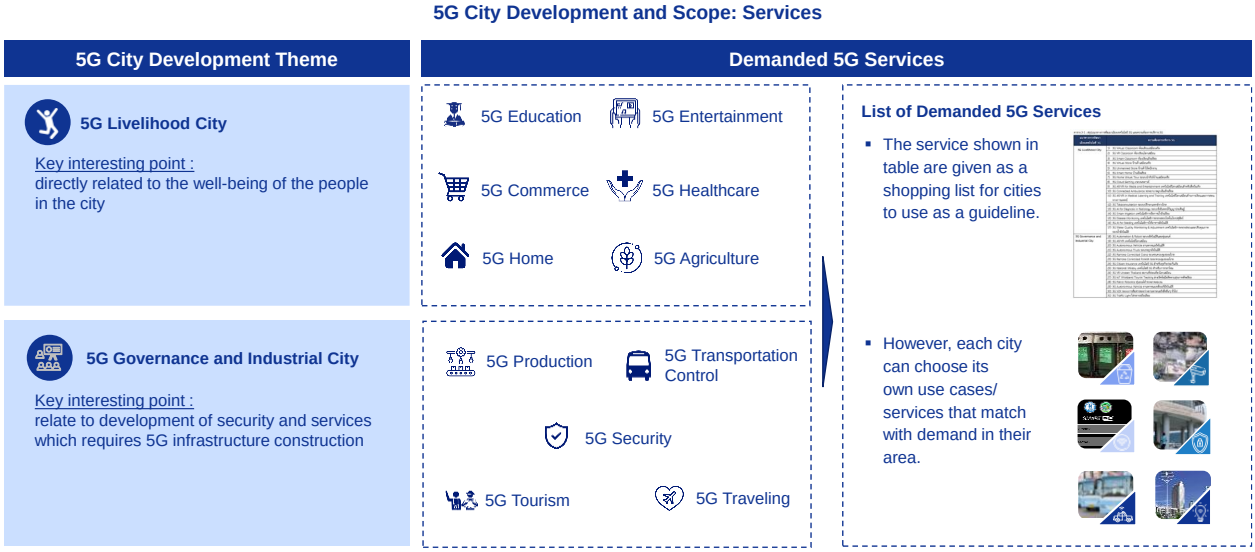


Figure 5-4: Service Identification in 5G City's Methodology

The demand for services in Thailand's 5G City could be summarized into 31 fundamental services based on the development of these two services, as detailed in Chapter 3.3, Summary of Guidelines for the Development of Services in 5G City. However, the service

described above is only an example of a preliminary service for those interested in creating 5G city; however, in the real 5G city development, the area can select other services that also meet the city development objectives.

5.2.3 Network in 5G City

5G City requires efficient infrastructure and networks to implement a diverse variety of smart services. The need for networks in 5G City will be divided into two categories as follows:

- **Basic Parameter** is the basic requirement that 5G networks in 5G City need to be able to support services in various areas of the city.
  - **Percentage of Population Coverage** because it is a preliminary criterion that can demonstrate that the local population can use the 5G network comprehensively in that area if there is a need for use in both public and private areas, as well as ensuring that businesses in an area that needs to use 5G networks can also do the same because it already covers majority of the population.
  - **Average User Experience Data rate** which can be divided into Uplink/Upload (or traffic from the device to the network) and Downlink/Download (or traffic from the network to the device) is critical because it is required to be able to connect to network equipment in real-time for industrial use or public services connection speed. As a result, speed is another key criterion for 5G networks.
  - **Latency** has a significant impact on services that require highly stable data transmission capabilities, which are a hallmark of 5G network deployments, such as data transmission between devices in an industrial production line, autonomous vehicle, or equipment that operates 24 hours a day with high accuracy. Service disruption will occur if the network does not have sufficient latency.
- **Advance Parameter** is an additional requirement of 5G network that depends on each use case
  - **Reliability:** stable connection for services that require remote device control or services that need to run 24/7 without network outages or interruptions.
  - **Availability:** the ability to support the use of devices that need to use the network concurrently at a specific point in time.
  - **Density:** since the area in 5G City have many IoT devices connected to the network, the network should be capable of supporting the connection density which will

allow the transmission of data between the large number of devices without interruption.

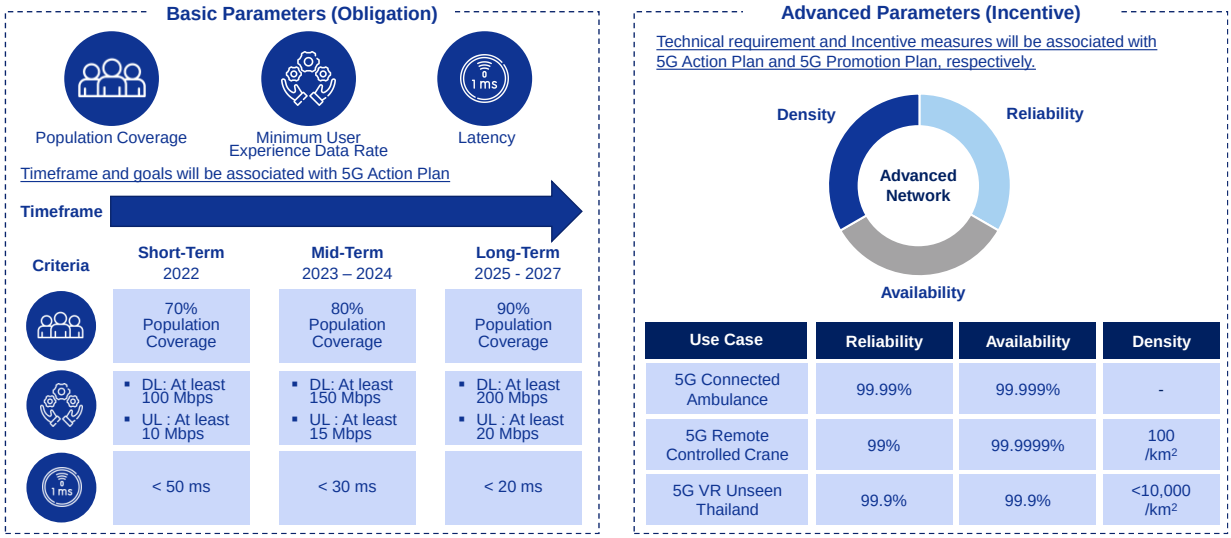


Figure 5-5: Network in 5G City

5.3 Proposal of Development Plan for 5G City

It is critical to develop a 5G city in Thailand by utilizing modern technology to produce smart services that can assist the alleviation of Thailand's problems and meet the requirements of the government, people, and industry sectors, as well as to use digital technology to drive Thailand towards the developed countries with stability, prosperity, and sustainability. The 4 flagship projects will lead Thailand to become a more efficient 5G City able to meet the demands of local people and industries. The following is an overview of each flagship project:

5.3.1 Flagship Project 1: The Development of Criteria for 5G Network for 5G City Certification

Rational Criterion

Currently, the development of smart cities that use technology to improve the quality of people's lives and city management, is an important policy in Thailand's social and economic growth. For such a development to be successful, Thailand must have a comprehensive communication system and a high-speed internet network as an intermediary. Therefore, 5G technology has been considered as a critical factor in the enhancement of smart cities to become 5G City by using its ability to support massive amounts of data transmission

and extremely low latency. As a result, the development of 5G City plays an important role in driving Thailand's forward, which is based on a high-quality and comprehensive 5G network for encouraging the full utilization of 5G technology to provide smart services in a wide range of industrial sectors and motivating the development of 5G technology networks criteria.

Target

Thailand has established 5G network criteria for 5G City to accelerate the development of high efficiency 5G City with a comprehensive network that capable of providing smart services and managing cities. This would increase the accessibility to smart services and enable Thailand to become a leader and be a role model in the development of 5G City in the ASEAN region.

Scope of work

The implementation of flagship project 1: The development of criteria for 5G network for 5G City certification consists of 2 main parts, 1) 5G City network criteria and 2) 5G City Certification with details as follows:

1) **The definition of 5G City network criteria** will consist of **basic parameters** as the basic requirements of the 5G network in the city. The criteria consist of the following factors: 1) Population Coverage 2) Average User Experience Data Rate, and 3) Latency. The network criteria for 5G City will be determined according to each period: a short-term plan in 2022, a mid-term plan in 2023-2024, and a long-term plan in 2025-2027, with the details as follows:

Table 5-1 : Scope of network criteria for 5G City according to flagship project 1

Basic Technical Factor	Short-Term (2022)	Mid-Term (2023-2024)	Long -Term (2025-2027)
Population Coverage of 5G Network	70 percent of the population in ▪ Bangkok ▪ EEC	80 percent of the population in ▪ Bangkok ▪ EEC ▪ Smart Cities from 12 provinces in 4 regions	90 percent of the population in ▪ Bangkok ▪ EEC ▪ Smart Cities from 36 provinces in 4 regions ▪ SEZ

Basic Technical Factor	Short-Term (2022)	Mid-Term (2023-2024)	Long -Term (2025-2027)
Average User Experience Data Rate	▪ D/L: at least 100 Mbps ▪ U/L: at least 10 Mbps	▪ D/L: at least 150 Mbps ▪ U/L: at least 15 Mbps	▪ D/L: at least 200 Mbps ▪ U/L: at least 20 Mbps
Latency	▪ Lower than 50 ms	▪ Lower than 30 ms	▪ Lower than 20 ms

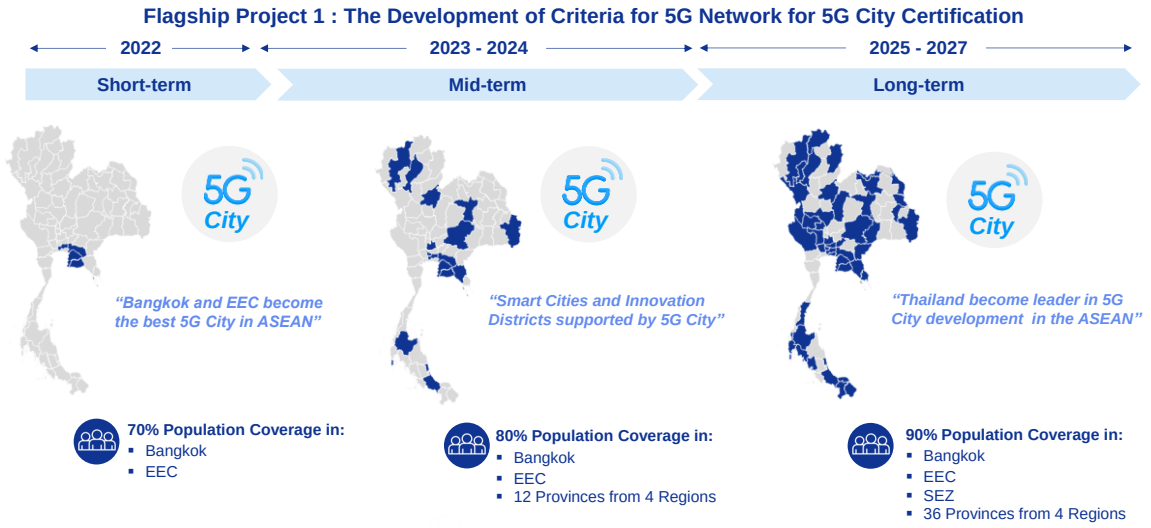


Figure 5-6: Scope of network criteria for 5G City according to flagship project 1

2) **The consideration for awarding 5G City certification** is to utilize 5G City network criteria as a standard for awarding 5G City certification to cities and telecom operators that have deployed an efficient 5G network in accordance with the defined criteria. The granting of the government's certification assures the area's credibility, which provides confidence to private sectors, leading to investments in the area. The awarding of 5G City certification can be driven by the Office of the National Digital Economy and Society Commission (ONDE) that collaborates with other related organizations such as the Office of the Broadcasting Commission and Telecommunications Commission (Office of the NBTC), telecom operators, and other local government agencies for providing 5G City certification to cities that meet the defined criteria.

Project Guidelines

- Discuss and collaborate with the Office of the Broadcasting Commission and Telecommunications Commission (Office of the NBTC) to implement the

development of cities and publish the 5G network criteria for awarding 5G City certification to cities and telecom operators that meet the defined criteria.

- Collaborate with telecom operators and local government agencies in areas that have the potential to drive and implement high-performance 5 G network deployment to develop into 5G City.
- Evaluate the performance of 5 G networks for awarding the 5G City certification to cities and telecom operators that meet the defined criteria.
- Follow-up and evaluate certified 5G cities to continue the improvement to be able to develop more efficiently in the future.

Responsible Agency

- Main agency: ONDE
- Supported agency: NBTC, DEPA, Bangkok, EEC, and PAO

Related agencies

- Telecom operator
- 5G Technology solution provider

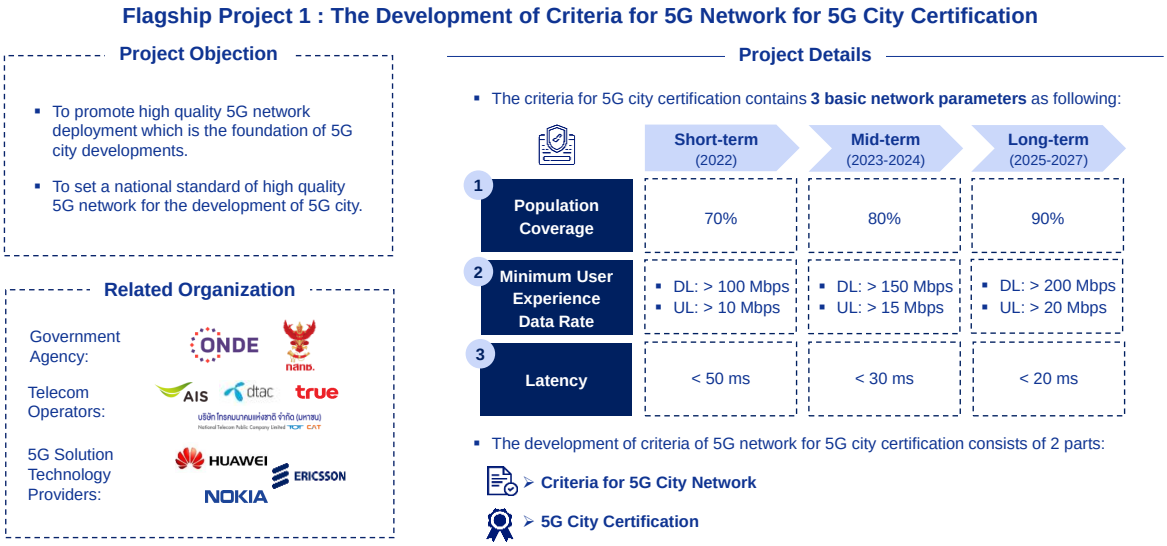


Figure 5-7: Flagship 1: The Development of Criteria for 5G Network for 5G City Certification (1)

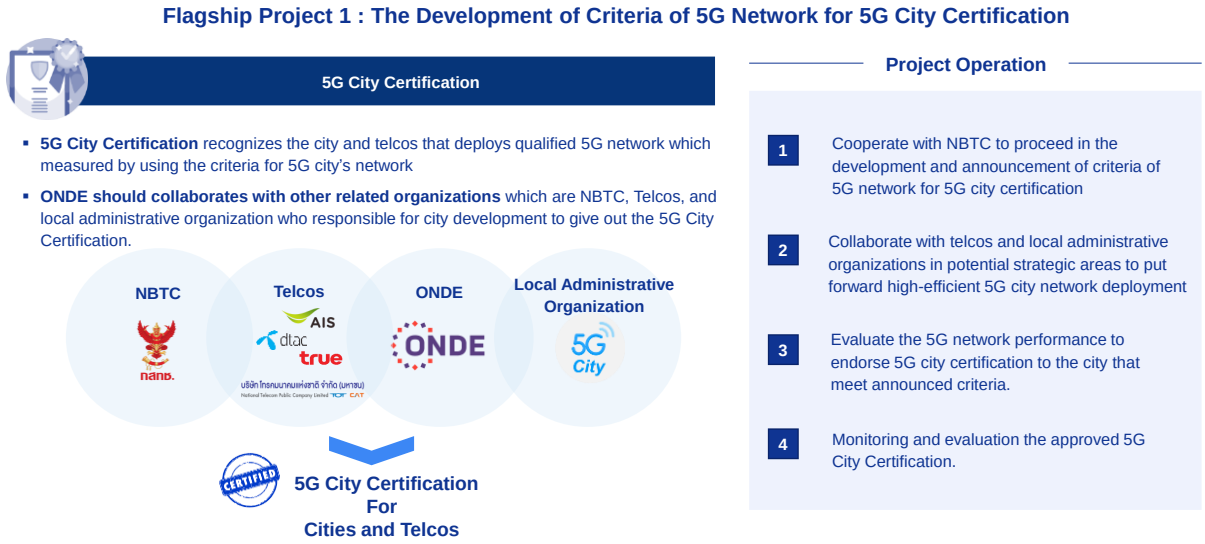


Figure 5-8: Flagship 1: The Development of Criteria for 5G Network for 5G City Certification (2)

5.3.2 Flagship Project 2: The Development of Pilot 5G Livelihood City

Rational Criterion

Currently, the smart services related to the quality of people's lives are still unable to optimize their performance due to network limitations of 5G technology that is a high-quality modern communication technology that will contribute to enhance the capabilities of smart services that affect people's lives by connecting devices and providing access to unlimited data. Furthermore, the development of the pilot area is an important factor in developing the other areas as well. As a result, the pilot area should be characterized by diverse categories that include a combination of residences, educational institutions, shopping malls, and hospitals, as seen in Bangkok. This can be considered a densely populated area suitable for development as a 5G City pilot area for improving the quality of people's lives that can be able to meet the requirements of the people sector.

Target

Develop a 5G City to be a pilot 5G City for improving the quality of people's lives to encourage better living in various fields, such as education, public health, commerce, or entertainment, etc. In addition, each development aspect must include examples of smart services that are on-demand services in the target area to demonstrate the guidelines for the development of smart services within the pilot city.

Scope of work

The implementation of flagship project 2: the development of pilot 5G livelihood city is the development of smart services by bringing in technology to enhance the city's potential. It is necessary to develop comprehensively in various fields to meet the requirements of the people in the area, as detailed below.

1) **Education sector:** the utilization of smart services to develop education for improving accessibility and teaching quality by providing smart services such as the 5G Virtual Classroom, which serves as a model for 5G smart services in the education sector.
2) **Public health sector:** bringing smart services to fulfill the demand for public health services such as doctor's visits and disease screenings, as well as becoming a center hospital with providing smart services such as 5G Teleconsultation to serve as a pilot for 5G smart services in public health.
3) **Commerce sector:** adopting smart services to improve the convenience of trading as well as support to solve the problem of personnel shortages and increasing the attentiveness of shop owners by bringing 5G smart services such as 5G Unmanned Store as a commercial 5G smart service model.
4) **Entertainment sector:** bringing smart services to improve the entertainment business, which is a high-demand industry in Thailand, through the use of 5G smart services to increase the variety of entertainment media, such as 5G AR/VR for Media and Entertainment, which will become a pilot for 5G smart services in the entertainment sector.

Project Guidelines

- Identify the target areas that should be developed into 5G cities for improving the quality of people’s lives, which the target area is expand from the development of Smart City and Innovation District by enhancing the smart service capabilities to unleash the potential to become a 5G Livelihood City.
- Recruit partners from both the public and private sectors to jointly develop the 5G Livelihood City pilot model.
- Establish a working committee for a pilot city development.
- Draft the development plans and planning an operation for establishing a pilot 5G Livelihood City.

- Test the deployment of smart services through high-performance 5G networks to get feedback and improve the development process more effectively.
- Implement smart services in targeted areas for the development of 5G Livelihood City.
- Evaluate the implementation of smart services to improve more efficiently, including the development guidelines that can be utilized as a model for the development of other cities in the future.

Responsible Agency

- Main agency: ONDE
- Supported agency: Bangkok, District office, Ministry of Commerce, Department of Internal Trade, Ministry of Education, Ministry of Higher Education, Science, Research and Innovation, Ministry of Public Health, and Department of Medical Services

Related agencies

- Telecom operator
- 5G Technology solution provider
- Other private entities in the area

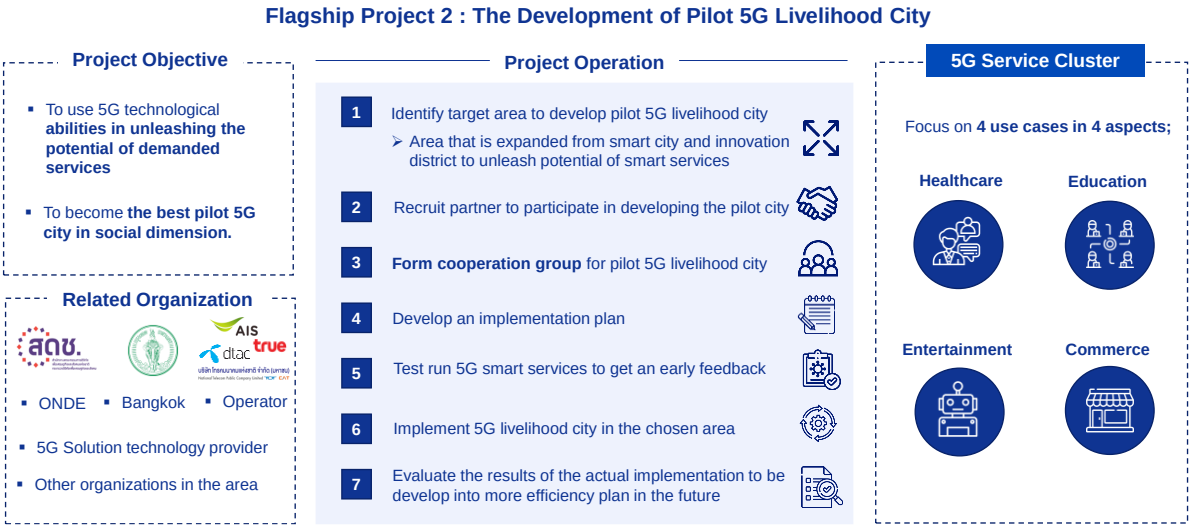


Figure 5-9: Flagship Project 2: The Development of Pilot 5G Livelihood City (1)

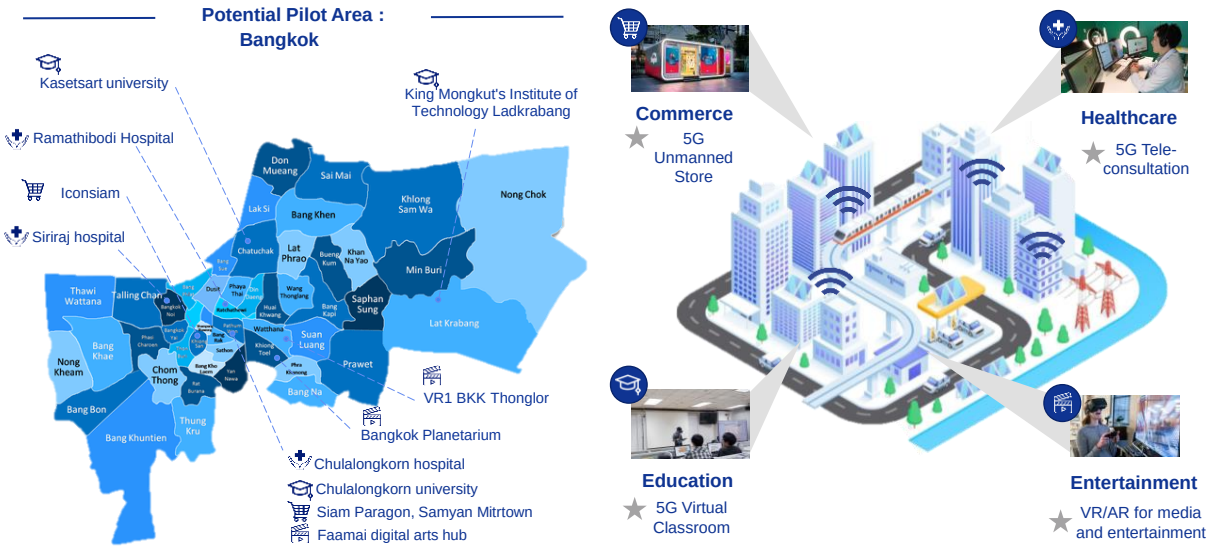


Figure 5-10: Flagship Project 2: The Development of Pilot 5G Livelihood City (2)

5.3.3 Flagship Project 3: The Development of Pilot 5G Governance and Industrial City

Rational Criterion

Nowadays, digital technology has been critical to Thailand's economic progress. This is in line with the government's strategy, which calls for Thailand to embrace digital technology as a tool and critical mechanism for driving and functioning in various processes, with the potential for 5G technology to provide a strong point capable of satisfying the demands of various government and industrial sectors. Additionally, the development pilot area is crucial for the development of the pilot city, as it enables the development of other areas as well. As such, it should be defined as a combination of industrial estate, transportation hub, and proximity to tourist attractions such as the Eastern Economic Corridor (EEC), which is regarded as the country's primary economic zone, making it suitable for development as an economic pilot area for the purpose of becoming a 5G Governance and Industrial City. Nevertheless, if network coverage is expanded in the area, a high-quality 5G network will enable the area to be transformed into a 5G City, leveraging various technologies to enhance the business sector's competitiveness to the point where it could attract investment from entrepreneurs in Thailand and overseas. This will entail improving people's livelihoods and business operations in that area.

Target

Develop a 5G City for Thailand to serve as a pilot 5G city for governance and industry in order to sustainably drive the economy and increase private investment by leveraging the

potential and prominence of 5G technology to meet the demands of smart services in a variety of sectors such as transportation control, manufacturing, and security. Additionally, examples of smart services that are on-demand services must be included in each development area to demonstrate the guidelines for the development of smart services within the pilot city.

Scope of work

Implementation of flagship project 3: the development of pilot 5G Governance and Industrial City is the development of smart services by bringing in technology to develop the city potential. However, in order to become a city, it is necessary to develop comprehensively in many sectors to meet the demands of the people in the area which have details as follows.

1) **Production Sector:** the use of smart services to accelerate the adoption of technology in the industrial sector in order to increase competitiveness and attract investors. Smart services such as 5G Autonomous Vehicle and 5G Autonomation & Robot serve as prototypes for 5G production services.
2) **Transportation Control Sector:** the use of smart services to promote more effective freight forwarding and cost savings in the logistics process by bringing 5G smart services such as 5G Remote Controlled Crane to be used in the port area as a pilot for 5G smart services in transportation control.
3) **Security Sector:** the use of smart services in tourist attractions and other related locations to enhance surveillance of danger or crime to the public by piloting 5G smart services such as 5G Patrol Robotics.

Project Guidelines

- Determine which locations should be developed into 5G Governance and Industrial City. The area to be built is an extension of development from Thailand's major economic areas, utilizing enhanced smart service capabilities to unlock the potential for establishing a 5G Governance and Industrial City.
- Recruiting partners from both the public and private sectors to jointly develop the 5G Governance and Industrial City.
- Establish a working committee for the development of a pilot city.
- Drafting the development plans and planning an operation for establishing a 5G Governance and Industrial City.

- Test the deployment of smart services through high efficiency 5G networks to get feedback to be able to improve the development quicker.
- Implemented smart services in targeted areas for the development of 5 G Governance and Industrial City.
- Evaluate the implementation of smart services to improve efficiency in the future including the development guidelines to be used as a model for the development of other cities in the future.

Responsible Agency

- Main agency: ONDE
- Supported agency: Municipality, EEC, Ministry of Industry, Ministry of Interior, Ministry of Tourism & Sports, Tourism Authority of Thailand

Related Agency

- Telecom operator
- 5G Technology solution provider
- Other private entities in the area

Figure 5-11: Flagship Project 3: The Development of Pilot 5G Governance and Industrial City (1)

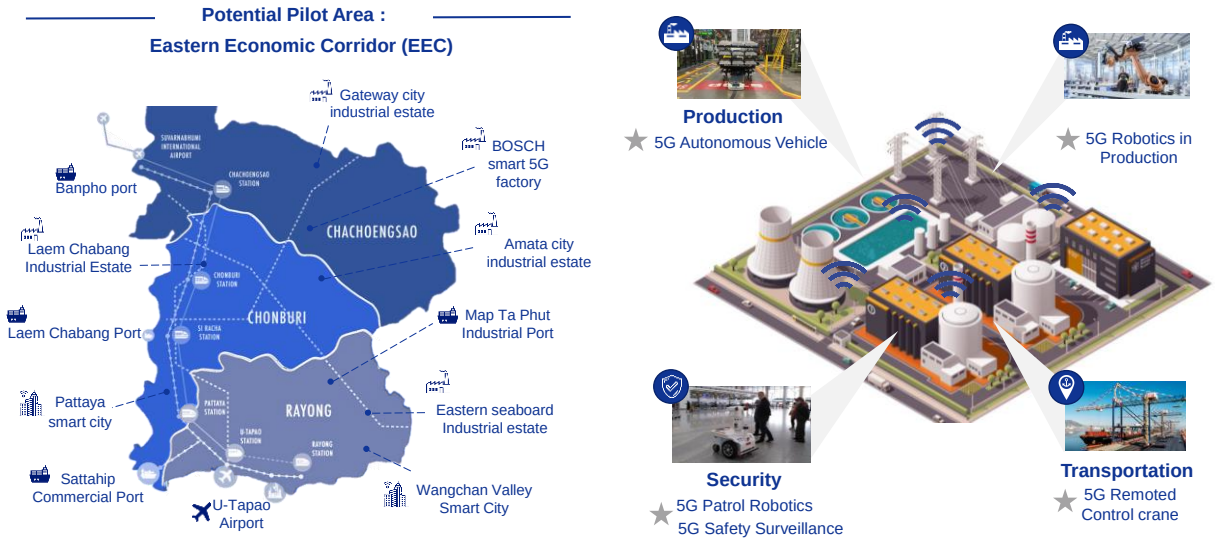


Figure 5-12: Flagship Project 3: The Development of Pilot 5G Governance and Industrial City (2)

5.3.4 Flagship Project 4: The Development of Long-Term 5G City Plan

Rational Criterion

5G City should be driven and developed continuously and sustainably to be in line with the policy to develop Thailand into a country that can create and utilize digital technology to its fullest potential to drive economic development and society of Thailand towards stability, prosperity, and sustainability. Smart services must be used as a primary tool for managing the country as well as to create innovations in production and services by applying full potential of 5G technology. As a result, the development of the most efficient 5G technology network is an important aspect of effective 5G City, which must consequences from the integration of cooperation between stakeholders in the 5G technology ecosystem, both public and private sectors, to jointly formulate guidelines and efficiently drive the development of 5G City. Therefore, developing a clear long-term plan for the development of 5G City in Thailand is critical.

Target

Thailand has established clear guidelines for developing a sustainable 5G City, which will result from the integration of cooperation among stakeholders in the 5G technology ecosystem, as well as the formalization of advanced network standards, in order to propel Thailand into a 5G City capable of providing smart services that use the capabilities of 5G technology to meet the demands of various sectors.

Scope of work

Implementation of flagship project 4: The development of long-term 5G City plan consists of 2 main parts which are 1) the establishment of the 5G Ecosystem Alliance and 2) the establishment of advanced network criteria for 5G City, with details of the scope of work as follows:

1) **The establishment of 5G Ecosystem Alliance** is a collaborative group that helps drive the development of 5G City from government policy to action from the private-sector activity. Members of the 5G Ecosystem Alliance are all participating in the 5G ecosystem, whether they are government agencies or private sector entities such as telecommunication service providers, 5G technology solution providers and private associations, etc.
2) **The establishment of advanced network criteria for 5G City** which includes determining advanced parameters based on particular use cases or smart services, such as reliability, availability, and density. These are extra 5G network requirements. The following are some examples of advanced technical aspects necessary in smart services.

Table 5-2 : Examples of Advanced Technical Parameters Required for 5G Use Cases

Use Case	Reliability	Availability	Density
5G Teleconsultation	99%	99.99%	-
5G Virtual Classroom	99%	99.9%	<10,000/km^2
5G Remote Control Crane	99.99%	99.9999%	<172/km^2
5G Autonomous Vehicle	99.99%	99.9999%	-

However, the development of 5G Private Networks is another approach that helps drive network development in accordance with advanced network parameters, which vary depending on the use case being deployed, because 5G Private Networks enable 5G network technology to have a high level of connection stability (Ultra-Reliability) greater than 99.99 percent, high performance in terms of service user data transmission (Uplink/Upload), and low latency, resulting in a better response time. Additionally, 5G Private Networks can effectively secure enterprise data because they adhere to the Network Equipment Security Assurance (NESAS) policy[28], which defines the security fundamentals and security assessment approaches necessary to protect against external network connections that attempt to invade

[28] Network Equipment Security Assurance Scheme (NESAS), GSMA

access to internal data. The features of 5G Private Network will enable 5G City to fully recognize the benefits of smart services by establishing innovative device connections in diverse industries and enterprises with the highest levels of security and efficiency. These connections can be customized and adapted to the unique needs of each industry group, particularly those that provide services or produce products for a specific group (Vertical Industry), such as manufacturing and automobile, etc.[29]

Each organization can benefit from implementing a private network by simplifying, cutting expenses, and shortening the time-consuming process of developing and installing networks.[30] Another critical issue to consider is the investment's cost and return on investment, as well as the ease and speed of operation that will enable the company to operate at peak efficiency. Numerous countries' research indicated that enterprises would prefer to set up private networks established by telecommunication service providers rather than by themselves due to lower investment, lower maintenance, and the ability to operate cheaply and rapidly.

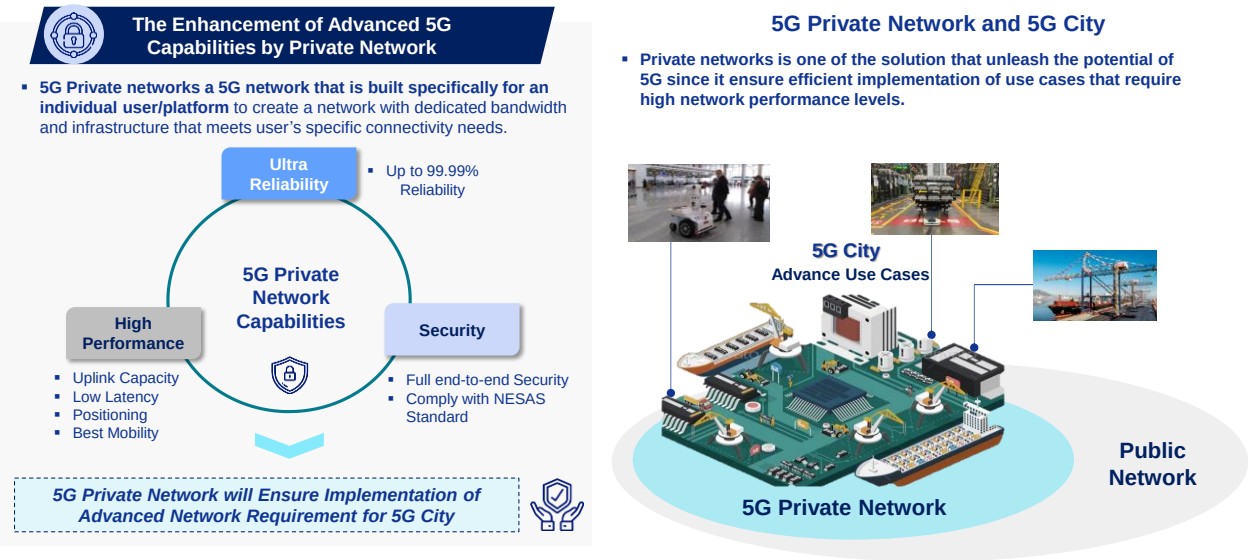


Figure 5-13: 5G Private Network

[29] Dtac 5G Private Network กุญแจปลดล็อกอุตสาหกรรมให้ไม่ตกขบวนโลกยุคโควิด, The Standard (2021)

[30] O-RAN an also-ran to Huawei 5G, Asia Times (2021)

Project Guidelines

- Develop and publish criterion of advanced technical network for 5G City that want to utilize each specific use case.
- Establish the 5G Ecosystem Alliance in collaboration with all stakeholders in the 5G ecosystem, including government agencies in all sectors and private sector agencies. for sustainable development.
- Collaborate with telecom operators and other vertical industries to drive and carry out network development in 5G City to meet the advance network criteria of 5G City.

Responsible Agency

- Main agency: ONDE
- Supported agency: NBTC, DEPA, and NIA

Related Agency

- Telecom operator
- 5G Technology solution provider
- Other entities in the ecosystem

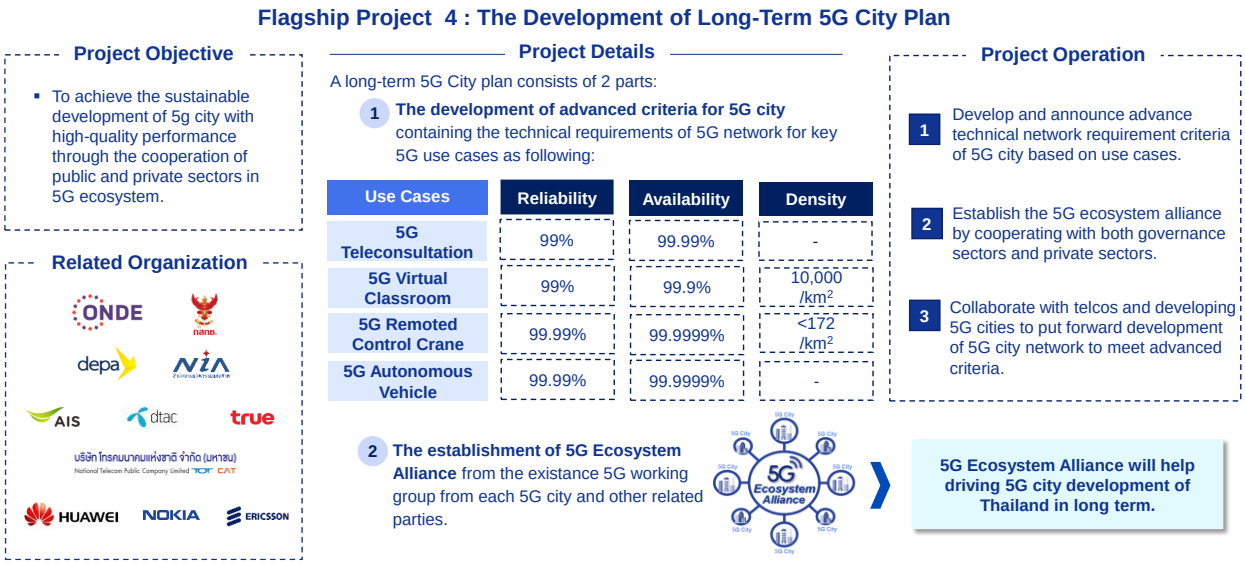


Figure 5-14: Flagship Project 4: The Development of Long-Term 5G City Plan

5.3.5 Summary of 5G City Development Plan

From the 4 flagship projects in the development of 5G City, the development guidelines can be characterized by breaking it into 3 phases, namely a short-term, a mid-term, and a long-term, with an overview of the development target for each phase as follows.:

- **The short-term in 2022**

  Plan to develop 5G City in Thailand's economic hubs in order to provide Thailand with the greatest 5G City in ASEAN and to serve as a model for other countries in the region.

- **The mid-term from 2023 to 2024**

  Plan to expand the coverage and quality of 5G networks in the country's major economic provinces to maximize service potential by leveraging 5G technology's capabilities. Additionally, initiate the creation of 5G cities in each of Thailand's regions.

- **The long-term from 2025 to 2027**

  Plan to build a 5G city covering the entire country and developing in accordance with the city development plan, relying on the coverage and high quality of the 5G network to efficiently drive the economy and society.

The development plan is divided according to each project as follows:

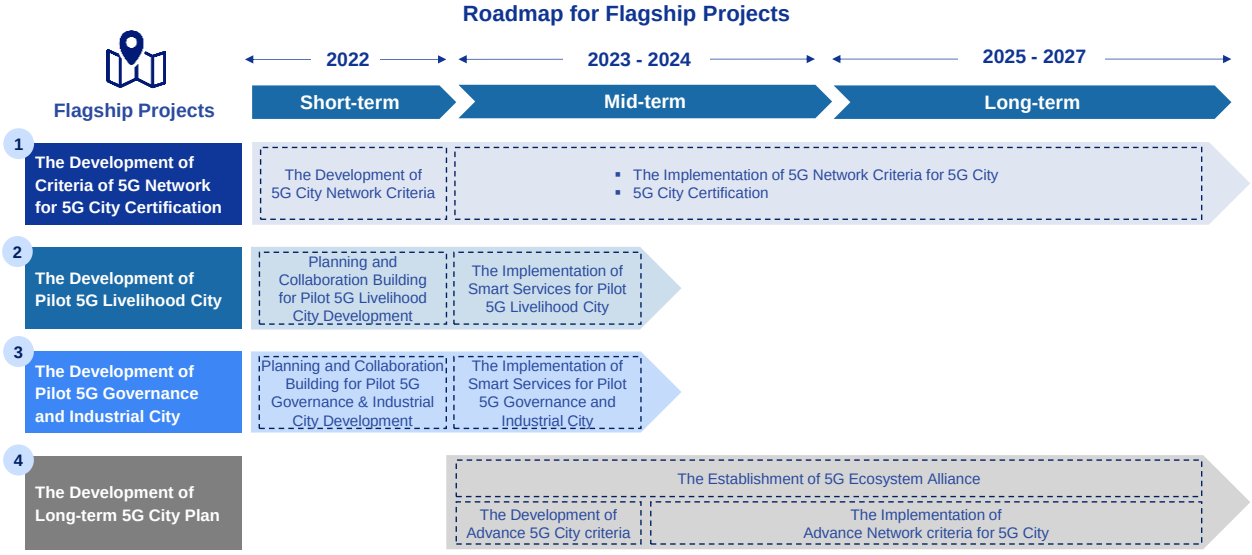


Figure 5-15: Summary of 5G City Development Plan

Flagship Project 1: The Development of Criteria for 5G Network for 5G City Certification

- **The short-term in 2022**

  Set 5G City network criteria to have population coverage at least 70 percent in Bangkok and EEC with basic 5G network requirements at average user experience data rate at least Downlink ≥ 100 Mbps, and Uplink ≥ 10 Mbps as well as latency below 50 ms.

- **The mid-term from 2023 to 2024**

  Set 5G City network criteria to have population coverage at least 80percent in Bangkok, EEC, and smart cities from 12 provinces in 4 regions with basic 5G network requirements at average user experience data rate at least Downlink ≥ 150 Mbps, and Uplink ≥ 15 Mbps as well as latency below 30 ms.

- **The long-term from 2025 in 2027**

  Set 5G City network criteria to have population coverage at least 90 percent in Bangkok, EEC, smart cities from 36 provinces in 4 regions, and SEZ with basic 5G network requirements at average user experience data rate at least Downlink ≥ 200 Mbps, and Uplink ≥ 20 Mbps as well as latency below 20 ms.

Flagship Project 2: The Development of Pilot 5G Livelihood City

- **The short-term in 2022**

  Plan the development plans and operation for establishing a 5G Livelihood City.

- **The mid-term from 2023 to 2024**

  Implement the development plan to become pilot city for improving people's quality of life (5G Livelihood City).

Flagship Project 3: The Development of Pilot 5G Governance and Industrial City

- **Th short-term in 2022**

  Plan the development plans and operation for establishing a 5G Governance and Industrial City.

- **The mid-term from 2023 to 2024**

  Implement the development plan to become pilot 5G Governance and Industrial City.

Flagship Project 4: The Development of Long-Term 5G City Plan

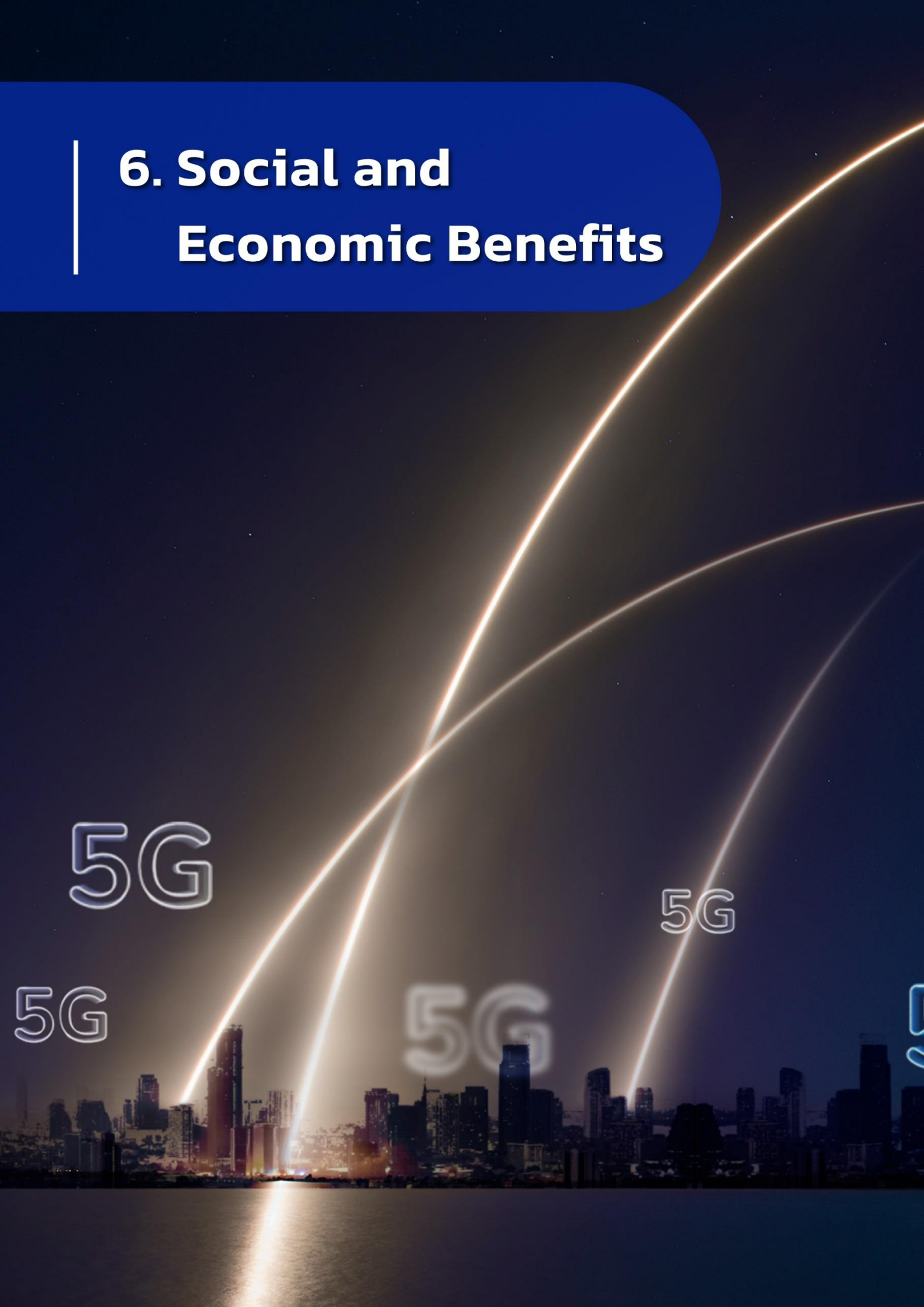
- **Mid-term (2023-2024)**

Establish the 5G Ecosystem Alliance and develop criterion of advanced technical network for 5G City as detailed in clause 5.3.4 and apply to the services available in the area.

- **Long-term (2025-2027)**

  Expand 5G Ecosystem Alliance that help drive the development of 5G City and apply the advanced technical network criteria detailed in clause 5.3.4 to the services available in the area.

6. Social and Economic Benefits



6. Social and Economic Benefits

The success of the 5G city development goal will have an economic and social impact on the targeted areas. As a result, assessing the two mentioned components allows for the demonstration of prospective impacts, and the details can be divided into three operational phases:

- **Identify objectives and scopes of assessment:** specify objectives for considering the social and economic impacts as well as the scopes of the targeted areas under the 5G City development plan.
- **Determine scopes of key indicators assessment**: In order to establish indicators of the effect assessment on the economy and society, the main indicators must first be identified. Following that, the key indicators will be used for evaluation in two dimensions, both of which will collect impact data. The first is the social dimension, which includes things like safety, health, convenience, living conditions, and the environment. The second aspect is the economic one, which includes employment, efficiency, cost-cutting, investment, and business potential.
- **Analyze data and assess in social and economic impacts**: In the case of deciding to develop under a guideline based on one of the development projects, the divided analysis is undertaken according to the flagship project of the 5G City developments to show intendedly impacts.

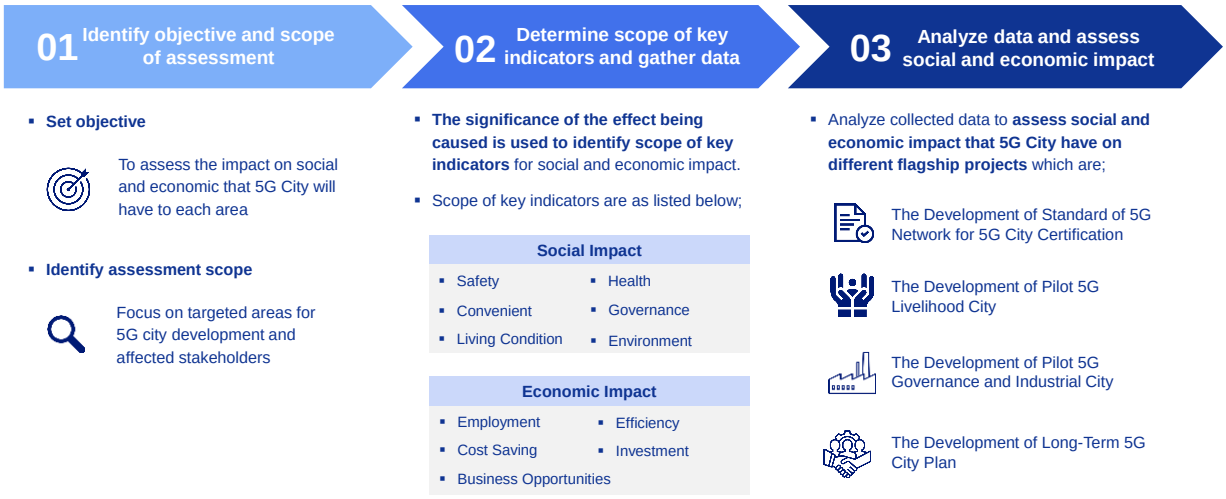


Figure 6-1: Social and Economic Impact Assessment Methodology

6.1 The Economic and Social Impact of 5G City Development

The building of Thailand's 5G metropolis will commence with the deployment of four major projects: 1) The creation of 5G network certification standards for 5G cities 2) Initiation of a 5G Livelihood City Pilot 3) Establishing a 5G governance and industrial city pilot, and 4) establishing a long-term 5G City plan, all of which will have a positive impact on the economy and society in the government, people, and industry sectors. The specifics of the overall economic and social impact are as follows:

Social Impact

Because of the high efficiency and extensive coverage of the 5G network, which can improve the quality of people's lives, resulting in a positive social impact on healthcare, education, security, and the environment, the development of 5G cities will help to improve the potential of smart services for use in many sectors, including the government, the private sector, and the people sector, as detailed below: Because of the high efficiency and extensive coverage of the 5G network, which can improve the quality of people's lives, resulting in a positive social impact on healthcare, education, security, and the environment, the development of 5G cities will help to improve the potential of smart services for use in many sectors, including the government, the private sector, and the people sector, as detailed below:

- **Healthcare: Because high-speed 5G networks will enable real-time and cost-effective teleconsultation smart services, the growth of 5G City will help people gain access to excellent health-care systems.** People's overall health will improve as a result. It can also help with health-care system administration at a lower cost. With a population of 66.8 million people in 2027, at least 31.3 million individuals, or 47 percent of the total population, will be able to use 5G Smart Healthcare services, according to the city development plan.
- **Education: 5G cities will assist students in gaining access to high-quality education,** decreasing educational inequities, and enhancing the quality of teaching and learning, all of which will help students have a better learning experience. According to the city development plan, 5G Smart Education services would provide access to high-quality education to at least 5.4 million students, at 47 percent of all students, with a projected student population of 11.5 million in 2027.

- **Public Safety: 5G City will increase public safety management** efficiency by utilizing 5G technology to boost communications and coordination with related departments in order to assist people in emergency situations more swiftly. involves the development of a surveillance system to improve the city's quality of life.
- **Environment: 5G City development is an important key to promoting an environmentally friendly city that results in sustainable development**, which can support energy-saving management in cities and manufacturing industries that have a positive impact on the environment, as well as the development of production processes to reduce greenhouse gas emissions such as carbon dioxide, and other greenhouse gases.

Economic Impact

- **The development of 5G City will help drive Thailand's economy with digital technology** by utilizing the full potential of 5G technology to improve the competitiveness of business sectors such as transportation, industry, and tourism, among others, which can help improve efficiency in business operations as well as boost investment from both the public and private sectors.
- **Increasing the competitiveness of the business sector,** the 5G City will enable to apply 5G technology for improving business operations more efficiently which can create new business opportunities.
- **Boosting investment for driving the country's economic growth,** the development of 5G cities will optimize investment both in the expansion of the 5G technology network and in the investments for developing smart services from the government, private sectors, and industrial sectors resulting in the improvement of working capital in the country and supporting the economic expansion.
- **Raising employment rate,** the investments in the 5G City development, both 5G network expansion and smart services development which will increase employment opportunities resulting in a lower unemployment rate and can reduce the problem of economic inequality in the country.

- **Increasing productivity and cost-efficient production,** by using high-quality 5G technology to improve production processes which lead to using resources wiser for better production costs management.

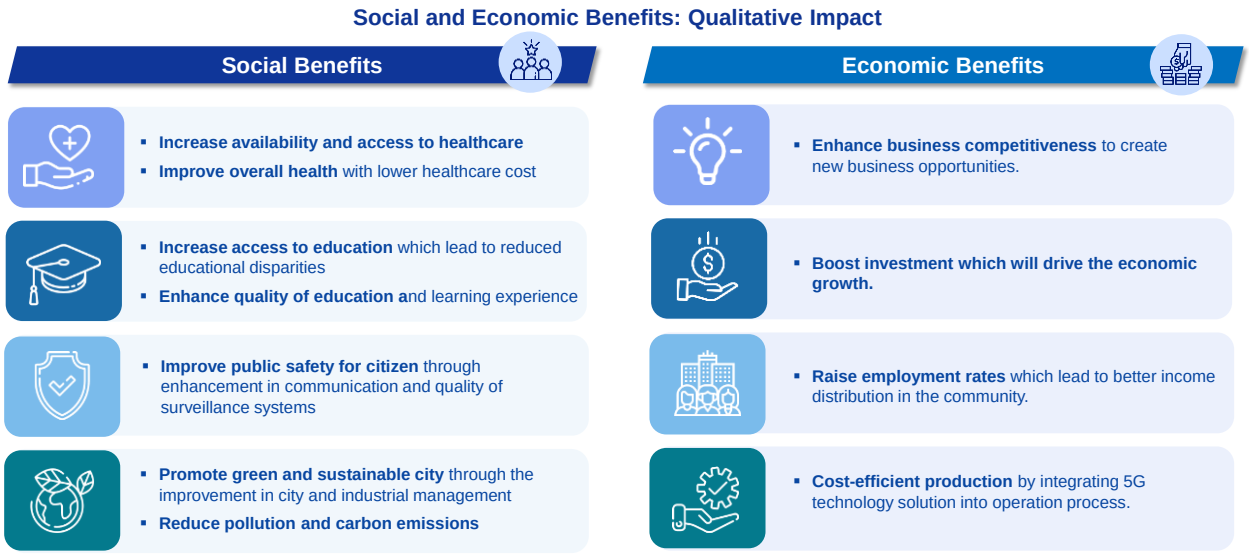


Figure 6-2: Qualitative Impact of 5G City Development (1)

In conclusion, based on the 5G City development framework plan 2022-2024, Thailand will be pushed to become a digital hub of the ASEAN region that fosters economic growth through digital technology. The 5G City development will be able to boost the country's gross domestic product (GDP) growth to around 244,021 million baht in 2027, accounting for more than 1.1 percent of total GDP. **The development of 5G City will improve Thailand's competitiveness and lead to improved performance in global innovation rankings**, such as the Global Innovation Index (GII) or the IMD Digital Competitiveness Ranking, which will lead to increased competitiveness in the ASEAN region, in line with the industry 4.0 policy to encourage the adoption of innovation in the industrial sector. It will also aid development in key areas such as smart cities, special economic zones, and the Bangkok region. The communication network is one of the important development tracks in the smart city development guidelines because of the different smart services in the city that require more effective networks in terms of data transmission, storage, and processing from smart devices. Because 4G technology may be unable to handle the rising demand for IoT devices, 5G technology will become a vital key of city growth, with networks' advantages in many aspects that can make existing services more efficient, affecting people's lives and the economy in cities.

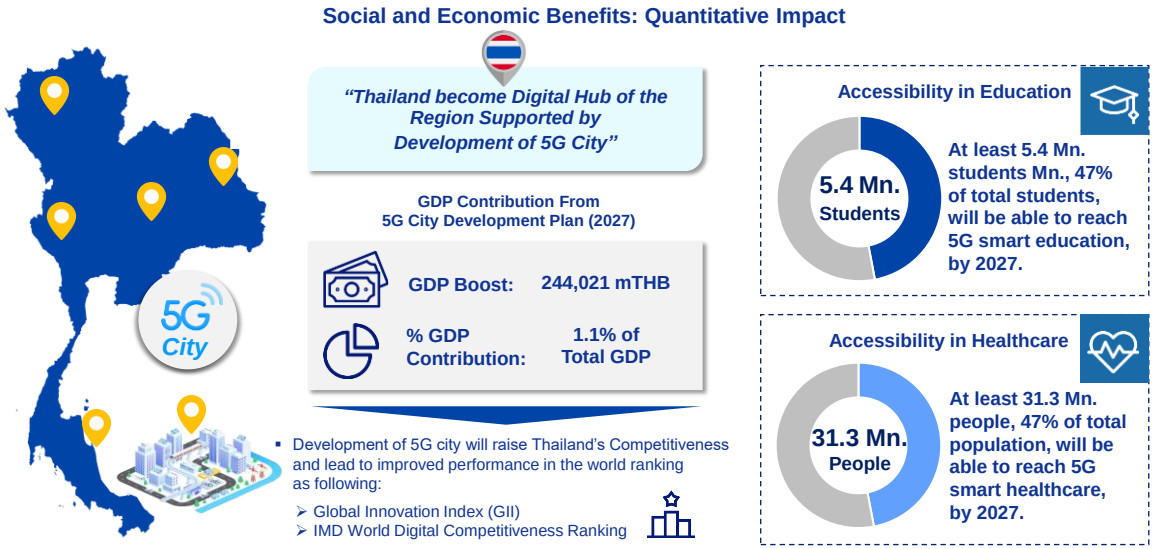


Figure 6-3: Quantitative Impact of 5G City Development (2)

The economic and social impact assessment can be divided into four flagship projects in this regard, 1) The Development of 5G Network criteria for 5G City Certification 2) The Development of Pilot 5G Livelihood City 3) The Development of Pilot 5G Governance and Industrial City, and 4) The Development of Long-Term 5G City Plan as follows:

6.1.1 Flagship Project 1 : The Criteria of 5G Network Development for 5G City Certification

Certifying 5G City's network will lead to effectively increase smart services as well as to accrue accessibility of utilizing services for local people as the establishment of infrastructures and high coverage networks.

In addition, obtaining a 5G City certification will assure an investor confidence to invest in any areas, which can drive the economic growth including improve the quality of people's lives in the areas and to achieve the goals of becoming a leading country, and being a country prototype under a 5G City development model among ASEAN. As a result, there are the positive social and economic impacts in terms of qualitative and quantitative impacts as follows:

Qualitative Impact

Social Aspect

Developing the network criteria of 5G cities will advantageously enhance smart services for many actors namely, governments, citizen, and industry sectors by specifying the criteria of 5G City network and providing 5G City certification, which have a qualitative impact on the social aspect are as follows.

- **Determination of 5G City's network criteria,** plays an important role to encourage the development of high-efficiency 5G cities which adhere to factors of basic network requirements as follows: 1) Population Coverage, 2) Average User Experience Data Rate, and 3) Latency, which enhance beneficial accessibility toward various smart services for governments, citizen, and industry sectors in any areas of the city through seamless 5G network with high-efficient. As a result, data can be transferred in a real-time without interruption covering the usage of the population in a wider range area.

  Consequently, the three basic network criteria amenable provoke the development of 5G cities, both in terms of improving the quality of people's lives and the heighten of government and industry in several dimensions, namely, the potential of IoT technology which to advance a public safety via CCTV cameras with the standardized 5G network.

  Because of those above improvements capable improve on the security surveillance system through a real-time video monitoring. Moreover, the 5G network can support connection of an autonomous vehicle technology to develop transportation systems as well as to analyze traffic situation for reducing traffic congestion in which to result in positive effects for environmental pollution. Furthermore, it can result in a better off travelling plan for commuters. Because of the production development processes, efficient 5G technologies can be applied in smart factories enabling improve on security and health of the local workers for better off. **Without intention on the development of the 5G City's network criteria, possibly leads on unsuccessfulness of the benefits as mentioned.**

  As a result, identify long-term development plans must be planed and established continuously, leading to the local people are capable access to 5G services in the covering areas under the expansion plan in Thailand, and their well-being will be supported as well, profitably enhance the latency in many

industries. For example, in a transportation, a healthcare, an education, a government, an energy management, and other industries that confront with a new normal life combining with a sustainable digital innovation.

- **Consideration to award 5G City certification,** in order to promote positive image toward 5G City development at local communities as well as to attract the local people for 5G City understanding and acceptation, obtaining the 5G City certification can create these benefits. To classify upon the local people advantages, it can cause a better quality of people's lives in many aspects toward use of the smart services. Under needs of the local people, there are in various dimensions such as a convenience, an upgrading of living conditions, a healthcare, and a social public safety.

  By being certified the 5G City that can achieve the network development and potential in various dimensions as mentioned, and 5G City certification will be benefits granting government incentives for the development of 5G networks continuously.

Economic Aspect

The development of 5G City's network criteria and certifying for cities that meet the criteria will create a positive impact on the economy, which will assist to drive the Thai economic growth as follows.

- **Determination of the 5G City's network criteria,** develops the 5G network according to the 5G City's network criteria through the three factors with fundamental techniques is played an important role for adding values in various industries. For instance, a health an industry, an education, a tourism, and manufacturing industries resulting in the economic growth of the Thai nation because it will add value and increase productivity.

  In consequence, impact higher employment rates as business expansion, by adoption of 5G technology that meets the required standards in smart services to develop the agricultural industry enabling farmers to manage their farms effectively, and this can display result in higher productivity rates as well as leading to the real distribution of income into communities. Moreover, a technological application in the manufacturing industry, which is directly affects the Thai economy will help reducing a cost of production by taking actions on production process management in effective, and it reduces time wastage as well. **Determining basic network criteria is crucial to continuous stimulate Thai economic growth through the long-term planning for**

the network development standards, encouraging Thailand to become a role model for developing technological cities. As 5G in the ASEAN region has high potential, enabling the region to have higher competitive advantages at an international level, leading to develop the drive of the Thai economy in a sustainable way.

- **Consideration to award 5G City certification,** as 5G City grants the 5G City certification under the government leading to the 5G City can create higher reliability with good latency in improving quality of life for people as well as several fields in different industries. Accordingly, building the development of 5G City to complete with the 5G's City network criteria.

  Besides, the 5G's City network criteria can stimulate a network in efficiency for corresponding with the smart services that can be applied in each industry for ultimate benefits, i.e., building a qualified image of the 5G City through digital innovation, attracting both domestic and foreign investors. This leads on financial investment distributing into each industry as both investors do their businesses on the innovative standard which assists to reduce operation cost energy consumption costs. Moreover, increasing efficiency among the industries through the continuous development of the smart technologies and services

Quantitative Impact

To identify the standardized network criteria for determining to grant a 5G City Certification, has purpose to improve a 5G network which is allowed the people to access into each covering area which be used the 5G network comprehensively. Under the 5G network plan, there are 3 ultimate goals as follows:

To begin with a short-term goal which is planned to implement in 2022, the plan has coverage of 5G network per 70 percent of the total population in Bangkok and EEC. Secondly, in a mid-term goal from 2023 to 2024 have 5G network which coverages of 5G network at 80 percent of the total population, expanding from the existing area to cover more in 12 provinces from 4 regions. Lastly, in a long-term goal from 2025 to 2027, developing the 5G networks covering at 90 percent of the total population, results in the covering areas in 45 provinces in Thailand.

In the case, the high-performance 5G network is built as planned, the plans will stimulate investment to build the network in a specific area. The investments used will be

determined by the infrastructure investment factors of the 5G network, as well as the number of users required to cover the targets in each area, which can calculate investments from the project's start in the short to long-term by 2027 to a minimum cumulative investment value of Baht 270,796 million.

6.1.2 Flagship Project 2: The Development of Pilot 5G Livelihood City

The development of 5G services to improve the quality of people's lives in the city, including inhabitants and tourists, by use of 5G technology to establish 5G Livelihood City, which covers various service industries. As a result, city citizens' general well-being in terms of public health, education, commerce, and entertainment will improve. The creation of this model city will have the following good economic and social effects.

Qualitative Impact

Social Aspect

The 5G Livelihood City development as a model for increasing people's quality of life by enabling them to access smart services through a high efficiency 5G network. In the areas of education, public health, business, and entertainment, this development initiative will have a favorable impact on society. The following are the specifics as below:

- **Education Impact**

  The COVID-19 pandemic has impacted learning opportunities, resulting in lower-quality education. Remote learning is a solution that plays a key part in teaching and learning at all levels, from elementary to higher education. The implementation of 5G technology in the education industry to increase access to distance education or locations where unsupported wireline connections exist, such as areas where high stability in a real-time online instruction is required. The various key technologies such as AR, VR, IoT, and Virtual Classroom have been applied to 5G technology as a 5G Virtual Classroom service to integrate teaching and learning systems through the virtual classroom environment in which teachers can interact with students to improve education efficiency and increase the opportunity for students in rural areas to have access to the education system in order to reduce education inequalities. Furthermore, the 5G City model, which has manpower and technology preparedness, will be able to serve as a remote learning center.

- **Healthcare Impact**

The adoption of 5G technology in public health can promote a model city area, which has located the large hospital center to be a hospital hub for 5G Teleconsultation services, which has specialized doctors in various fields for providing services in distant areas, increasing access to the healthcare system and reducing travel costs to the city's hospitals. Since the COVID-19 epidemic, this service has been in use, and it can assist doctors be more available to patients and shorten treatment time, as well as reduce the transmission of the virus through social distance. Furthermore, 5G technology has the advantage of providing a high-speed connection that allows the doctor to monitor the patient's status in real time, allowing for quick treatment in cases of odd symptoms.

- **Commerce Impact**

Since most consumers nowadays choose to buy online rather than in-store, e-commerce plays an essential role in shaping consumer behavior. The adoption of 5G technology will improve the online shopping experience by allowing customers to choose products freely as if they were in a store or shopping district without having to travel through the 5G Virtual Store service, which combines 5G technology with AR and VR technology to allow customers to try products in a virtual environment. As a result, improving the shopping experience so that customers can buy products as a prerequisite to lessen the problem of returned products. Furthermore, the deployment of 5G technology to enable 5G Unmanned Store service, which may generate new experiences and increase convenience for consumers, will improve a service offering holistically through high-efficiency automated services.

- **Entertainment Impact**

Broadcasting and streaming, as well as Cloud Gaming, which uses 5G technology to decrease reception issues and signal disruption, are currently available in Thailand and require steady connections and huge bandwidths for a better viewing experience. It also improves real-time reaction capabilities, enhancing the entertainment experience and introducing new experiences for viewers, such as 5G AR/VR for Media and Entertainment or 5G Cloud Gaming services, among others. Furthermore, 5G technology can aid in the dissemination of city news via technological media, allowing individuals to receive city information more quickly.

Economic Aspect

The 5G Livelihood city development model will promote people's well-being in the city by providing high-efficiency smart services. It has the potential to have a positive impact on the economy in a variety of areas, including education, public health, commerce, and entertainment.

- **Impact on Education**

  The adoption of 5G technology to develop remote learning systems can reduce teaching personnel, which are severely scarce in backcountry areas that unable to access education. Moreover, it will help reducing costs and resources of school construction in rural areas with having an insufficient number of students and staff for opening new schools. Therefore, the high-efficient 5G technology will develop a learning platform through 5G Virtual Classroom, which helps to solve such problems and encourage the education development to reduce inequality and limitation in remote education as well as developing the knowledge skill of students that will improve the future of the nation. In addition, investments in basic teaching and learning technologies by the government can also help to boost overall economic growth.

- **Impact on Healthcare**

  The advancement of healthcare using 5G Teleconsultation to improve medical diagnosis, hence increasing the accessibility and quality of healthcare for patients in remote places and reducing travel time and costs. It can also help to reduce the cost of building a network hospital in remote locations, which, if launched as a branch, can be a loss when compared to the operational costs of opening a hospital in a small town, as well as the cost of medical professionals, which is a major cost of hospital operations and is in short supply right now.

- **Impact on Commerce**

  Trade is a vital industry that propels Thailand's economy forward. It is an industry that employs more than two-thirds of Thailand's workforce. Using effective 5G technology to build smart store services, such as 5G Unmanned Store, that can be used in practice and satisfy customer demands in purchasing products while allowing operators to conduct their businesses steadily, will reduce the cost of managing the number of employees in the storefront as well as the problem of staff shortages,

which is a problem that most store operators face today. It can also increase revenue by drawing customer attention using modern technologies to adapt to produce a positive customer experience. Increasing the effectiveness of competition in online channels such as the 5G Virtual Store service, or even increasing the purchasing option for customers, for example, would have an impact on future revenue development.

- **Impact on Entertainment**

Technology is being used to provide a variety of entertainment for viewers through smart services such as 5G Cloud Gaming and 5G AR/VR for Media and Entertainment. This allows viewers to view images and interact with virtual reality through devices such as virtual reality glasses that can be simulated to see 360-degree images, resulting in new experiences that allow viewers or gamers to feel as if they are in a realistically simulated game world, greatly enhancing the entertainment experience and attracting players to experience a different dimension, resulting in the growth of the entertainment economy by attracting players to experience a different dimension, resulting in the growth of the entertainment economy by attracting players to experience a different dimension This can help to boost the entertainment industry's overall economics by attracting new clientele who are interested in seeing entertainment through cutting-edge technology and innovation.

Quantitative Impact

The development of services connected to improving people's lives in the city will be focused on four areas, each of which will have significant services that will serve as a model for urban development. To accomplish such a service, investments in devices such as IoT AI or platform, as well as interconnection charges that produce income for telecom operators, are required to become a service that can provide services in the city. In addition, in 2024, a model city development goal was created, which was expanded to 45 provinces by 2027, with at least one each province. The development of prototype city project, 5G Livelihood City, will be able to accelerate the minimum cumulative investment of Bath 2,378 million until 2027 based on all of the elements indicated above.

6.1.3 Flagship Project 3: The Development of Pilot 5G Governance and Industrial City

Government and industrial development have continuously driven Thailand's economy by helping to increase regional competitiveness by effectively applying 5G technology in various services that cover each industry group such as manufacturing services, transportation controls, and security services by focusing on development to stimulate private sector investment and create regional competitiveness.as follow:

Qualitative Impact

Social Aspect

Developing 5G cities as a model for government and industry by establishing effective 5G networks that allow the public sector, government sector, and industrial business sector to access smart services that benefit all sectors. It has a favorable impact on society in a variety of areas, including manufacturing, transportation, and security, as detailed below.

- **Impact on Production**

  Because the introduction of industrial technology will increase the overall efficiency of production produce, the growth of industrial production technology will have a direct impact on the society surrounding the production region. As a result, residents in the area have a higher employment rate, resulting in increased income, which has an impact on driving quality of life by bringing technology and innovations to help upgrade the manufacturing industry, such as 5G Autonomous Vehicle services, 5G Automation & Robot services, automatic machines, automatic cargo trucks, and industrial robots. It can also aid in improving the working conditions of workers in hazardous jobs, as the possibility of accidents or labor that requires constant supervision can have a negative impact on workers' health, lowering productivity. It may also assist in the distribution of workers in order to establish other jobs that require sophisticated skills and cannot be automated. In addition to the before mentioned services, 5G AR/VR is one of the technologies that may be used to teach personnel in dangerous tasks that require a lot of experience and reduce the chance of an accident due to inexperience through virtual simulation. This also makes the workflow process' summary easier to comprehend and see.

- **Impact on Transportation**

The technology used in the transportation control industry has a direct impact on the workers in the shipping chain's quality of life. Nowadays, such high-risk tasks as long-distance transportation or jobs that require 24-hours management, such as crane control, still necessitate human labor. Working in this manner is an unfavorable working environment that has a long-term harmful impact on workers' health. As a result, when using services like 5G Autonomous Trucks to replace human workers, it will help reduce accidents caused by long-distance driving, which may impair driving ability, or 5G Remote Controlled Crane to replace human labor, it will improve working conditions because the operator can control the crane remotely, reducing the time required to monitor crane operation.

- **Impact on Public Safety**

Bringing in 5G technology to improve security would help relieve the pressure on cops, which is a significant aspect affecting people's quality of life. Through the service of 5G Patrol Robotic, an automated patrol robot that comes to help monitor the incident and can be utilized constantly for 24 hours, decreasing the job of security professionals, people may live their lives with confidence, safety, and risk. Employees gain from improved health as a result of this, as well as the ability to respond rapidly in an emergency, enhancing the ability to keep people safe. The cameras are used to monitor and detect the movement of strangers, and to communicate photos to employees in real time so that varied information may be saved on a central database and used to detect fleeing criminals using face detection technology. Furthermore, instead of employing staff who may be at risk of close contact with an infected person, autonomous robots can be used to assess temperature and screen people at risk of COVID-19 at various locations. This will significantly minimize the spread of the pandemic while also improving hygienic conditions.

Economic Aspect

Through an efficient 5G network in smart services, the development of a pilot 5G governance and industrial city will help improve the potential of diverse industries. This has a good impact on the broader economy in a variety of areas, including production and transportation sector control and safety. The following are the specifics.

- **Impact on Production**

When the ratio of industrial production value to gross domestic product is considered, the industrial sector plays a critical role in Thailand's economic development. By bringing 5G Autonomous Vehicle services and 5G Automation & Robot services, machines and robots with high potential and precision to replace the usage of employees, 5G technology in the manufacturing sector will help cut labor costs and the number of unskilled workers. The cost of production is decreased as a result of the introduction of automation systems, which can benefit in a variety of ways, including increased precision in production. This eliminates waste generated in the manufacturing process, as well as the transportation of items in each production line, as well as the continuity and relationships in that manufacturing process, as well as time loss and employee workload to run 24 hours a day. Furthermore, maintenance via AR/VR systems will allow for efficient machine quality checks. As a result, maintenance expenses are lower, and equipment can operate for longer periods of time. Bringing smart services to the development of manufacturing will make investment viable and offer Thailand enough capability to compete in the area in the future to become ASEAN's largest production base.

- **Impact on Transportation**

The transportation sector is a vital link in the distribution of goods across numerous industries. As a result, transportation costs will be decreased if 5G technology can be employed to assist in the process. It has a wide impact on other business sectors as well, as transportation costs are decreased. This will improve the ASEAN market's competitiveness. Although investing in technology may seem expensive at first, the solutions are cost-effective in the long run. It will be able to solve logistics industry problems using technology in smart services, such as the 5G Autonomous Truck service, which will help to solve the current driver shortage problem and achieve efficient freight management, or the 5G Remote Controlled Crane service, which relies on real-time remote crane control and command. Because of the large number of ships along the port, it can move products swiftly and reduce cargo drops. This smart solution will allow workers working on heavy equipment cranes with a high risk of accidents boost their capacity to move, save operational time, and increase safety. As a result, goods are transported more efficiently in commercial ports.

There was a drive for Thailand, which has an important port and serves as the ASEAN region's logistics hub, to maximize economic mobility.

- **Impact on Public Safety**

  The introduction of 5G technology to improve citizen and tourist security can boost tourist confidence and create a positive image of the city, which considers upgrading the quality of life through the service of 5G Patrol Robotics, a patrol robot that monitors dangerous situations and reduces crime, leading to the city becoming a city without danger. Furthermore, it will increase the credibility and confidence of tourists and people, attracting both Thai and foreign tourists, resulting in increased economic added value, resulting in an increase in employment rates due to the business's continued expansion and help build a career, generate income, and distribute income to the community, stimulating economic growth and positively impacting local businesses and the city's overall economy. In addition to improving safety by averting risky incidents, In the current condition of COVID-19, which provides autonomous robots to replace receptionists to decrease the cost of hiring humans to measure temperature and screen people who come to utilize the service in that area, health safety is an important consideration. This will decrease exposure and closeness, as well as the spread of disease, in order to avoid expenditures associated with employee infection during the initial screening. It will also be able to help boost staff and consumer confidence in corporate pandemic prevention strategies.

Quantitative Impact

The creation of a pilot 5G governance and industrial city using smart services to aid in the development of capabilities in a variety of industries, including manufacturing. Transportation and safety will be a priority in key locations for the Thai economy, such as industrial estates in the Eastern Economic Corridor (EEC), which have the potential to be the backbone of long-term economic growth.

Developing 5G networks in accordance with the requirements outlined in Flagship Project 1, detail item 5.3.1, which has a development strategy that will allow smart services to be used efficiently throughout the EEC region. If the network can be developed in accordance with the objectives, the investment will be significantly accelerated. The appropriate operators will make investments based on factors such as the number of industrial factories in the EEC region and the size of the associated industrial estates. The total value of

the smart city development zone in the EEC area, the number of machines and equipment used in smart services, which are devices that require additional investment to support 5G technology connection, and the upcoming interconnection charges, which can calculate the minimum accumulated investment value until the year 2027, is Baht 47,111 million, which is considered an important part in the development of the country's industrial area to be the highly effective.

6.1.4 Flagship Project 4: The Development of Long-Term 5G City Plan

The 5G Ecosystem Alliance, which is involved in the 5G ecosystem in both the public and private sectors to drive and support the development of advanced networks criteria resulting in enhancing the potential of smart services to be able to use in various industries with maximum efficiency to meet the economic and social requirements, is driving Thailand to become a country with a long-term 5G City plan. In accordance with Thailand's Sustainable Development Goals (SDGs), which aim to improve the quality of people's lives in areas such as livelihood, education, public health, and the environment, as well as economic promotion, the following details are provided:

Qualitative Impact

Social Aspect

The establishment of the 5G ecosystem alliance will be an important role to collaborate with all stakeholders for developing and determining advanced networks criteria to improve the potential of smart services by considering advanced technical parameters in terms of a high-stable connection (Reliability), the accessibility (Availability), and massive devices connection (Density), these factors are network requirements that directly affect the efficiency of smart services in various fields which create a positive social impact in healthcare, education, public safety, and the industrial sector are as follows.

- **The establishment of 5G Ecosystem Alliance** with the goal of promoting public-private sector and stakeholder cooperation in the 5G technology ecosystem, which is an important step in developing and encouraging 5G technology adoption in various sectors to drive Thailand's digital innovation in the long run by brainstorming and exchanging knowledge to develop the complete 5G ecosystem.

  The 5G ecosystem alliance will be a fully integrated operation center that will combine essential technologies like Cloud, AI, and IoT for use in a variety of sectors. As a result,

this can increase the potential of smart service that brings the greatest benefits to both the public and private sectors, leading to the development of a high efficiency 5G City for improving people's quality of life, public safety, healthcare, and well-being in an environment that facilitates in many ways.

- **The determination of advanced network criteria for 5G City,** it is a critical phase in the development of the 5G network since it directly influences the performance of smart services by determining sophisticated technical parameters that vary by service: 1) Dependability 2) Density; and 3) Availability. These are extra requirements for 5G networks to be used in smart services such as public health, such as offering 5G Teleconsultation in medical diagnostics through high-efficiency communication between patients and doctors to improve healthcare accessibility in rural areas. To enable real-time learning and support the devices that need to access the learning system concurrently without interruption in the education sector that uses 5G Virtual Classroom, improving the quality of education and adjusting to new normal life in COVID-19 situation to enable real-time learning, and support the devices that need to access the learning system concurrently without interruption. for the purpose of decreasing educational distance limits and inequities, as well as promoting the growth of educational staff Furthermore, the tourism sector can use 5G technology to serve attractions in fully immersive virtual reality environments by providing 5G VR Unseen Thailand service to enhance tourism experience with VR technology and can support groups of tourists who want to access the service at the same time with high-efficiency of advanced network factors to improve the new experience from a different perspective. Using 5G Autonomous Vehicles (AGVs) for carrying product loads from one location to another constantly through remote control in part of the manufacturing business, resulting in improved production efficiency, reduced production time wastage, and reduced worker workloads.

  Furthermore, the 5G Private Network is the only approach that can help drive network development by meeting advanced technical network criteria such as highly stable connections (Ultra-Reliability) to improve services that require real-time communication and data transmission with a high-security network that can improve data protection and prevent data breaches. A 5G private network's main advantage is that it can be custom-built for unique use cases in each company, such as manufacturing, transportation, and public health, and so on.

The collaboration of associated organizations is most substantially necessary for creating 5G cities to be high-efficient 5G City models in the long run. involves the development of sophisticated network capabilities to suit the smart service requirement for increasing 5G service accessibility across all industries. This aligns with Thailand's aim of being a leader in 5G City development and a digital hub for the ASEAN region that can sustainably drive the digital economy using 5G technology.

7. Appendix

7. Appendix

7.1 Example of 5G City in Various Countries

By the end of 2020, it is estimated that at least 558 cities will have deployments in 5G cities, including those identified by member states in the EU 5G Implementation Plan and identified in the Europe-wide 5G trials roadmap version 4.0, including 5G pilot cities and cities where 5G technology is already being used

The table below shows a selection of significant cities in the EU that are actively participating in 5G technology, including cities with private 5G trials or pilot projects, national 5G technology initiative, platform implementation, 5G Test Corridors, and 5G Infrastructure Public-Private Partnership (Infrastructure PPP).

Table 7-1 : Example of 5G City in Various Countries

Country	Activities Related to 5G Technology	Key City	Note
Austria	■ 5G Private Trials & Pilots ■ 5G Test Corridors ■ 5G-Live Cities	Innsbruck, Graz, Linz, Vienna, Worgl, Wortersee	1,000 locations with commercial 5G services and 100 cities with commercial 5G services which cover 40% of population
Belgium	■ 5G Private Trials & Pilots ■ 5G Test Corridors ■ 5G-Live Cities	Antwerpen, Brussels, Ghent, Leuven	60 municipalities with commercial 5G services
Bulgaria	■ 5G Private Trials & Pilots ■ 5G Test Corridors ■ 5G-Live Cities	-	27 city centers of districts capitals including Sofia
Croatia	■ 5G Private Trials & Pilots ■ 5G-Live Cities	-	24 parts of cities including Zagreb, Rijeka, Spilt, Osijek, Samobor และ Sveta Nedelja

Country	Activities Related to 5G Technology	Key City	Note
Cyprus	■ 5G Infrastructure PPP	Limassol	-
Czech Republic	■ 5G Private Trials & Pilots ■ 5G-Live Cities	Prague, Brno, Bilina, Jesenik, Karlovy Vary, Plzen, Usti Kolin, Labem	-
Denmark	■ 5G Private Trials & Pilots ■ 5G Test Corridors ■ 5G-Live Cities ■ 5G Infrastructure PPP	Copenhagen, Aalborg, Odense, Aarhus, Helsingor	-
Estonia	■ 5G Private Trials & Pilots ■ 5G Test Corridors	Tallinn, Tartu, Parnu	-
Finland	■ 5G Private Trials & Pilots ■ 5G Test Corridors ■ 5G-Live Cities ■ 5G Infrastructure PPP	Espoo, Helsinki, Muonio, Oulu, Sodankyla, Tampere, Turku, Ylvieska, Vantaa, Jyvaskyla, Jarvenpaa, Kerava, Tuusula, Kaarina, Naantali	40 municipalities with commercial 5G services
France	■ 5G Private Trials & Pilots ■ 5G Test Corridors ■ 5G-Live Cities ■ 5G Infrastructure PPP	Angers, Bordeaux, Chatillon, Clermont-Ferrand, Douai, Lannion, Le Mans, Lens, Lille, Lyon, Marseille, Metz, Montlhery, Montpellier, Mulhouse, Nantes, Paris Pau, nice, Rennes, Toulouse	20 commercial 5G cities

Country	Activities Related to 5G Technology	Key City	Note
Germany	▪ 5G Private Trials & Pilots ▪ 5G Test Corridors ▪ 5G-Live Cities ▪ 5G Infrastructure PPP	Aachen, Berlin, Bremen, Cologne, Detmold, Dusseldorf, Hamburg, Ingolstadt, Merzig, Munich,	60 commercial 5G cities

7.2 The Importance of 5G Smart Pole and Key Functionalities

To evolve into a 5G city that embraces modern technology and innovation that contributes to more effective city management services, a flawless management system is necessary. This is where the Intelligent Operation Center (IOC) comes in as the city's brain and central nervous system, connecting and processing data in the city's information platform via remote control and real-time monitoring of city's incidents through the dashboard and central control systems. The deployment of 5G technology would enhance the connectivity of IoT devices by combining Big Data and AI technologies to improve the benefit in various areas such as public security, by analyzing criminal faces using real-time data from CCTV cameras. Additionally, IOC can assess traffic conditions based on real-time traffic data to help improve transportation management. As a result, the IOC center will leverage city databases to aid in the efficient creation of 5G City in the near future.

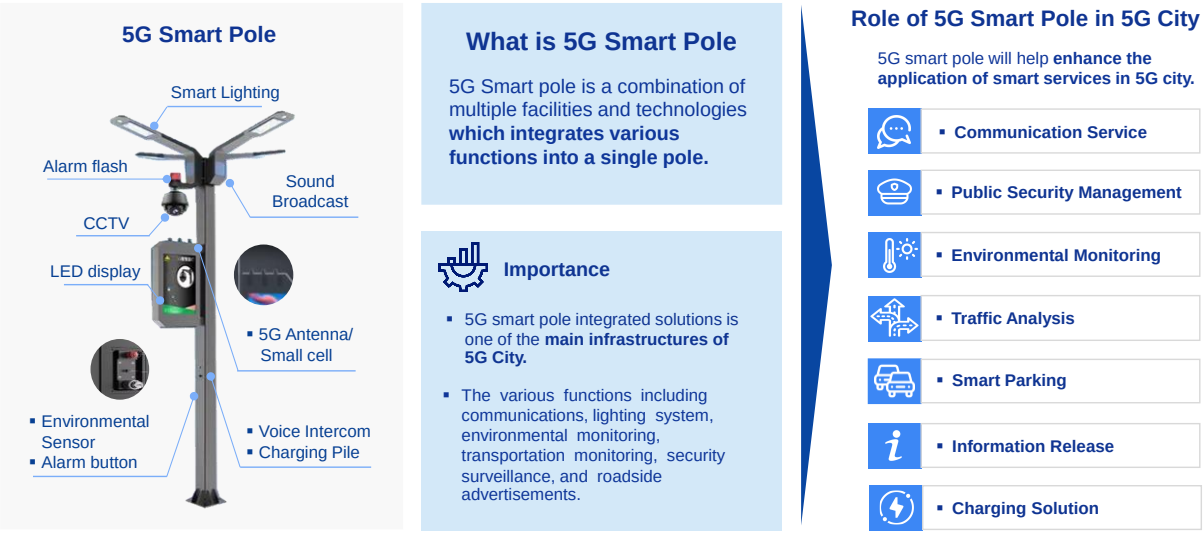


Figure 7-1: 5G Smart Pole for 5G City Development

Smart Pole is one of the most popular solutions for 5G city development because it combines technology and innovation to create an integrated solution capable of providing a variety of functions such as CCTV cameras, solar energy systems, environmental monitoring sensors, LED displays, EV charging stations, and Wi-Fi hotspots and so on, by transmitting data to the Intelligent Operations Center (IOC) for control and management of city information as well as coordination with related departments[31] for developing more efficient city. For instance, environmental monitoring sensors that detect air pollution, light intensity, and air pressure, etc. These data will be sent to a database for the purpose of

[31] Source: บ้านฉาง เมืองต้นแบบ 5G สู่ Smart City, Thaipublica (2021)

forecasting weather and disasters. In the event of a disaster, the IOC center will inspect and work with related departments to handle the situation, as well as disseminate various news to ensure that people are informed and prepared adequately for protection. This improves people's safety and well-being, allowing for optimum efficiency in the development of 5G City.

At the present, 5G technology is critical for the advancement of communication efficiency, which has resulted in the development of smart poles that support 5G signal (5G smart pole) as one component of technology deployment via Internet of Things (IoT) technology, which serves as the foundation for seamlessly connecting devices and other systems. 5G Smart poles are used to develop 5G cities in a variety of fields, including providing convenience for citizens and reproducing beautiful city scenery, as well as improving public security and enhancing the quality of people's lives. This is accomplished by integrating multiple functions into a single pole that can promote resource efficiency while seamlessly connecting usability. As a result, 5G city services can be developed in various systems[32] , as follows:

1. **Communication Service**

   The 5G smart pole can help improve the communication system by developing 5G hotspots and providing public Wi-Fi access points, with the purpose of providing widespread coverage for a variety of services including communication, entertainment, transit, and industrial. 5G technology will significantly improve the ability to transmit massive amounts of data, including photos, audio, and other types of data, over high-speed connectivity. This enhances the connection of IoT devices and enables more effective communication.

2. **Smart Lighting System**

   Innovative smart lighting drives the work process and can link to IoT devices, increasing efficiency using sensors to reduce resource consumption and energy consumption, while also improving the quality of people's lives. The following are the primary functions of smart lighting.

   - Using automated On/Off Controls for Lighting system through the installation of motion sensors for detecting movement of people including optical sensors to

[32] Source: China Smart Pole Tower White Paper, China Institute of Communications (2019)

control the lights automatically based on the light conditions for reducing energy consumption.

- Monitoring real-time usage data and store in database for analyzing energy consumption.
- Controlling smart lighting system remotely.
- Providing alarm reports in the event of an intelligent power outage, allowing for rapid coordination and correction.

3. Public Security Monitoring System

Video surveillance can be used to monitor public security systems in order to ensure the safety of people's lives. The information will be stored in a city database so that the Intelligent Operation Center (IOC) can control and monitor all city activities, thereby fully developing people's security capabilities, which is a necessary condition for promoting the city's well-being. This will be accomplished by improving the public security system's primary functions, which include the following:

- Able to capture real-time video by utilizing CCTV cameras to capture real-time data that can be combined with AI technology to detect abnormal behavior for crime analysis in the city by utilizing recognition technology for license plate detection and facial recognition stored in the city's database via the high efficiency 5G network for transmitting data with a 4K high resolution to clearly and accurately detected.
- Capable of remote control via the Intelligent Operations Center (IOC) to monitor accidents or crimes that may occur in the future.
- Providing emergency button with the function of one-button police calling that the public security department can properly locate the target location and deliver prompt services.

4. Environmental Monitoring System

Environmental monitoring systems can alert residents to weather forecasts and pollution alerts for both air and noise pollution. Environmental issues are critical to be aware of since they have a direct impact on public health. As a result, the 5G smart pole has built an environmental monitoring system through the installation of IoT devices that can connect to a high-quality 5G network. The main functions of environmental monitoring systems are as follows:

- Examining the air quality by installing sensors such as Carbon dioxide, air pollution sensors to control emissions that affect public health.
- Measuring noise pollution by installing sensors for monitoring road noise from vehicles and construction operations through the sound sensor for controlling environmental noise to acceptable standard levels.
- Providing weather forecasting by using the micrometeorological sensor to monitors meteorological information such as wind speed, atmospheric pressure, rainfall, and ultraviolet light intensity.
- Additional optional sensors, such as harmful gas sensors, smoke sensors, and flood sensors, can be added to the other systems to enable more complex operations. For instance, in an emergency, an alert is sent to the control center, which is already connected to the video surveillance system and coordinates with pertinent departments to monitor the situation remotely and resolve it quickly.
- Capable of real-time data collection and storage on a central cloud database that connects to the control center for the purpose of analyzing and forecasting future weather or natural disasters.
- connecting to the city's alarm system for disaster and emergency alert notification, residents can rapidly become aware of and plan for protection, thereby boosting safety and minimizing property loss.

5. Transportation System

Transportation control management is the main factor in driving the economy and people's livelihoods, which smart poles will contribute to develop of the transportation system by collecting and managing traffic data through the adoption of 5G technology to effectively connect IoT devices. The main functions of transportation systems are as follows:

- Capable of storing vehicle-generated data about cars, road conditions, and traffic conditions using traffic monitoring cameras and traffic detectors.
- Capable of collecting data in real time as well as storing and uploading it to a central cloud database, which requires extensive and high-performance 5G technology in order to prepare for the future development of remote-controlled driving and self-driving automobiles.

- Capable of analyzing traffic density and forecasting travel conditions in order to improve transportation management. Additionally, it can design a smart parking management system that assists in managing parking spaces efficiently and can be reserved via an application to increase convenience and improve traffic management.

6. **Information Release System**

Smart poles installed in densely populated urban areas are ideal for sharing information via LED display devices attached to the poles. Residents can obtain information about the city, including traffic conditions, emergencies, weather predictions, air quality, and advertising media. In the event of an emergency or disaster, the information will be publicized and linked to an alert system that will tell people to evacuate promptly. It allows the distribution of media content in a variety of formats, including photos, slides, animations, audio, video, and scrolling captions. Additionally, the information can be connected via a 5G network to the digital media control center, allowing for effective remote control of the information displayed on the LED screen.

7. **Energy Services**

Nowadays, technological advancements have led in an increase in electronic consumption for smartphones and electric automobiles. However, Thailand continues to have a small number of charging stations, which the installation of a smart pole will resolve by integrating power supply to support charging electronic devices or electric vehicles, as well as the deployment of 5G technology to reduce charging latency.

Additionally, it can allow applications for reservation services and real-time location tracking of charging stations in order to promote energy services in the city.

Smart poles lay the foundation for the development of 5G cities, which will support the needs of technology development to improve living conditions. As a result, the initiative for implementing high efficiency 5G technology is being used to construct more efficient cities, with plans to expand in a number of nations, such as China and Finland.

Nanyuan Smart Pole Project in Hangzhou

Figure 7-2: Example of Smart Pole in China

China has already developed the smart pole, which is operated by Fonda Technology as part of the Nanyuan Smart Pole Project in Hangzhou. The smart pole provides an integrated solution for a variety of functions, including IoT data collection, smart street lighting, wireless Wi-Fi coverage, video monitoring, emergency alarm, environment monitoring via LED display, charging pile for electric vehicles, and the ability to connect to a 5G base station for data backup. These data are connected via the central management command center, which can perform automatic monitoring and assigning responsibility to responsible departments 24 hours a day. The data collected by the system can also be connected to the City Brain system,[33] which is a project that leverages Alibaba Cloud to effectively manage and control the city's traffic conditions by monitoring and analyzing road conditions in order to provide basic data for developing smart city management.

In 2021, China is continuing to develop 5G cities through the implementation of a 5G technology infrastructure expansion plan. There are approximately 480,000 5G base stations in China, with two cities already having 5G full coverage: Beijing, the capital of China, and Shenzhen, the southern China's largest city. As a result, the market demand for smart poles has increased to approximately 117.6 billion yuan, according to the Shenzhen Industrial and Information Technology Bureau. The city plans to build 4,526 new smart poles in 2020 and 24,000 poles by 2022 for infrastructure development and the development of a more intelligent and digitalized smart city.

[33] Source: Alibaba Cloud, Brandinside (2018)

Additionally, Finland developed the LuxTurrim5G project, an innovative ecosystem led by Nokia and other research organizations dedicated to the development of 5G infrastructure through the installation of 19 smart poles along the route from Nokia's Espoo headquarters to Kera Railway Station and surrounding areas. This smart pole is equipped with 5G technology and is connected to 250 IoT devices, combining diverse features such as environmental sensors, CCTV cameras, and radar devices, which can help improve safety and traffic monitoring for self-driving vehicle remote control. Additionally, there is an electric charging station for electric vehicles and drones that may land on the pole. Furthermore, the LuxTurrim5G project has piloted the development of smart bus stops using LED displays to display city information and has plans to develop smart poles in the Otaniemi Keilaniemi area that will enhance sensor connectivity and various information platforms capable of transmitting data at high speeds using 5G technology, thereby promoting the sustainable development of smart cities in the future.

From researching information and initiating initiatives related to smart poles in order to address the need for more efficient telecommunications services, poles were transformed into 5G base stations that combine a variety of functions, including Wi-Fi access points, CCTV cameras, environmental sensors, LED displays, charging stations, and security systems with integrated emergency buttons and alarm systems. Additionally, 5G technology can boost IoT connectivity, enabling IoT devices to receive/transmit massive amounts of data in real time, enabling various industries to grow and people's livelihoods to improve, culminating in a city's ability to become an efficient 5G City.

It was discovered during the development of 5G smart poles in many difficulties that infrastructure installation is critical for providing a comprehensive and high-efficiency network. As a result, it is necessary to install a small cell, which is a small transmitter designed to improve cellular network coverage and support densely populated areas by increasing data transmission mobility, including the ease of installation and low power consumption. Small cells can be installed on existing infrastructure such as utility poles, street light poles, traffic light poles, telephone booths, buildings, and billboards. To achieve network coverage, it is necessary to install numerous tiny cells, which are expensive and require numerous installation processes. Thus, the pole sharing concept will enhance infrastructure construction by adding small cells to existing facilities and implementing an antenna sharing system with several operators, thereby expanding the 5G network's coverage and lowering operational costs while increasing resource efficiency. Additionally, the 5G smart pole may be used to

promote energy consumption through green energy, which has a good influence on the environment and helps construct a sustainable 5G City.

As the above mentioned, there are some recommendations for 5G smart pole to accelerate investment and development in Thailand as it can develop technology and innovation for maximum efficiency by integrating various functions into a single pole that can be linked to other systems seamlessly to reduce duplicated investment and promote resource efficiency. The main functions of the 5G smart pole should be as the following detail:

1. **5G Antenna/ 5G Small Cell**

   5G small cells are installed to improve the expansion of infrastructure to cover a wide range of areas, which can be easily installed and low power consumption, requiring the installation of a large number of small cells to support densely populated areas and improve data transmission mobility. As a result, it increases the potential for IoT devices to connect and transmit data to various departments efficiently.

2. **Pole Sharing**

   The pole sharing function has an antenna sharing system to promote cooperation with more than one telecom operator to share the pole for improving network coverage, including using existing facilities to install 5G small cells for supporting infrastructure sharing, which can reduce duplication of investment and promote resource efficiency. As a result, the 5G network will be able to cover a wide area, enabling the population and various industries to acquire benefits from high efficiency 5G technology. This contributes to promoting the network infrastructure for a sustainable 5G city development.

3. **CCTV Camera**

   CCTV cameras are used for real-time video surveillance by connecting to a high-speed 5G network to transmit high-resolution video, which is combined with the adoption of AI technology for facial and behavioral recognition. This can accurately detect abnormal behavior and transferring data to the Intelligent Operation Center, which will use various data from the city's database to remotely control and monitor any accidents or crimes situation that may occur in the future to improve the city's public security level. Furthermore, real-time data from CCTV cameras can be used to analyze traffic conditions based on the number of vehicles on the road, allowing for better forecasting of travel and more efficient transportation management.

4. **Emergency button**

   In emergency case, can press the emergency button with one-button police calling function that can connected to the Intelligent Operation Center, which collaborate related department to accurately determine the target position and provide responsive services to help immediately.

5. **Environmental sensors**

   Installing environmental sensors for measuring, monitoring, and recording environmental parameters such as temperature, humidity, noise, wind speed, wind direction, and air quality in real-time, which store data on a central database that connects to the control center with coordinating related departments to analyze weather and disaster forecasting that may occur in the future. Notifying residents of the city before a disaster strikes or air pollution levels climb to the point where humans are harmed, allowing people to prepare for protection promptly.

From the various functions mentioned above, it is a basic function that is integrated into a single pole, enabling the various functions to be holistically combined across various systems and contributing to the development of 5G cities by enabling smart services to provide benefits for the government, the industrial sector, and the people sector. The characteristics of 5G smart poles should be consistent with the area that need to be installed and can be adjusted to meet the requirements of different areas such as narrow streets, parks, densely populated city centers or community areas, etc., by designing smart poles with additional functions to allow for proper installation in each area and selecting the materials such as metal, which consider the community's durability and safety. The 5G smart pole should have high-strength properties with buckling and vibration resistance, including an electrical leakage protection system, waterproofness, corrosion resistance, and weather resistance. As a result, to be able to fulfill the high-quality development of 5G smart poles that can effectively promote 5G city development in various industries.

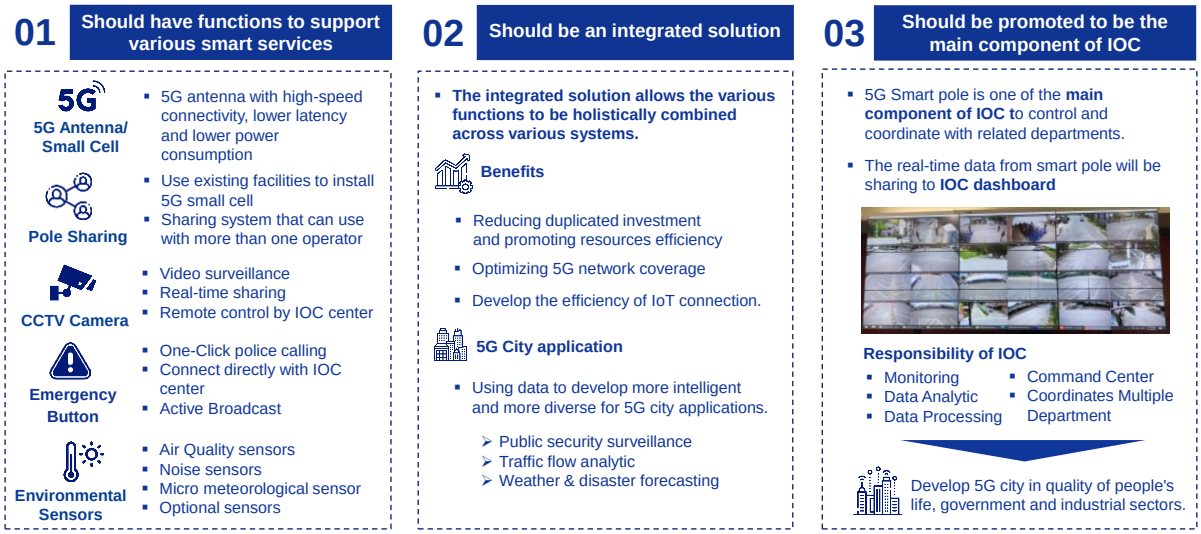


Figure 7-3: Recommendation of 5G Smart Pole

The development of 5G smart pole to promote the network foundation of 5G city, it is required cooperation and support from related organizations for driving the development of 5G smart pole. There are relevant agencies and recommendations for supporting 5G smart pole development as follows:

Table 7-2 : Recommendation of the Agencies for the Development of 5G Smart pole

Related agencies	Recommendation to support 5G Smart pole development
1) Telecom Service Provider e.g., AIS, TRUE, DTAC and NT AIS dtac true บริษัท โทรคมนาคมแห่งชาติ จำกัด (มหาชน) National Telecom Public Company Limited TOT CAT	Provides a high-quality 5G network and installs 5G Small Cells to enhance network coverage in a wide area for supporting various functions in smart poles to be able to use more efficiently by cooperating with all telecom operators to share infrastructure for providing extensive coverage to develop an efficient 5G city.
2) 5G Technology Solution Provider HUAWEI NOKIA ERICSSON	Develop the device more stable and more efficiently in terms of usage and energy consumption for promoting the power efficiency.
3) Provincial Administrative Organization (PAO)	Collaborate with the provincial and electricity sectors to request authorization for installing 5G small cells in existing facilities, which can enhance network coverage and support infrastructure sharing, reducing duplicate investment and promoting resource

Related agencies	Recommendation to support 5G Smart pole development
4) Electricity sectors: Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA)	efficiency. Furthermore, conferring on the appropriate installation of 5G smart poles in various areas, which can be utilized in actual situations and provide the maximum benefit to users.
5) Transport Sector: Ministry of Transport) (MOT) and Office of Transport and Traffic Policy and Planning (OTP)	Driving the development of 5G smart poles to analyze traffic conditions by using real-time data from CCTV cameras to develop the efficiency of transportation systems, including conferring and providing advice based on actual usage as a guideline for improving smart poles to support the development of transportation management.
6) Public Health Sector: Ministry of Public Health (MOPH) and Department of Health	Promoting the adoption of 5G technology in connection with the IOC Center to assist people in an emergency immediately, as well as supporting the development of a 5G Connected Ambulance that allows doctors in the ambulance to communicate with specialists who need additional diagnoses for a patient's treatment to be more accurately.
7) Administrative Sector: Ministry of Interior (MOI), Royal Thai Police Headquarters, Community Development Department, and Department of Disaster Prevention and Mitigation	Establishing a public security team that collaborates with the IOC center to use data from CCTV cameras for surveillance monitoring to analyze crime forecasts and use the information to improve disaster prevention and mitigation plans, including promoting the learning process and public participation through the utilization of 5G technology to improve the quality of people's lives in terms of increasing the efficiency of crime prevention and enhancing public security.

7.3 Examples of Technical Requirements of 5G Use Cases

The technological requirements for implementing 5G technology in the creation of various smart services varies, as does the 5G network design. This chapter describes the technical requirements of 5G networks for each of the key services, emphasizing the significance of creating 5G network capabilities to deliver smart services efficiency and develop future growth toward becoming a 5G City, with the following examples of services:[34]

1. 5G Remote Driving and In-Car Entertainment

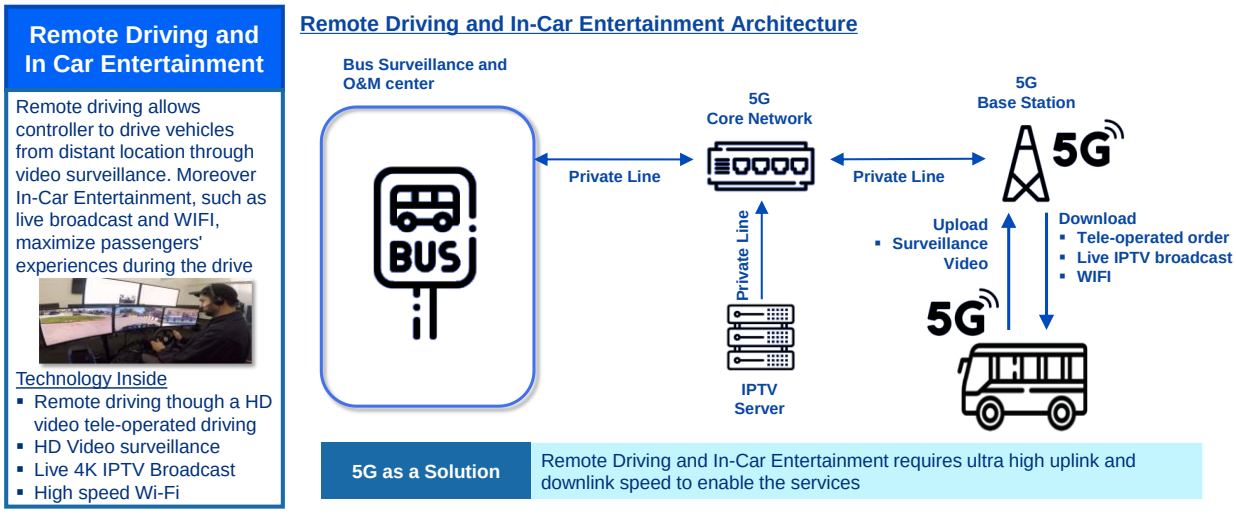


Figure 7-4: Remote Driving and In-Car Entertainment Architecture

Remote driving service with in-car entertainment is a service that will drive the car through human control remotely. This is generally a service that requires an efficient and comprehensive broadband internet network to operate the vehicles safely and efficiently. Remote Driving was originally a technology that was used in deep-ocean or space exploration. It is controlled by the operator through a screen that broadcasts the actual situation in front of the vehicle via WLAN or telecommunication networks (UMTS, LTE).

Remote driving and in-car entertainment have been developed to provide passengers with a complete and comfortable travel experience through various in-car services such as television broadcasts with 4K clarity or high-speed Internet service (Wi-Fi) while also broadcasting live driving situations in HD to drivers in the O&M center. **All this work requires 5G technology that capable of exchanging large volumes of data quickly so that all remote vehicles with in-vehicle entertainment can operate safely and efficiently.**

[34] Source: Huawei

Table 7-3 : Technical Requirements of Remote Driving and In-Car Entertainment

Resolution	Coding	Uplink Coding Rate	Distributed Bit Rate
SD	MPEG2	8-10Mbps	3.2-4.8Mbps
HD	AVS+/H.264	18-24Mbps	8-12Mbps
4K/VR	AVS2+/H.265	60-75Mbps	30-36Mbps
4K (100P)	Dual Layer	100-120Mbps	50-60Mbps

2. 5G Safety Zone Monitoring and 5G Vehicle Self-driving

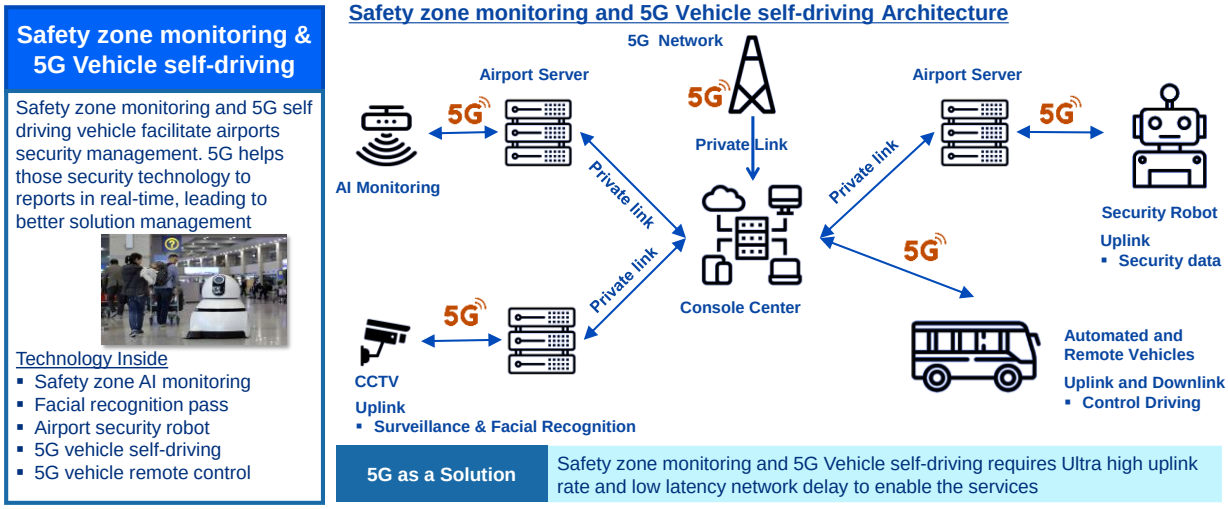


Figure 7-5: Safety Zone Monitoring and 5G Vehicle Self-driving Architecture

The safety zone monitoring system service within the airport was developed original only for human security system. However, nowadays innovation and digital technology has helped to promote and develop security by a combination of AI Monitoring and security robot applied through the 5G network that can transmit high-definition images in 4K, so that abnormalities can be clearly detected and scanned, and it is necessary to display images in real time by transmitting images and performing control over long distances smoothly and timely.

In the service of 5G Vehicle Self-driving) within the airport, it is a service that can effectively reduce the use of resources in both fuel and human resources for the convenience of passengers or moving things, including creating a new experience as well. With the development of 5G technology to enhance efficiency in operation and control, it is also

possible to live stream the driving situation in HD and control long distance driving from the driver in the operation center via 5G network.

With these intelligent services, **5G technology plays a very important role in the application to achieve efficient operation of both high-volume and high-resolution data transfers to achieve speed and distance control in real-time form of security and autonomous driving.**

Table 7-4 : Technical Requirements of Remote Driving and In-Car Entertainment

Use Case	Function	Uplink Rate	Network Delay
Safety zone AI monitoring	5G fixed camera (4K)	> 20 Mbps	≤ 100 ms
5G patrol vehicle self-driving/ Airport security robot	Security robots for HD surveillance	≥ 40 Mbps	≤ 100 ms
5G patrol vehicle video backhauls	UAV 4K single-channel video	≥ 15 Mbps	≤ 100 ms
5G patrol vehicle self-driving/ 5G patrol vehicle remote control	UAV-based remote control	≥ 1 Mbps	≤ 40 ms

3. Conference VR Live Broadcast

Conference VR live broadcast is a unique viewing experience for the users of the conference, which is the viewing of images or videos that are being broadcast live while the viewer and broadcaster are in different places. By live broadcasting, AR technology has been applied ร n which the images are sent to the cloud or a central server in the live broadcast and viewers can watch by wearing a device that supports AR technology through 5G networks that are effective in transferring large amounts of data and processed quickly.

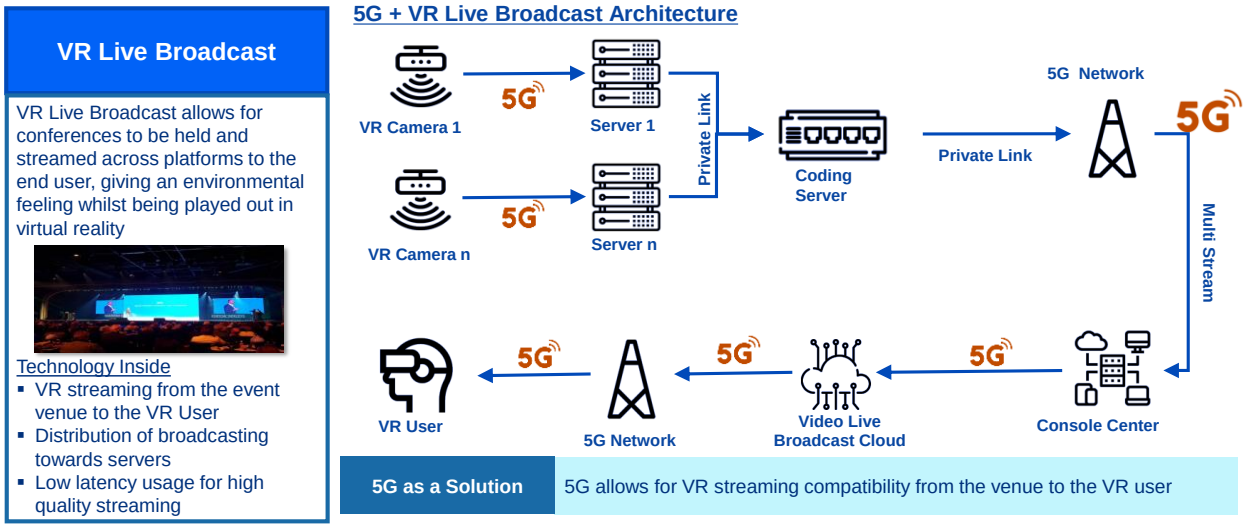


Figure 7-6: 5G + VR Live Broadcast Architecture

Using 5G and augmented reality technology in live broadcasts, there is a significant need for 4K images that can be shown rapidly and gracefully.

Table 7-5 : Technical Requirements of 5G + VR Live Broadcast Architecture

Resolution	Coding	Uplink Coding Rate	Distributed Bit Rate
SD	MPEC2	8-10 Mbps	3.2-4.8 Mbps
HD	AVS+/H.264	18-24 Mbps	8-12 Mbps
4K / AR	AVS2+/H.265	60-75 Mbps	30-36 Mbps
4K (100P)	Dual Layer	100-120 Mbps	50-60 Mbps

4. Wireless Monitor and Location Track

Wireless monitoring system and patient location tracking in the hospital has been developed to apply digital technology to use in emergency services in the hospital to use the shortest time to find and reach the patient by relying on the 5G network signal that covers both inside and outside the hospital to determine the location of the device attach to the patient so that the patient's location can be displayed at any time or when a call for help is sent as well as being able to detect abnormal heartbeats of patients then send the signal back to the laboratory. This will allow for faster and more accurate patient identification and access, as well as the control room to assist patients in a timely manner.

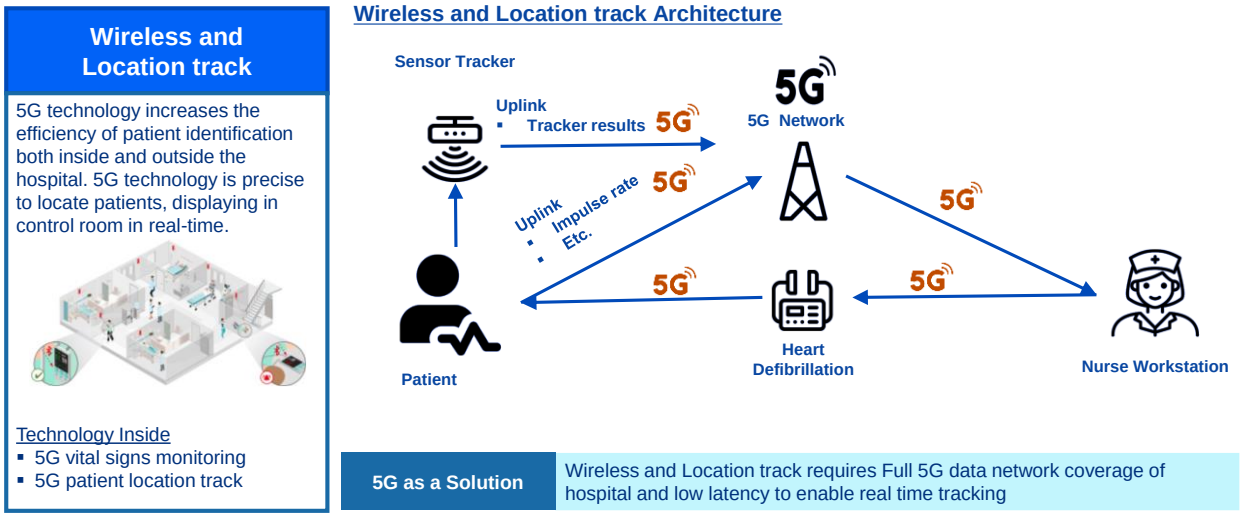


Figure 7-7: Wireless and Location Track Architecture

Therefore, **5G technology is essential to improve service efficiency by enabling accurate geolocation and up-to-date display to the control room for monitoring.**

Table 7-6 : Technical Requirements of Wireless and Location Track Architecture

Use Case	Location Precision	Data Speed	Telecom Time Delay	Location Time Delay	Coverage Range
Patient Location	Indoor ≤ 10 m	UL ≥ 10 kbps	≤ 200 ms	≤ 2 s	Full coverage of In-patient Building
Vital signs monitoring	N/A	UL ≥ 200 kbps			
Patient Location Track	Indoor ≤ 10 m Outdoor ≤ 20 m	UL ≥ 100 kbps	≤ 200 ms	≤ 2 s	Full coverage of Hospital and prefer continuous outside coverage

5. 5G Remote Diagnostic and Ambulance

Remote diagnostics is a service between doctors and patients who are far away from each other to treat or monitor symptoms including ultrasound without having to meet in proximity. This is considered the use of 5G technology to help display images and videos to communicate with each other in real time.

In the field of remote-controlled ambulances, it is the adoption of 5G technology to enhance diagnosis and treatment procedures in communication between physicians in primary hospitals and mobile medical units before patients are taken to hospitals. Large-scale high-definition HD data transmission such as CT scans and ultrasound images over 5G networks, as well as surveillance cameras, can broadcast all the activities inside the ambulance by sending real-time images and video back to the hospital to observe the patient's condition. This can help reduce the mortality rate.

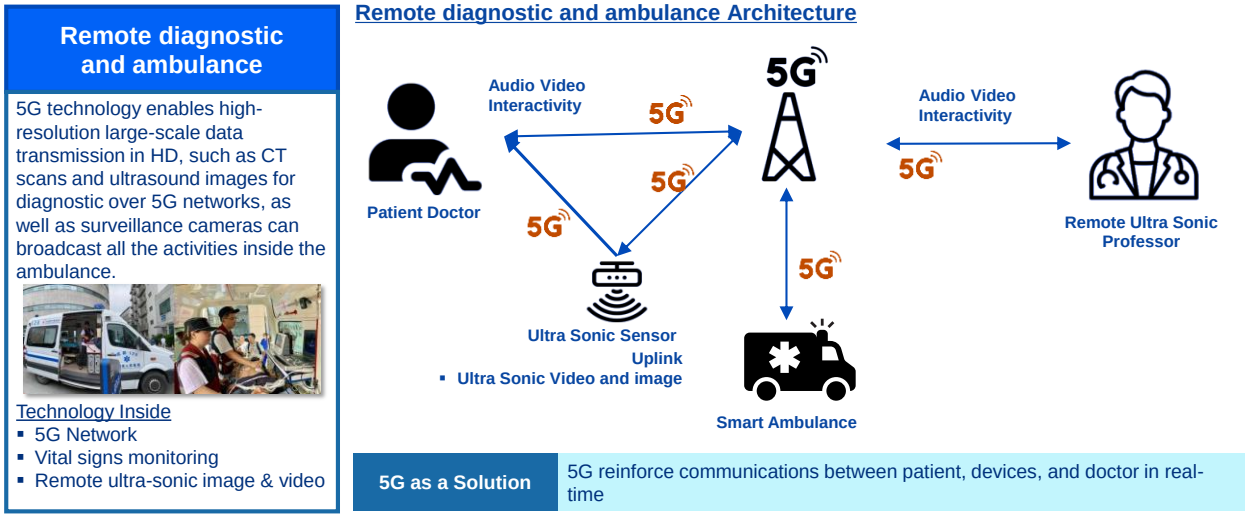


Figure 7-8: Remote Diagnostic and Ambulance Architecture

5G technology is needed to process high-resolution HD images and transfer data in real time, thereby enhancing the efficiency of medical teams to help patients in a timely manner.

Table 7-7 : Technical Requirements of Remote Diagnostic and Ambulance Architecture

Use Case			Data Speed	Time Delay	Coverage Range
Remote Ultra-sonic diagnostic	Patient side	Patient video (1080P)	UL 5 Mbps	≤ 50 ms	Full coverage of clinic building and in-patient building
		Ultra-sonic image and video (1080P)	UL 5 Mbps		
		Doctor video (1080P)	DL 5 Mbps		
	Doctor side	Patient video (1080P)	DL 5 Mbps		
		Ultra-sonic image and video (1080P)	DL 5 Mbps		
		Doctor video (1080P)	UL 5 Mbps		
Smart Ambulance	HD video transfer (1080P)		5 Mbps	≤ 50 ms	Full continuous coverage in or outside Hospital
	Remote ultra-sonic image (1080P)		5 Mbps		
	Vital signs monitoring		200 Kbps		

6. VR Interactive Tourism

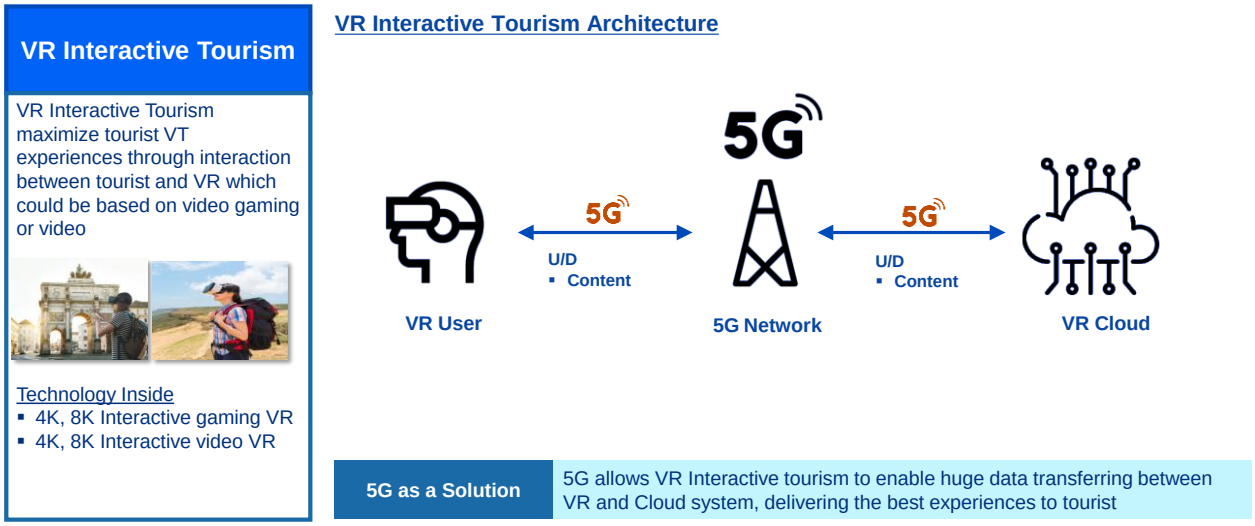


Figure 7-9: VR Interactive Tourism Architecture

VR Interactive Tourism is a service that supports Smart Tourism in smart cities, where tourists can travel like they are in real places by wearing AR/VR cameras. This technology improves communication between travelers or wearers to be able to respond to the virtual

image enabling them to travel and move in a virtual image, such as walking in ancient places or reading the descriptions of the sights they walk through on the camera.

Table 7-8 : Technical Requirements of VR Interactive Tourism Architecture

VR Application	Resolution	DL Speed (Mbps)	Time Delay
Light Interactive application (video based)	VR 360 4k (2018)	50	Normal
	VR 360 8K (2019-2020)	140	Normal
	VR 360 12K (2021)	230-870	Normal
Heavy Interactive application (gaming based)	VR 360 4k (2018)	80	20
	VR 360 8K (2019-2020)	260	15
	VR 360 12K (2021)	500-1000	10

Virtual Reality Camera Travel offers travelers the ultimate travel experience, where the quality of images and video transported in VR cameras contributes to travelers creating the most realistic experiences. However, virtual reality formats such as video games or high-definition videos such as 4K or 8K require the connection of VR devices and networks for tourists to exchange large amounts of data fast can respond in both virtual and real time while traveling.

7. 5G Classroom and Campus

5G Classroom and Campus is to prepare for various smart services in teaching and securing a school or university. There are a variety of ways to apply use cases within the classroom, whether it is an AR/VR camera that allows students to see a virtual reality during teaching in the classroom or remote classroom or supporting devices inside the classroom such as a smart board that connects to student communication tools for expressing opinions and asking questions during the lesson. It can also improve the security of the school or university area by the introduction of face detection technology to detect outsiders or using robots to patrol the campus, etc.

Therefore, 5G technology is very necessary to connect various technologies to the university network to effectively control, monitor and provide smart services within the university in terms of teaching, learning and safety on campus.

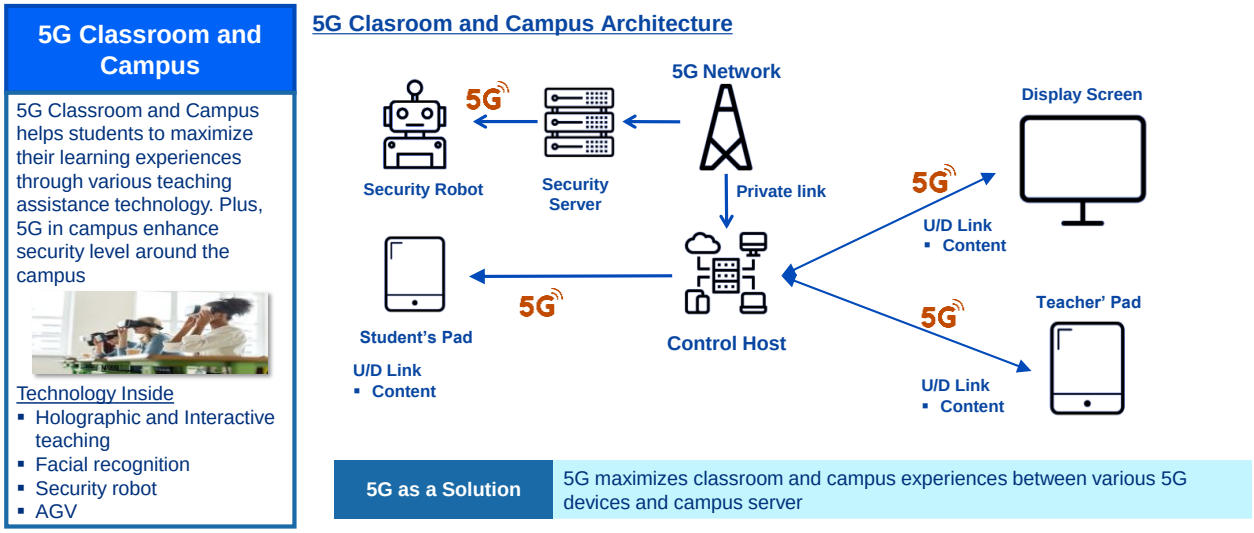


Figure 7-10: 5G Classroom and Campus Architecture

Table 7-9 : Technical Requirements of 5G Classroom and Campus Architecture

Topic	5G Smart Campus
Network	■ Speed QoS: downlink > 100Mbps/ Uplink > 20Mbps ■ Latency: 30-50 Ms ■ Reliability: 99.99%/SA-8
Devices	■ CPE x2 +AR, Industry Module
Network Solution	■ 700 MHz +2.6GHz as fundamental layer, 4.9 GHz with 1:1 /1:2 frame structure, Super uplink by FDD 2.1 GHz, R15 eMBB slicing, QoS, UPF plunge and play
Services	■ MEC Planning: Location, Service server evaluation ■ Private Service over Public Network design & QoS planning
Use Cases	Campus Security: ■ Enterprise Campus (local LAN design), 1k/2k AR/VR, Remote control, Surveillance CCTV 1080P, Security robot, AGV,Local CCTV management, Facial recognition

8. 5G Port and Factory

5G smart port is to prepare and develop the ability of ports or ports in smart cities to operate efficiently through the use of various technologies that allows operations within the port or port to be convenient and fast. For example, RTG Remote Control technology, Unmanned Container Truck or UAV Drone, etc. need to be connected to the internal systems of the smart port to operate efficiently and safely. 5G technology will play an important role in the communication between devices from these various technologies and the control room.

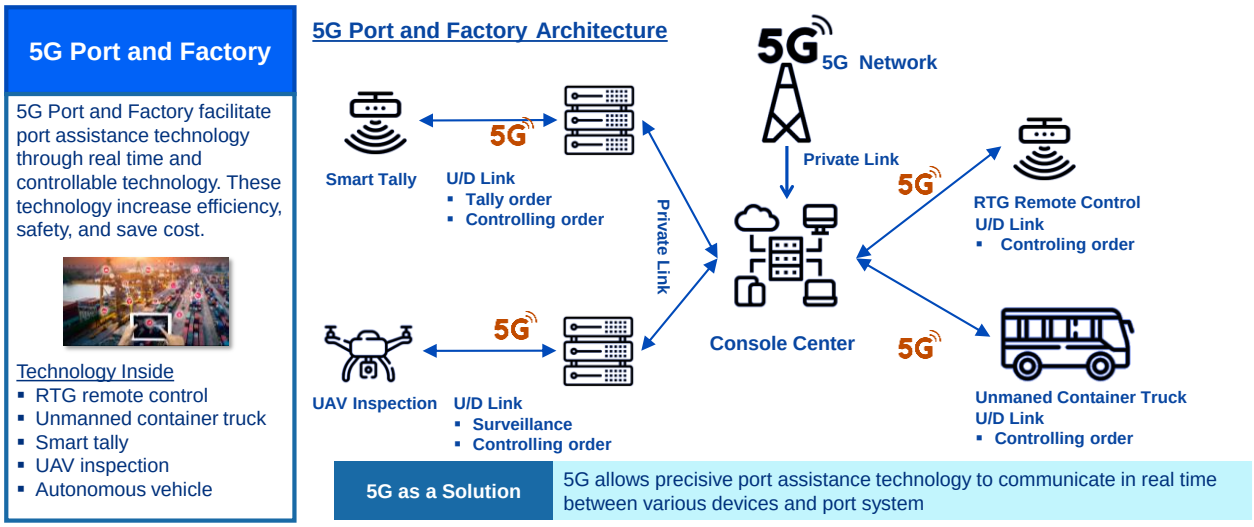


Figure 7-11: 5G Port and Factory Architecture

Table 7-10 : Technical Requirements of 5G Port and Factory Architecture

Topic	5G Smart Campus 2.0
Network	▪ Speed Qos : uplink >200Mbps ▪ Latency : 15-30ms ▪ Reliability : 99.95%/SA-4
Device	▪ Integrated Industry Module
Network Solution	▪ 5G Carrier Aggregation, R16 uRLLC slicing, super uplink 2.0, R15 eMBB slicing, MEP+GPU+AI, ARM Ecosystem, 3rd Apps
Service	▪ 3rd party pre-integration, quality validation ▪ Private network speed and latency improvement
Use Cases	▪ **Factory Manufacturing:** Cloud AR/VR/MR, 4k/8k industry cams/Machine Vision, 5G auto driving, UAV (Drone), Production & Quality monitoring

7.4 Glossary

Table 7-11 : Glossary

5G AI for Diagnosis in Radiology	The use of AI technology to increase the efficiency of diagnostic radiology such as X-ray, magnetic resonance (MRI) and ultrasound, etc.
5G AI For Feeding	The concept of applying IoT and AI technology to increase the efficiency of feeding livestock and aquatic animals, analyze data collection and make accurate recommendations on the required mineral and food intake including estimating the number size and weight to help reduce the amount of excess waste and costs incurred from overfeeding.
5G Base Station	5G network core equipment, which provides coverage of 5G technology both wireless and wireless transmission between wired communication networks and wireless terminals.
5G Citizen Insurance)	The adoption of 5G technology will be involved in the insurance business from the beginning to the end of the insurance policy issuance process, allowing customers to quickly transmit information about their risks and coverage needs to insurance companies.
5G City	5G City is a city with high efficiency 5G Network, an important infrastructure for developing intelligent services in various fields. 5G City provides many benefits to the government, the private sector, and the people sector such as an extensive coverage network. It allows the users to have a better connection to high-speed connectivity and it also supports the implementation of 5G intelligent services in the city. Moreover, 5G technology does not only promote energy conservation and green energy but also brings a positive impact on the environment developing a sustainable 5G City.
5G Connected Ambulance	The introduction of technology and innovation will enhance the efficiency of long-distance communication between ambulance doctors and specialists in the event of a need for further diagnosis to make the treatment of patients more accurate.
5G Coverage	Network coverage can be determined from the coverage area of 5G network, such as hot spot coverage, urban coverage and areas covered at the provincial or national level, etc.

5G Disease Monitoring	The concept of bringing IoT and AI technology to help farmers who grow crops, livestock, and aquaculture to monitor farm environment and animal health to prevent the spread of the epidemic which leads to massive losses.
5G Patrol Robotics	Adopting technology to develop robots for patrol, surveillance, and security for the people to reduces the burden of staff who must have to oversee 24 hours a day. It can improve security and reduce sanitation risks during the epidemic.
5G Private Network	Network system within the organization which connects the networks in each branch together by using the Internet as an intermediary, suitable for large enterprises that need flexibility in data transmission between branches. Moreover, a private network will answer the question in terms of data security.
5G Remote Controlled Crane	The application of 5G technology allows operators to remotely control container cranes to help manage cargo in commercial ports more efficiently.
5G Remote Controlled Forklift	The adoption of 5G technology helps remotely control forklift trucks to move things from one point to another in real time and accurately which increased safety in high-risk work.
5G Sandbox	Areas with special regulatory requirements, which are different from the usual ones, will allow for more flexibility and agility to allow for more flexibility in the development and testing of innovations during development and testing, allowing for trials of 5G services.
5G Small Cell	A small diffuser designed to provide a greater coverage of the service area, especially in the case of 5G service at high frequencies with low signal coverage.
5G Smart Irrigation	The development concept using IoT technology to install various sensors, as well as apply Machine Learning and Cloud Computing technologies to develop a more efficient water management irrigation system.
5G Smart Pole	A smart light pole with multiple functions by combining various technologies and innovations integrated into a single pole to be part of laying the foundation for the development of 5G City in many areas.

5G Technology Development Policy, 14th Five-Year Plan	China's National Strategic Plan that determines the country's direction in the period 2021 - 2025, with the main development issues: 1) Economic development policies to make GDP growth goals to be more flexible by setting an annual GDP growth target and can be adjusted according to the situation; and 2) the environmental quality development policy by focusing on reducing carbon emissions to pave the way for a carbon-free country to be achieved by 2060, while supporting the clean energy industry. In addition, it pays attention to investment in innovation and to improves people's quality of life.
5G Unmanned Store	Smart unmanned shop service that uses the stability of the network signal to connect all systems, combining the use of AI, IoT and Big Data technologies to meet customer convenience and reduce the number of employees in service.
Area-based Innovation	Area-based Innovation aims to enhance the area to have innovation potential which will contribute to economic and social development leading to a good quality of life for people in the area, divided into 3 levels: 1) Innovation District is an area/community that can easily travel to each other and operates business in the same group.2) Innovation City is a district that comes together to form city identity. 3) Innovation Corridor covering many innovation cities, with leading universities, research firms, innovations in digital technology, and BIOs along the journey between cities.
Artificial Intelligence: AI	It is a branch of computer science that deals with how to make computers have human-like abilities or imitate human behavior, especially the ability to think for themselves or have intelligence. This intelligence is created by humans for computers, so it is called artificial intelligence. Each person's perspective on AI may differ depending on whether we need intelligence with regards to environmental behavior or the cognitive abilities of AI products.
ASEAN	Southeast Asia is a sub-region of the Asian continent consisting of countries bordering China in the north, India in the west, Papua New Guinea in the east, and Australia in the south
Augmented Reality: AR	Augmented Reality or AR is the presentation of perspectives in the form of a mixture of the real world and augmented with virtual objects resulting in a unique perception experience. It

	consists of three characteristics: (1) It is a technology that combines real and virtual (2) It can be interactive in real time. (3) It displayed in 3D format (Registered in 3-D).
Automated Guided Vehicle	Vehicles used for automated unmanned loading and unloading of goods using magnetic strips, vision, or laser to tell direction to the car when moving which help to reduce labor problems, space saving, reduces raw material delivery time, increase production efficiency in industrial works, factories, warehouses to transport goods from one point to another.
Autonomous Vehicle	A car that can drive itself without human control It is another automotive technology that is likely to enter the world market sooner than expected. Self-driving cars are a combination of technologies such as mapping systems, systems that act as an ear for self-driving car and artificial intelligence processing systems, etc.
Availability	Compatibility to support different devices with the need to use the network at the same time at any one time
Average User Experience Data Rate	The actual traffic received by the subscriber with average usage over the coverage area for areas such as urban or suburban areas, the actual data rate received by the subscriber should be at least 100 Mbps. However, in the hot spot area, the actual data rate received by the subscriber should be at much higher, such as 1 Gbps inside the building, etc.
Bandwidth	The communication speed or connection speed is the maximum data transfer rate of a cable or network device. This is used to measure the speed of data transmitted over both wired and wireless connections. The unit is in bits per second.
Bandwidth	The ability of a network connection that bandwidth will indicate the amount of data that can be sent along with the network. The more bandwidth, the more data it can download (via network) only faster. It is mostly used to refer to the Internet connection or connection in the mobile network, etc.
Big Data	The volume of data that is very large (Tera Byte or Peta Byte level) beyond the processing capacity of a simple database system, and the data changes rapidly, such as social media data, trading data, financial transaction data or the use of phone calls or data from Sensors, which allows data to have a variety of formats (Variety), both formatted and unformatted, which may

	be in the form of RDBMS, text, XML, JSON or image. For Big Data Technology is a technology in bringing huge amounts of data to analyze, processed, and displayed in an appropriate way. Big data analytics make it easier to use data for planning purposes or decision making, known as Big Data Analytics.
Business-to-Business: B2B	Trade between business and business together with the purpose of meet business needs of whether the raw material production of goods or services for the benefit or development of the business of the organization without using it for personal consumption or consumption, such as buying fabrics to make shirts.
Business-to-Customer: B2C	A business that sells goods or services between a business owner (B) and an individual consumer (C) or is a type of e-commerce business that has a short-term relationship between the business owner and the direct buyer. Examples of B2C businesses are product categories such as food, clothing, and service types such as airlines, hotels, etc.
Cloud Gaming	Gaming via cloud without relying on any hardware or devices to process the game.
Cloud service	Providing cloud computing is a service concept that takes advantage of an interconnected IT infrastructure with multiple servers working as one. to provide various applications. The advantage is that it reduces the complexity of the user who wants to use the service, saves energy, and reduces costs because of cloud computing works through technology as a system, so it is not limited in terms of performance and capability of using processors from different systems since many services such as Internet conferencing, Web Conferencing, Online Meetings, users may be in the same room or far from each other in different hemispheres.
Commercially Launched	Providing services in a form that various sectors engage in the purchase and/or sale of goods or services
Connection Density	Connection density is the total number of devices connected to the network per area size (per square kilometer). The 5G network can support the connection of up to 1 million devices per square kilometer.

Dashboard	Dashboards used to summarize executive data from various perspectives for easy viewing, shorter interpretation times, and addressing business or managerial needs.
Data Center	A center that has space for the placement of central processing systems, computer networks and communications equipment. Data center design must consider important factors such as stability, availability, maintenance, investment, suitability, security, and support for future expansion. Data centers are therefore required to be properly designed and constructed to meet standards to provide uninterrupted service quality, including in emergency situations.
Database	The part used to collect data to provide quick and convenient storage and access to central information. Related information is kept together in a systematic way with clear relationships between the information. A database system consists of several data files that contain data. They are interrelated in a systematic manner and allow users to use and maintain and protect the information effectively.
Density	A network capable of supporting connection density, which allows uninterrupted traffic between many devices.
Door and Window Magnetic Sensor	Two magnetic contact sensors are mounted between two doors and a door frame to detect the opening of a door or window. The sensor sends a signal to the camera to provide alerts via mobile application, email, and siren.
Download Speed	The speed of retrieving data from the provider's server.
Dual Giga Architectural	A high-speed communication network architecture capable of delivering broadband Internet services at high speeds of more than 1000 megabits per second (Mbps) or 1 gigabit per second (Gbps) in both wireless and wired connection (Wireline) for communication and services to be connected seamlessly.
Eastern Economic Corridor: EEC	The Eastern Economic Corridor is an area to support systematic and efficient economic driving through management mechanisms under the supervision of the Eastern Economic Corridor Policy Committee chaired by the Prime Minister. In the first phase, the area will be an upgraded of 3 provinces, namely Chonburi, Rayong and Chachoengsao.

Edge Computing	Processing data to display faster as close to the speed of the network as possible. It can be processed from small data centers, specialized on-site data centers such as micro data centers, or IoT connectivity.
Enhanced Mobile Broadband (eMBB)	Applications where high-speed data transmission in gigabits per second (Gbps) is required, where these applications meet the growing demand for data transmission and reception.
Facial Recognition	The system detects human faces and automatically adjusts the face image by using frame that appears to detect face and the focus, color, and metering values are automatically adjusted.
Fiber Optic	The cable made of glass and covered with a special fiber that is shockproof and insulated. It features like a tube to transmit light from source to destination and there are devices at the source and destination that convert light signals into data signals for use.
Fifth Generation Technology	The ITU-R's development of standards for 5G, or IMT for 2020 and beyond, has a fundamentally different objective from past cellular systems from the 1G to 4G era since 5G isn't just for connectivity, communication support and access to people's information (Humancentric communication) alone anymore. but also intended to support the communication needs of all things (Machine-centric communication) in various sectors of the economy, or what we call Verticals, including the industrial sector, the transport sector, the financial sector, or the media sector, etc. as the 5G system can support communication in various sectors of the economy. As a result, our world has stepped into the 4th era of the industrial revolution, an era of full transformation towards a digital society. Industry trends are interconnected between devices and tools also known as the Internet of things (IoT), and automation will play a key role by doing various tasks that will replace current human routine job by technology.
First-mover advantages	The advantage of entering the market before competitors both in terms of access to resources target groups and markets, etc.
Flexible Working Time	Flexible working system where employees can enter or leave work at any time within the time frame specified by the organization, just by completing the hours specified by the organization.

Home Automation	It is part of the building automation control system that covers only the control of the residential or home part. Such systems will consist of various technologies such as lighting control, temperature, humidity control, closing control of doors and windows, and security systems, etc.
Intelligent Operation Center: IOC	The center of the smart brain and nervous system of a smart city that acting in the control and management of various systems, including remote coordination through large screen displays and state-of-the-art central control systems, information can be brought to real-time surveillance of events in the city.
Internet of Things: IoT	The Internet of Things or IoT is an environment consisting of things that can communicate and are connected to each other through both wired and wireless communication protocols. An environment that is interactive and interoperable, IoT will transform industrial patterns and processes into a new era known as Industry 4.0 which relies on the interconnection and collaboration between machines, humans, and data to empower fast and highly accurate decision-making. The technology that makes IoT a reality and has a wide impact can be divided into three groups: (1) technologies that enable things to perceive information in a relevant context, such as sensors; (2) technologies that enable objects to communicate, such as embedded systems. This includes wireless communications that use powers such as Zigbee, 6LowPAN, Low-power Bluetooth, and (3) technologies that enable objects to process data in their context.
Latency	Latency in data transmission or the speed of response to data transmission Milliseconds (ms) or 1/1000 of a second.
LTE Technology	LTE, short for Long Term Evolution, is a technology that was tested in the 4G era. It has evolved to be 10 times faster than the 3G era, capable of transmitting data and multimedia streaming with speeds of at least 100 Mbps and speeds of up to 1 Gbps.
Machine Learning	Enabling computer systems to process, predict, and judge problems manually through learning the input dataset.
Manchester's Triangulum Project	Manchester's 5G Tech City Development Program is a European Commission-funded project to develop smart cities. The main aim of the project is to develop the Oxford Road Corridor as one

	of the low-carbon European cities and able to develop the city to create high economic value, with a total of three areas aiming for development in Manchester which are energy, transport and information technology.
Massive Machine Type Communications (mMTC)	Applications where many devices are connected in the same area with a volume of up to millions of devices per square kilometer by transmitting device data in this manner. It is a small data transmission that does not require high speed or low latency. The equipment is generally cheap and has a longer battery life than conventional devices. This capability makes 5G systems suitable for the operation of devices such as IoT devices.
Millimeter Wave (mmWave)	Frequency bands higher than 24 GHz (High Band), which is a frequency that has a very short millimeter wavelength. It has a very wide bandwidth, so it can support ultrahigh capacity and very low latency with high traffic or high data rate requirements
Mixed Reality: MR	Virtual and real-world technology combines AR and VR by simulating what you see in the real world as part of the virtual world. As a result, the user can see through the device and the data or images are simulated overlapped where the user will be able to interact with what he sees.
Mobility	Mobility is the fastest speed that can still achieve the quality of service as defined by standards. 5G networks can be used in situations where speeds are faster than 500 kilometers per hour.
Multi-access Edge Computing (MEC)	Edge computing network or processing near the actual traffic area for reducing latency and supporting real-time application of various technologies.
Network Slicing	The structure of the 5G network that can or supports a separate simulated network for various applications is divided into different sections of the network into slides, with each slide representing the end-to-end network.
Over-the-top (OTT)	Providing any content through the internet without the OTT provider investing or owning the internet network itself.
Park and Ride	The project to promote energy conservation is a project that improves the place to park cars at the end of the sky train so that people can leave the car parked, then ride a free shuttle service to the train to travel to their desired destination instead of using their own car on the road.

Peak Data Rate	The maximum possible throughput, which is under ideal conditions, per user per device, in Gbps. By standards, high-speed data transmission can be as high as 10 Gbps, but in some situations can be as high as 20 Gbps.
Platform	A computer program system that can expand its capabilities unlimitedly to have new functions or modules developed all the time. There are always new innovations and can be connected to other systems. The platform is not limited to software but also to the website or services that other people can program to connect to or extract data automatically.
Pole Sharing	The concept of using 5G smart light towers as a distribution point through cooperation with more than one telecom operator to share the towers to enable the network to cover all areas. This includes promoting the use of existing facilities in Small Cell installations to share the infrastructure and reduce duplication of investment. This will also contribute to the establishment of a network foundation for the development of a stable smart city.
Private/Local Network	Local Area Network (LAN) or is a network used within a limited area where the connection in a private network is a network connection under a single system. As a result, the technical characteristics of that private network can be adjusted to suit the type of use, as well as the private network is highly secure due to usage data in private networks will not go through third parties.
Real Time	A system that can provide a response from a system like immediately upon receiving input Ideally, this real-time system would be a system with zero processing time, in other words, zero processing time.
Reliability	Stable connection for services that require remote device control or services that run 24/7 without network outages or interruptions.
Remote Surgery	The use of robots and information technology allows doctors to perform surgery on patients even in different locations. With 5G technology, it plays an important role in making the surgical images clearer and showing more real time results for the doctor to accurately control the surgery from a distance.
Reversible Lane	Special lanes which will be opened in special cases to drain cars during rush hour.

RFID	A type of identification technology stands for Radio Frequency Identification, that have main purpose to attached to objects to indicate a specific identity or as an identification number, for example, used in place of a label or bar code attached to the product by radio waves. The key components are the reader and the tag. The tag transmits its unique information or identification number in radio waves when stimulated by some process from the reader. For the reader there is a section that can receive radio waves to decode the information sent from the tag.
S-curve	The driving economic growth can be divided into two types: 1) 5 industries with potential (First S - Curve) namely intelligent electronics industry, good income tourism industry, health tourism, agro-industry and biotechnology, food processing industry, and modern automotive industry.2) 5 future industries (New S-Curve) including the integrated medical industry, logistics and aviation industry, digital industry, biofuels and biochemical industries, and industrial robots.
Smart City	A city that takes advantage of modern and intelligent technology and innovation to increase the efficiency of service and city management, reduce the cost and resource utilization of the target city and population with an emphasis on good design and the participation of business and people in urban development under the concept of urban livelihood, modern cities, urban citizens have a good quality of life with sustainable happiness.
Smart Home	Using technology to develop smart homes in four areas: health, environment safety and convenience through connecting with smart home devices with AI and IoT technology.
Smart Pole	It is a concept that combines technology, innovation, and creativity to create something new with a variety of functions such as CCTV cameras, solar lights, charging stations and internet access points, etc.
Smart Services	Bringing traditional services to digital services that customers can choose to use via a variety of devices.
Smart Shuttle Bus	Smart buses that do not require a driver.
Smarter London Together	London's 5G Tech City Development Plan is a consequence of the Smart London Plan in 2013. The plan focuses on collaborating on the development of 5G city and applying new technologies for urban development. In addition, the plan also

	has a mission to provide services that meet the needs of people, collect data for further use and has a connection service and smart roads, etc.
Solar Cell System	The renewable energy generation system is a type of renewable energy that can be used naturally. Such energy is clean, pollution-free and has high potential.
Special Economic Zone: SEZ	The area that the Special Economic Development Zone Policy Committee (NEPC) has designated as a border special economic development zone where the state will support the development of infrastructure, investment benefits, round-trip management of migrant workers, one-stop service, and other necessary services that focus on the development of the city by taking advantage of connecting with neighboring countries for people to have a better life.
Streaming	Transmission signal and transmission of multimedia files, both video and audio over the internet network using technology without downloading files such as Live on Facebook or YouTube, which are supported by many devices such as computers, smartphones, tabs. tablets, including smart TVs.
Teleconsultation	Remote medical consultation via teleconference system or other telecommunication systems and/or transmitting other information such as medical records X-ray image or the sound of the heartbeat through the system from one counselor to others.
The development of 5G Governance and Industrial City	Development of services related to city government and industrial business in various fields. It covers a group of services related to security development, including development that benefits the government, industrial business and tourism business which is the core of driving Thailand's economy sustainably.
The development of 5G Livelihood City	Development of services related to improving the lives of people in the city, tourist, or industrial groups covering various service groups related to the improvement of people's quality of life.
The establishment of 5G Ecosystem Alliance	The establishment of an alliance to help drive the development of 5G City, from the government policy level to the practical level in the private sector. The members of the 5G Ecosystem Alliance will be all involved in the 5G ecosystem, whether government or private sector entities such as telecommunication

	service providers, 5G technology solution providers, and private associations, etc.
Throughput	The amount of transmitted data that can be done. There are two types of throughput units, bit per second and byte per second.
Traffic Signal Control Optimization	A system used to change the time factor with the duration of the green light for each traffic period. Optimizing traffic light timing reduces both idle and vehicle acceleration, resulting in less fuel burn and less CO2 emissions.
Ultra-Reliable and Low Latency Communications (URLLC)	Applications that require very stable data transmission capability Including latency or latency in the transmission is as low as 1 millisecond (current 4G systems support 10 milliseconds). This capability makes 5G systems suitable for applications that require precision. High (Critical Application), such as remote surgery factory machinery control or control of driverless cars, etc.
UMTS	UMTS stands for Universal Mobile Telecommunication System which is a network in the 3G era that has evolved from GSM, GPRS and EDGE networks with data transmission speeds of up to 2 Mbit/sec.
Vehicle-to-everything (V2X)	Vehicle-to-vehicle communication with everything that affects the vehicle's drive or route and vice versa which can be both communication between vehicles, communication between vehicles and traffic infrastructure, communication between vehicles and pedestrians, and much more.
Vertical Industry	References to the different types of businesses in the industry from upstream to downstream
Virtual Classroom	Technology that helps in teaching which allows teachers and students to communicate with each other online as if they were studying in the same room.
Virtual Reality: VR	3D simulation of the scenery to enhance the user experience and in some applications users can interact with events in virtual reality. VR technology must be used in conjunction with VR glasses.
Wireless	It is a technology that helps in communication between computers and other devices that can connect to the network, such as smartphones, tablets, digital TVs, to be able to

	communicate with each other via access point. By communication, this will be a connection without the use of cables. Instead, radio waves are used as a communication channel the traffic between them is through the air.
Wireless	A data communication system with a form of wireless communication using radio frequency transmission in the RF radio and infrared waves to transmit and receive data between computers through the air, through walls, ceilings, or other structures without the need for wiring
Wireless fidelity (Wi-Fi)	A popular technology that allows electronic devices to exchange data or connect to the Internet wirelessly that is compatible with the wireless computer network (WLAN) standard using radio waves.
Wireless Sensor Networks	Using many tiny sensors to measure the properties of the environment and process that information to create new knowledge of the environment or react automatically to changes in the environment.
Wireline	System for transmitting data via wires such as telephone lines and fiber optic cables.

7.5 Agency Abbreviation

Table 7-12 : Agency Abbreviation

Abbreviation	Agencies
AIAT	Artificial Intelligence Association of Thailand
AOT	Airports of Thailand
DEPA	Digital Economy Promotion Agency
DGA.	Digital Government Development Agency (Public Organization)
DIP	Department of Industrial Promotion
DOA	Department of Agriculture
DOA.	Department of Airport
EECO	Eastern Economic Corridor Office of Thailand
FTI	The Federation of Thai Industries
MDES	Ministry of Digital Economy and Society
MHESI	Ministry of Higher Education, Science, Research, and Innovation
MNRE	Ministry of Natural Resources and Environment
MOAC	Ministry of Agriculture and Cooperatives
MOC	Ministry of Culture
MOE	Ministry of Education
MOF	Thailand Ministry of Finance
MOI	Ministry of Industry
MOI	Ministry of Interior
MOPH	Ministry of Public Health
MOT	Ministry of Transport
MOTS	Ministry of Tourism and Sports
NBTC	National Broadcasting and Telecommunication Commission
NIA	National Innovation Agency
NSTDA	National Science and Technology Development Agency
ONDE	Office of the National Digital Economy and Society Commission
TAT	Tourism Authority of Thailand
TC	Thai Customs Department
TPQI	Thailand Professional Qualification Institute (Public Organization)

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