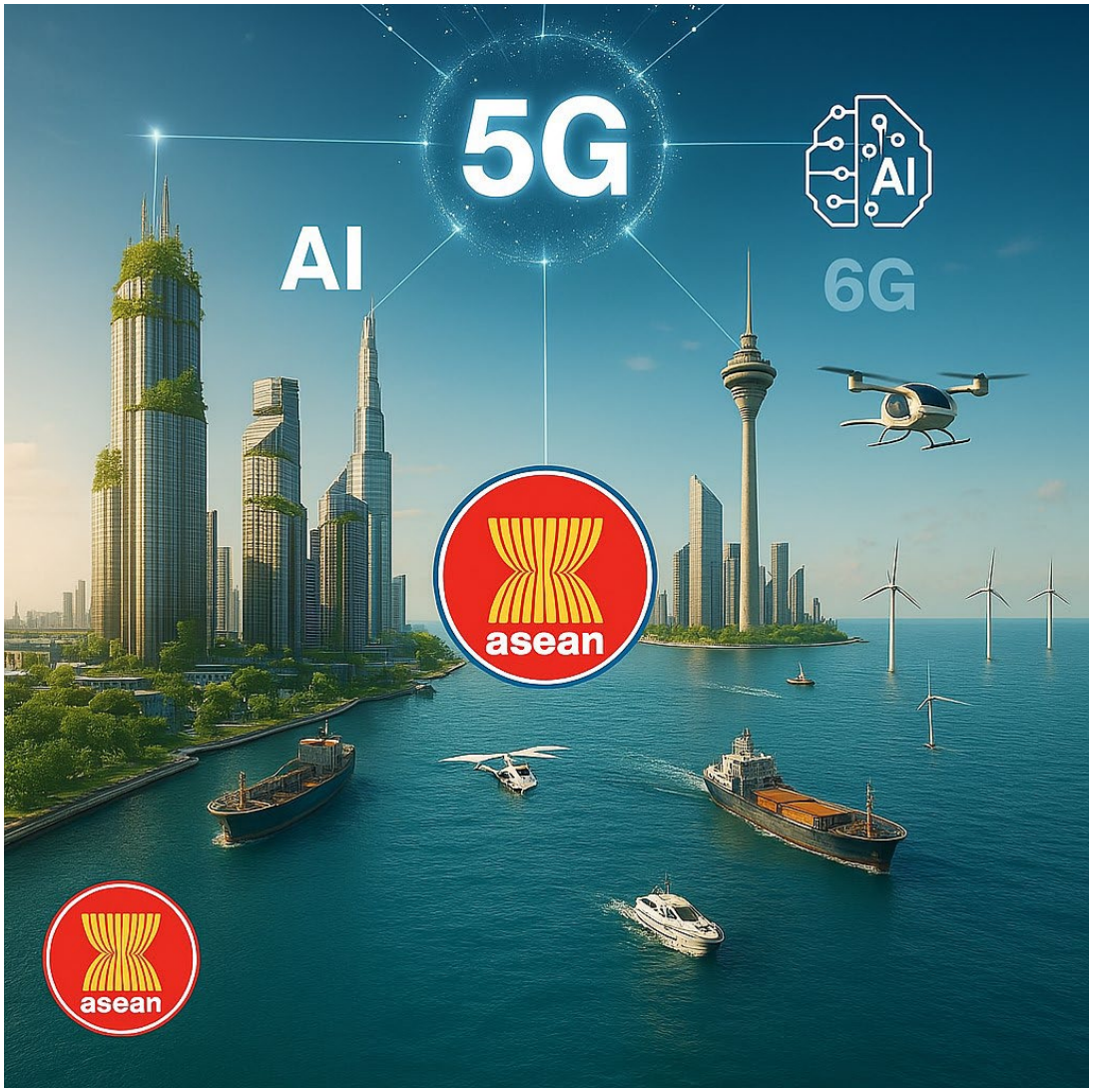
Leveraging 5G to Accelerate AI-Driven Transformation in ASEAN

Imperatives, Policy Insights, and Recommendations



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Executive Summary

ASEAN stands at a defining juncture. The convergence of 5G and artificial intelligence (AI) presents an extraordinary, time-sensitive opportunity for the region to leapfrog into a future shaped by intelligent connectivity, digital sovereignty, and inclusive, sustainable growth. But this window is closing fast—and the cost of inaction is escalating.

5G is not merely a boost in network speed—it is the digital foundation for ASEAN's next era of development. When integrated with AI, 5G becomes the infrastructure of innovation—enabling smart factories, precision agriculture, immersive education, AI-powered healthcare, and climate-resilient infrastructure.

This report identifies three transformative strategic shifts necessary to unlock the full potential of 5G in ASEAN: (i) From connectivity to value creation—shifting focus from infrastructure rollout to delivering high-impact, industry-specific services. (ii) From content to solutions—reorienting digital innovation from entertainment toward AI-powered tools that address real-world development challenges; and (iii) From siloed ICT to AI-powered ecosystems—moving beyond hardware investments to build integrated, cross-sector platforms that scale impact and foster resilience.

These shifts are not theoretical. They are already unfolding—most notably at Singapore's Tuas Port, where a bold vision set in 2012 is now materializing into a fully automated, AI-driven logistics hub powered by triple-band 5G. In less than three years since launching operations, Tuas has handled over 10 million TEUs with zero on-site operators—replacing manual processes with networked machines, predictive AI, and a transformed, tech-enabled workforce. It is not just a port—it is a living model of how ASEAN can lead with vision, embrace experimentation, and unlock digital competitiveness at scale.

Yet, progress across the region is uneven. While leaders like Singapore, Malaysia, and Thailand have advanced with nationwide deployments and industry testbeds,

many others still face spectrum bottlenecks, fragmented policies, underinvestment, and widening digital skills gaps.

Drawing on expert interviews, regional surveys, and field insights, this report identifies 10 critical Insights:

1. ASEAN urgently needs coordinated, high-level digital leadership—fragmentation is slowing the progress.
2. 5G must be treated as a strategic AI enabler—not just a telecom upgrade.
3. Infrastructure gaps, particularly in rural and industrial zones, must be prioritized.
4. Private 5G networks are vital to enabling industry 4.0 and SME transformation.
5. Widening skills gaps in digital and AI capabilities are impeding enterprise adoption.
6. Spectrum pricing and allocation models must evolve to promote accessibility and innovation.
7. Regional fragmentation hinders scale, investment, and interoperability.
8. Cybersecurity and trust frameworks require urgent strengthening.
9. The private sector is ready to invest—but needs policy clarity and confidence.
10. The clock is ticking—inaction today risks dependence and missed opportunity tomorrow.

To respond, ASEAN must act decisively, with unity, foresight, and execution. This report presents 10 strategic policy recommendations, built around five top strategic priorities:

1. Establish national 5G-AI development strategies (2025–2030), with integrated roadmaps to unlock synergy between 5G and AI.
2. Create empowered national 5G-AI agencies to coordinate policy, investment, and cross-sector implementation.
3. Deploy a forward-looking spectrum policy that ensures accessibility, affordability, and regulatory certainty.
4. Foster a vibrant, AI-driven 5G ecosystem through public-private collaboration—anchoring investment in scalable, value-added services.
5. Implement robust KPIs and monitoring frameworks to assess readiness, adoption, and socioeconomic impact.

Additional imperatives include scaling testbeds and innovation hubs, accelerating future-ready workforce development, and deepening regional cooperation to harmonize standards, align investment, and amplify ASEAN's collective digital power. It is no longer futuristic to imagine ASEAN leading a 5G-AI-powered world, where:

- Enterprises scale globally through agile, intelligent manufacturing
- Farmers increase yields using IoT sensors and AI-driven analytics
- Autonomous drones and vessels protect marine ecosystems in real-time
- Hospitals perform remote surgeries with speed, precision, and confidence
- Smart cities thrive, enhancing liveability, sustainability, and operational efficiency
- Students in remote areas access immersive, AI-powered education
- People connect and learn across languages, seamlessly through real-time mobile translation

Realizing this vision requires ASEAN to act with bold leadership, strategic foresight, unified resolve, and an integrated platform for coordinated action. This report serves as both a roadmap and a call to action—for policymakers, business leaders, and regional institutions to lead decisively, collaborate purposefully, and shape a digitally empowered future for all.

Section 1

Introduction

The digital age, driven by revolutionary technologies like the Internet, mobile connectivity, and AI, has profoundly changed the world. It has reshaped the global economy and inspired bold mindsets with forward-looking visions for the future.

As a general-purpose technology (GPT) akin to electricity, these digital innovations embody the defining characteristics outlined by Bresnahan and Trajtenberg (1995): **'pervasiveness'**, reflected in their rapid penetration across sectors and all facets of society; **'improvement'**, driven by continuous advancements in performance and cost efficiency; and **'innovation spawning'**, enabling breakthroughs in R&D productivity, fostering creativity, and establishing new paradigms for growth and transformation.

In addition to these features, digital technologies possess unmatched capabilities to foster synergy-enhancing ecosystems. They drive integration, facilitate interaction, expand market reach, and enable effective coordination, thereby creating a dynamic environment that accelerates economic and societal progress globally and ensures inclusion, touching every corner of the population.

The benefits of embracing the digital revolution are vast, profound, and rapidly expanding, driving transformation across economies and societies. These benefits manifest through eight key channels (Vu et al., 2024):

(i) Lower communication costs and enhanced speed and exchange effectiveness.

(ii) Fostering learning and innovation, providing unparalleled access to global information, knowledge, and wisdom, and empowering individuals and organizations to innovate and grow.

(iii) ICT—enhanced by AI—significantly strengthens the ability and effectiveness of decision-making for individuals, businesses, and governments by delivering rich, real-time insights, enabling broad platforms for idea exchange, and expanding access.

(iv) Boosting automation and operational efficiency.

(v) Enabling rapid scalability and global market reach, allowing even resource-constrained or geographically disadvantaged players to scale rapidly and access global markets.
(vi) Fostering coordination, synergy, and the platform economy.
(vii) Enhancing transparency, accountability, and social responsibility; and
(viii) Promoting social inclusion, reducing regional disparities, and enhancing resilience to external shocks and natural disasters.

The advent of 5G, combined with groundbreaking advancements in AI, is significantly amplifying the digital revolution's transformative potential, making it far more foundational than ever before. This shift creates an urgent need for policymakers worldwide to deepen their understanding of the profound impacts of these emerging technologies, especially 5G and AI, and formulate effective strategies and action plans to harness them for economic growth, global competitiveness, and social development.

This imperative is particularly critical and strategic for ASEAN as an economic community. It has the potential to enhance the bloc's overall economic performance, strengthen its global competitiveness, and bolster its future readiness as the world enters an era of paradigm shifts.

ASEAN, comprising 11 member states[1] with a combined population of approximately 700 million, ranks among the world's five largest economies in both USD and PPP terms (Table 1.1). Despite this, the region's GDP per capita remains well below the global average and far below the US level (6.7 in USD; 20.7 in PPP$, taking US=100), reflecting significant development disparities across the region (Table 1.1).

However, ASEAN also boasts a standout success story in Singapore—a nation that has not only leapfrogged from a third-world to a first-world economy within a few decades but continues to advance rapidly by strategically harnessing global megatrends and technological progress. A vivid, unfolding example of this is Tuas Port, Singapore's next-generation maritime hub. Conceived through a bold vision in 2012,

[1] In May 2023, during the 42nd ASEAN Summit in Labuan Bajo, Indonesia, leaders adopted a roadmap outlining Timor-Leste's path to full membership in the association. Timor-Leste's leaders have expressed aspirations to achieve ASEAN membership by 2025.

Tuas demonstrates how infrastructure—when integrated with AI and 5G—can become a powerful platform for resilience, intelligence, and long-term competitiveness.

Built entirely on reclaimed land and launched into commercial operations in late 2022, Tuas Port achieved a major milestone by 2025: handling over 10 million TEUs, enabled by AI-powered automation, 5G network slicing, and a future-ready workforce. Tuas is more than a port—it is a living model of vision-driven transformation, offering a compelling blueprint for how ASEAN can thrive through the synergistic power of AI, 5G, and advanced digital technologies.

Table 1.1: ASEAN Overview, 2024

Economy	Population		Total GDP (current prices)			GDP per capita			
			(Billion)		(PPP$)	At current prices		US=100	
	(Million)	ASEAN=100	US$	PPP$	ASEAN=100	US$	PPP$	US$	PPP$
Singapore	5.8	0.8	547	910	7.4	90,674	150,689	105.7	175.6
Brunei	0.5	0.1	15	42	0.3	33,418	7,970	38.9	9.3
Malaysia	35.6	5.1	422	1377	11.2	11,867	38,729	13.8	45.1
Thailand	71.7	10.3	526	1771	14.4	7,345	24,708	8.6	28.8
Indonesia	283.5	40.8	1396	4663	37.8	4,925	16,448	5.7	19.2
Viet Nam	101.0	14.5	476	1655	13.4	4,717	16,386	5.5	19.1
Philippines	115.8	16.7	462	1366	11.1	3,985	11,794	4.6	13.7
Lao PDR	7.8	1.1	17	76	0.6	2,124	9,788	2.5	11.4
Cambodia	17.6	2.5	46	141	1.1	2,628	7,970	3.1	9.3
Timor Leste	1.4	0.2	2	7	0.1	1,343	4,758	1.6	5.5
Myanmar	54.5	7.8	74	327	2.7	1,359	5,997	1.6	7.0
ASEAN	**695.1**	**100.0**	**3,984**	**12,333**	**100.0**	**5,732**	**17,742**	**6.7**	**20.7**
China	***1,419.3***	204.2	***18,744***	***38,190***	309.7	***13,303***	***27,105***	15.5	31.6
India	***1,450.9***	208.7	***3,913***	***16,191***	131.3	***2,697***	***11,159***	3.1	13.0
Japan	***123.8***	17.8	***4,026***	***6,408***	52.0	***32,476***	***51,685***	37.8	60.2
USA	***345.4***	49.7	***29,185***	***29,185***	236.6	***85,810***	***85,810***	***100***	***100***
World	**8,162.0**	**1,174.1**	**111,326**	**197,428**	**1,600.8**	**13,673**	**24,248**	**15.9**	**28.3**

Data source: World Bank's World Development Indicators Database; accessed July 20, 2025. Note: The GDP values are reported at current prices.

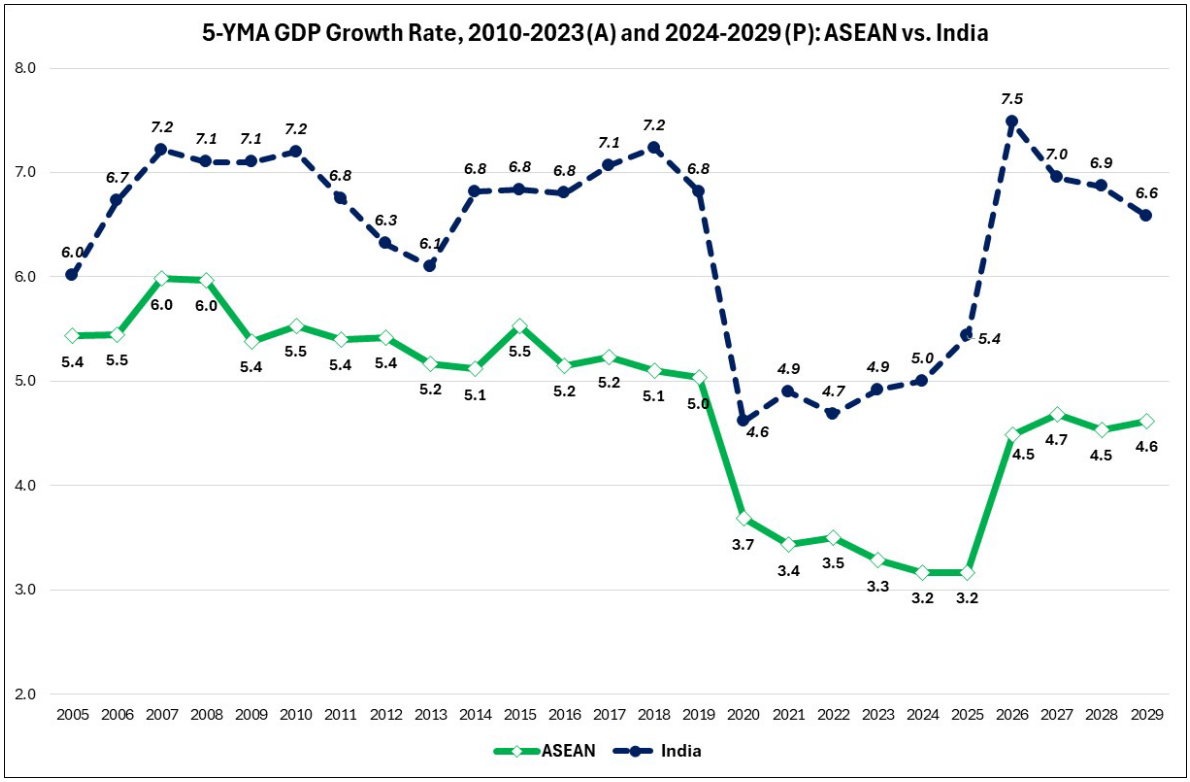
Strategically positioned between two economic giants—China and India, each with over 1.4 billion people and accelerating growth—ASEAN faces both vast opportunities and intensifying pressure to remain competitive. Securing long-term prosperity will require a strategic and synergistic approach to digital transformation, anchored in the effective adoption of breakthrough technologies such as 5G, 6G, and AI.

This imperative is underscored by two pressing challenges: first, ASEAN’s economic performance continues to fall short of its full potential; and second, the region is projected to lag behind global peers in 5G adoption—threatening its future competitiveness unless bold, coordinated action is taken.

Figure 1.1 clearly illustrates ASEAN's underutilized economic growth potential, showing that since 2000, its performance has consistently lagged behind India—a comparable economy in terms of overall development. From 2005 to 2023, ASEAN's 5-year moving average GDP growth has consistently trailed behind India's, a trend expected to persist from 2024 to 2029. The growth gap between the two economies is projected to remain significant, exceeding 2 percentage points from 2024 onward. This underscores ASEAN’s ongoing challenges in fully capitalizing on its economic potential and strengthening its position in the post-COVID-19 era.

It is essential to emphasize the tremendous growth potential of ASEAN as an economic community. The region hosts four of the eight High-Performing Asian Economies (HPAEs) identified in the World Bank's 1995 *East Asian Miracle* report: Singapore, Malaysia, Thailand, and Indonesia. Furthermore, while Singapore remains a leader in global competitiveness and innovation, Vietnam and the Philippines have emerged as two of the world's fastest-growing economies. In addition, ASEAN has become a vital hub in the global value chain for semiconductors and electronics, which are key drivers of digital transformation.

Figure 1.1: Economic Growth Trends Since 2000: ASEAN vs. India



Source: Compiled by the authors using data from the IMF World Economic Outlook 2024 database, accessible at https://www.imf.org/external/datamapper/datasets/WEO.

In terms of 5G penetration, the ASEAN community must urgently implement more decisive and better-coordinated actions to accelerate its deployment and adoption. As illustrated in Table 1.2, the 5G penetration rate in 2024 is significantly lower in Southeast Asia and Oceania (9.4% of 1,160 million subscriptions) compared to India, Nepal, and Bhutan (23.1% of 1,180 million subscriptions). Furthermore, this disparity is expected to become even more pronounced by 2030, with the rate climbing to 74% for India, Nepal, and Bhutan, compared to 51.5% for Southeast Asia and Oceania.

Southeast Asia and Oceania include ASEAN, Australia, and New Zealand, with ASEAN lagging behind Australia and New Zealand in 5G adoption. Additionally, India is outpacing Nepal and Bhutan, indicating that ASEAN is falling behind both India and the global average in 5G adoption. More importantly, if the region continues to follow the deployment patterns observed in recent years, it risks falling even further behind in these comparisons.

Table 1.2: 5G Penetration in Asia and World, 2023-2030

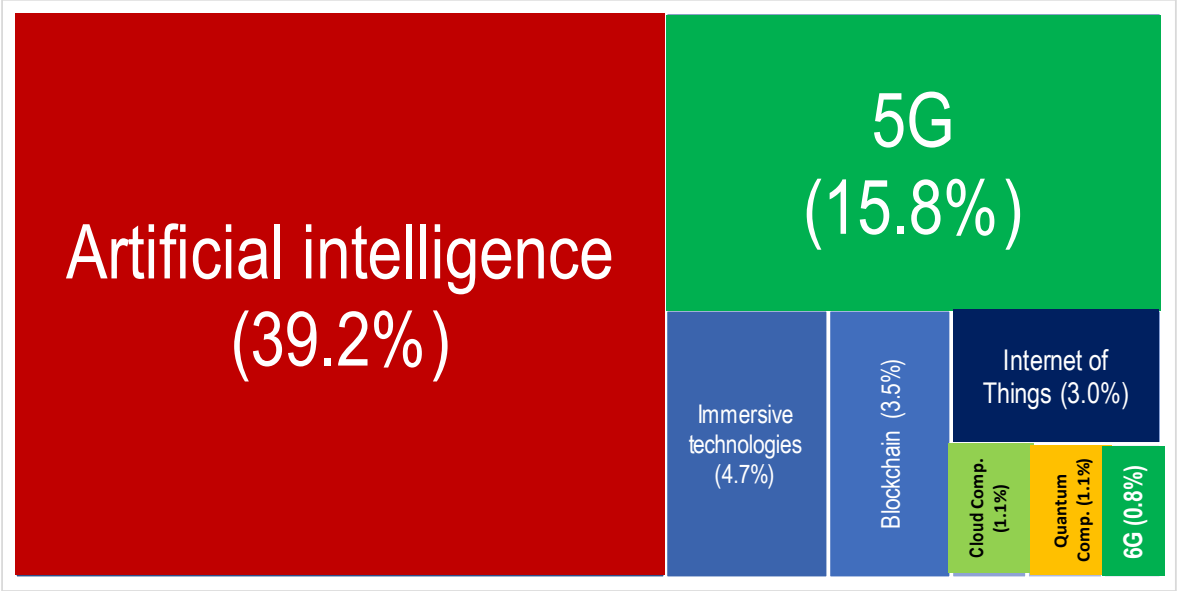
Region	2023	2024	2030 (f)	Pace of Change* 2024–2030
Smartphone Subscriptions (million) [A]				
South-East Asia and Oceania	1,160	1,190	1,320	*1.7%*
India, Nepal and Bhutan	1,180	1,180	1,310	*1.8%*
China	1,740	1,800	1,880	*0.7%*
World	6,930	7,160	8,330	*2.6%*
5G Subscriptions (million) [B]				
South-East Asia and Oceania	61	112	680	*35.1%*
India, Nepal and Bhutan	135	272	970	*23.6%*
China	779	986	1,670	*9.2%*
World	1,603	2,270	6,350	*18.7%*
5G Penetration Rate [B/A]				
South-East Asia and Oceania	5.3%	9.4%	51.5%	***42.1 ppts***
India, Nepal and Bhutan	11.4%	23.1%	74.0%	***51.0 ppts***
China	44.8%	54.8%	88.8%	***34.1 ppts***
World	23.1%	31.7%	76.2%	***44.5 ppts***

Source: Data from Ericsson (2024)
Notes: CARG for 'Smartphone Subscriptions' and '5G Subscriptions'; The pace of change for the '5G Penetration Rate' is calculated by subtracting the penetration rate in 2024 from that in 2030, measured in percentage points (ppts).

While the challenges faced by ASEAN are substantial, they also underscore the region's tremendous potential to accelerate economic growth and boost competitiveness. This potential can be unlocked through well-coordinated efforts to strengthen synergy in integration, coordination, and innovation, especially in expediting digital transformation and utilizing groundbreaking technologies like 5G and AI.

From a global perspective, 5G and AI dominate the policy landscape. A recent OECD survey (2024) of 38 OECD countries and partner economies reveals that approximately one-third of the 1,200 policy initiatives examined in 2023 focus on promoting the effective use of digital technologies to enhance social prosperity and drive innovation. Among these, Artificial Intelligence (AI) and 5G stand out as the most frequently cited technologies (Figure 1.2).

Figure 1.2. The Dominance of AI and 5G in the Policy Landscape of OECD Countries and Partner Economies



Source: Adapted from OECD (2024)

Note: The percentages under each technology represent the frequency of its mention among the 1,200 policy initiatives.

One of the main reasons many nations have placed strategic importance on 5G deployment and adoption is its potential economic contribution. According to a recent GSMA study (2024), the mobile ecosystem is projected to contribute $1 trillion to the Asia-Pacific economy by 2030. This growth will primarily result from the expansion of the mobile ecosystem and the integration of mobile technologies across industries to enhance productivity and efficiency. Notably, 5G alone is anticipated to add $130 billion to the region's economy by 2030, accounting for nearly 12% of the total economic impact of mobile technologies. Furthermore, the Asia-Pacific's growth rate (15%) in mobile's economic contribution surpasses the global average (12%), highlighting the region's rapid adoption and integration of advanced mobile technologies.

In this context, this report aims to provide the audience with a comprehensive understanding of the factors influencing 5G deployment, as well as international best practices for its promotion and notable use cases. Drawing on strong insights from research and expert interviews, the report presents a set of actionable policy recommendations for ASEAN policymakers to collaborate effectively, enhancing their collective efforts to accelerate 5G deployment and fully leverage its transformative

benefits in an era defined by unprecedented advancements in AI and its profound impact in the coming years.

The remainder of this report is structured as follows. Section 2 offers a critical global perspective on the evolution, potential, and transformative power of 5G—positioning it not merely as a network upgrade, but as the foundational infrastructure of an AI-driven digital future. By examining global trends in 5G development—spanning technological advances, deployment models, and emerging use cases—this section lays the groundwork for understanding the broader dynamics of next-generation connectivity and their strategic relevance for ASEAN. Section 3 examines the role of digital transformation in ASEAN, highlighting how 5G can accelerate economic and technological advancements across the region. Section 4 presents insights from stakeholders and expert interviews, offering a grounded perspective on the current state and challenges of 5G deployment. Moving beyond implementation, Section 5 discusses how 5G serves as the foundation for AI-driven transformation, setting the stage for the transition to 6G. Section 6 outlines strategic policy recommendations to optimize 5G adoption and maximize its impact. Finally, Section 7 concludes the report by distilling the key findings and outlining strategic priorities to guide ASEAN in harnessing 5G-AI transformation for long-term prosperity.

Section 2

5G Technology: Promises, Rollout Patterns, and Key Insights

2.1. The ongoing evolution of mobile technologies and the promises of 5G

As we enter the 2020s, 5G has emerged as a transformative technology with capabilities that far surpass those of 4G, particularly regarding data rates (10-20 times higher), latency (10 times lower, achieving the critical threshold of 1 millisecond), and connection density (10 times higher per square kilometer) (Table 2.1). This marks a pivotal moment in network evolution, as its integration with AI creates a new paradigm aimed at connecting everyone and everything—virtually and intelligently—including machines, objects, and devices (ITU, 2024b).

Table 2.1. Comparative Target Capabilities: 5G vs. 4G

Capability	Description	4G	5G
Peak data rate	Maximum achievable data rate under ideal conditions per user or device	1 Gbit/s	20 Gbit/s
User-experienced data rate	Data rate available to mobile users and devices throughout the coverage area	10 Mbit/s	100 Mbit/s
Latency	Radio network's contribution to the time elapsed between the source sending a packet and the destination receiving it	10 ms	1 ms
Mobility	Maximum speed at which a defined quality of service and seamless transfer between radio nodes belonging to different layers or radio access technologies can be achieved	350 km/h	500 km/h
Connection density	Total number of connected or accessible devices per unit of area	10^5 devices/km^2	10^6 devices/km^2
Network energy efficiency	For networks, "energy efficiency" refers to the quantity of information bits transmitted to and received from users per unit of energy consumed by the radio access network		100 times more than 4G
Spectrum efficiency	Average data throughput per unit of spectrum bandwidth, per cell		3 times more than 4G
Area traffic capacity	Total traffic throughput per geographic area	1 Mbit/m^2	10 Mbit/m^2

Source: World Bank (2024)

With its revolutionary features—ultra-low latency, massive device connectivity, and exponentially faster speeds—5G powers groundbreaking applications such as autonomous vehicles, remote surgery, smart agriculture, industrial automation, and immersive communication experiences. For example, while 4G remains sufficient for applications like video streaming, which relies on buffering to mitigate network fluctuations, 5G is uniquely suited to scenarios requiring near-real-time interactivity. Immersive communication experiences, such as interacting with virtual objects, physical environments, or other users, are only achievable through 5G's unparalleled responsiveness and low latency, ensuring seamless and lifelike engagement (Ekudden, 2024).

As 5G continues to expand globally, its integration with recent breakthroughs in artificial intelligence (AI) is set to drive transformative impacts. This synergy is expected to redefine industries, enhance productivity, and create new opportunities, paving the way for a truly intelligent and interconnected world. Furthermore, it

establishes the foundation for the emergence of 6G, anticipated by 2030, which will further elevate connectivity and technological innovation.

2.2. Global Trends in 5G Rollout

South Korea, the U.S., and China were among the first countries to launch commercial 5G networks, which started in the late 2010s. South Korea emerged as one of the most aggressive embracers of 5G, achieving nationwide coverage in 2019. This success resulted from substantial infrastructure investments and strategic government support.

The United States was not far behind, with Verizon rolling out its initial 5G services in select cities as early as 2018, though these were pre-standard implementations. By 2019, both Verizon and AT&T had launched standard 5G services, primarily targeting enhanced mobile broadband and fixed wireless access applications.

In late 2019, China, with its leading operators—China Mobile, China Unicom, and China Telecom—started aggressively deploying 5G networks at an unprecedented pace and scale. This rapid expansion enabled China to emerge as the largest 5G market, characterized by extensive infrastructure and high levels of 5G adoption.

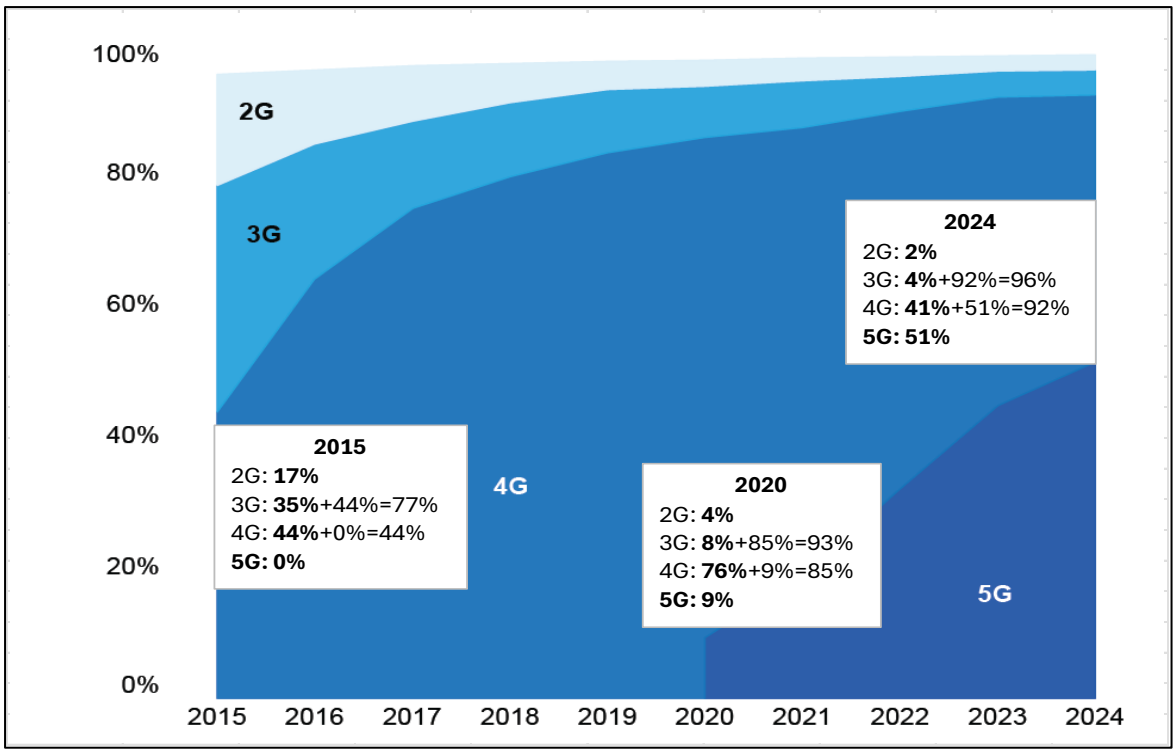
Since then, most countries have embarked on efforts to deploy commercial 5G networks. By the end of 2024, 348 operators across approximately 100 markets have launched commercial 5G services (Spirent, 2025; GSMA, 2024a)

Two key indicators—‘5G population coverage,’ which represents the share of the total population with access to 5G, and ‘5G penetration rate,’ which denotes the percentage of 5G subscriptions relative to total mobile subscriptions—can provide a broad overview of 5G deployment in a given market.

5G population coverage

As illustrated in Figure 2.1, global 5G population coverage reached 9% in 2020, only one year after its commercial launch in leading markets like South Korea, the United States, and China. This figure grew rapidly, hitting 51% by 2024.

Figure 2.1. Population coverage by type of mobile network, 2024

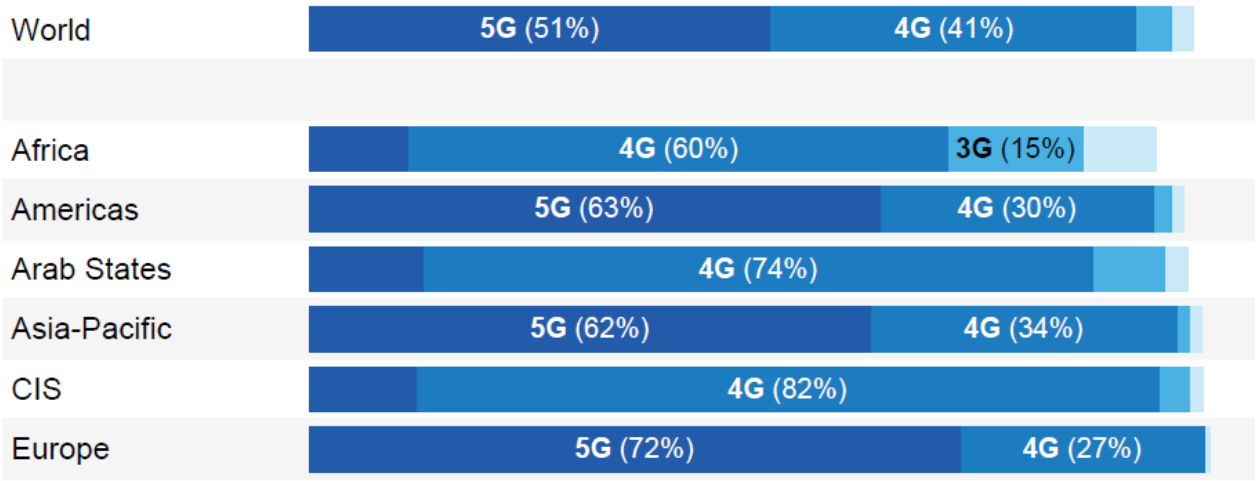


Note: The values (in bold) for 2G, 3G, and 4G networks show the incremental percentage of the population lacking coverage from more advanced networks.
Source: Adapted from ITU (2024b)

By geographic region, 5G population coverage in 2024 was highest in Europe (72%), followed by the Americas (63%) and Asia-Pacific (62%). In contrast, Africa and the CIS region recorded the lowest coverage rates at 11% and 12%, respectively (Figure 2.2).

Although specific data for ASEAN is unavailable, it is likely below the Asia-Pacific average of 62%, given the high coverage rates of regional giants—96% for China and 80% for India (Spirent, 2025). Within ASEAN, coverage varies significantly, from zero in Myanmar to 95% in Singapore. Based on observed patterns—such as India's 5G population coverage being approximately 2–4 times its 5G penetration rate—it is reasonable to estimate ASEAN's overall 5G population coverage to be in the range of 20–40% (Figure 2.2).

Figure 2.2. Population coverage by type of mobile network and area, 2024



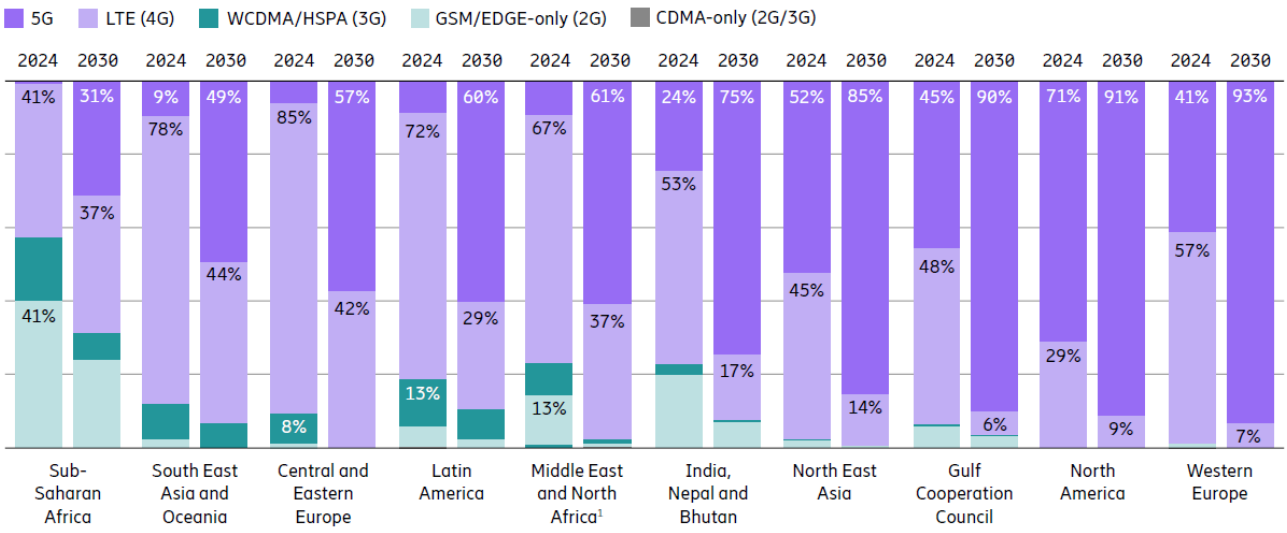
Note: The values for 2G, 3G and 4G networks show the incremental percentage of the population that is not covered by a more advanced technology network.
Source: ITU (2024b)

5G subscription penetration

Driven by the rapid expansion of 5G coverage, the penetration of 5G subscriptions has seen significant growth. By 2024, total 5G subscriptions reached 2.3 billion, resulting in a global 5G penetration rate of 25% (Ericsson, 2025). Notably, 5G penetration rates in 2024 varied widely across regions, ranging from less than 5% in Sub-Saharan Africa and Eastern Europe to 71% in North America. Although this regional disparity is expected to persist, it is projected to narrow considerably by 2030, with penetration rates reaching 31% in Sub-Saharan Africa, and 57% in Eastern Europe, while North America is expected to maintain its leadership position at 91% (Figure 2.3).

At the same time, it is worth noting that Southeast Asia and Oceania, as a group, are not strong regional players in the global 5G adoption landscape. The group as a whole lags behind India, Nepal, and Bhutan—a less developed region—with penetration rates of 9% versus 24% in 2024 and 49% versus 75% in 2030 (Figure 2.3).

Figure 2.3. Mobile Subscriptions by Region and Technology: 2024 (Actual) vs. 2030 (Projected) [2]



Source: Ericsson (2025)

The geographic disparities in 5G coverage and penetration—along with ASEAN's risk of falling behind—underscore the urgent need for the region to reassess its recent efforts in 5G deployment and adoption. The observations in the following subsection offer deeper insights into the challenges and opportunities confronting policymakers and business leaders as they seek to harness 5G as a catalyst for AI-driven digital transformation across ASEAN.

2.3. Key Observations

Since its major commercial launch in 2019, the global deployment of 5G, coupled with advancements in the digital revolution, has offered valuable insights. This subsection presents five key observations that policymakers and businesses can leverage to harness 5G effectively for future growth and success.

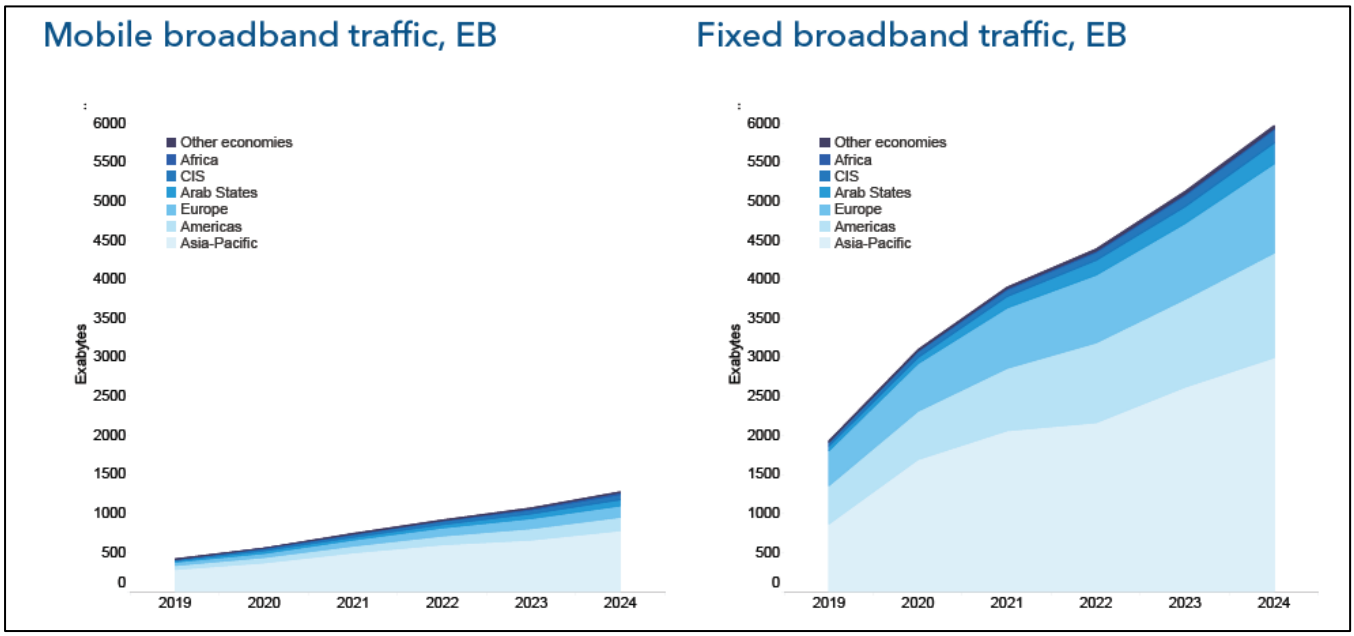
Observation #1: Over the past five years, 5G has achieved rapid penetration but has yet to deliver its anticipated transformational impact.

Since its launch in 2019, 5G has quickly expanded, achieving substantial population coverage and significant growth in subscriptions. However, it has not yet driven revolutionary changes. The limited number of prominent 5G use cases and their slow adoption highlight this gap. Furthermore, as shown in Figure 2.4, the notably low

[2] This region primarily includes ASEAN countries, along with Australia and New Zealand.

volume of mobile broadband internet traffic compared to fixed broadband traffic reinforces this assessment.

Figure 2.4. Internet Traffic



Source: ITU (2024b)

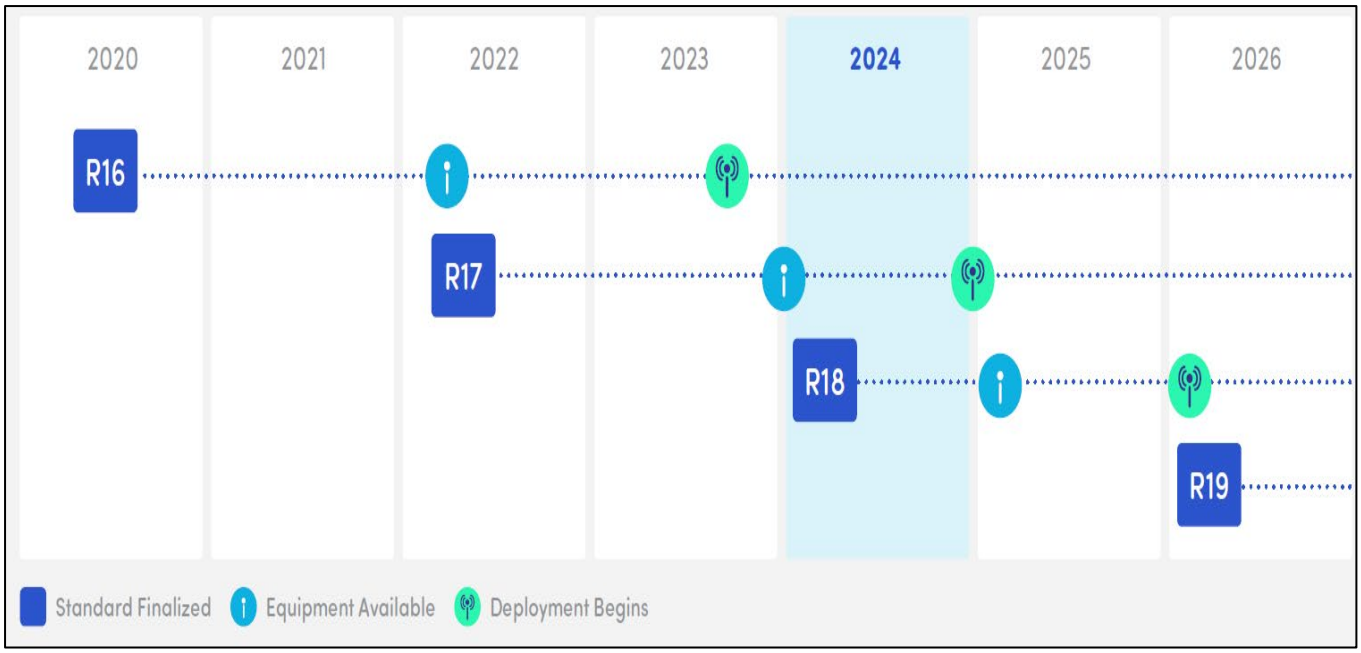
Note: Refers to traffic within the country. 1 exabyte (EB) = 10^{12} megabytes.

The incremental evolution during the first five years of 5G's commercial availability can be attributed to several factors.

First, 5G is still very much a work in progress. Currently, while more than 300 operators have launched commercial 5G services, fewer than 20 percent of these are 5G Stand-Alone (SA) deployments, which are essential for unlocking the full range of 5G's capabilities (Ericsson, 2024b). Additionally, 5G-enabled applications depend significantly on the advancements from the 3rd Generation Partnership Project (3GPP) releases. Each release introduces new features that enable or enhance support for revenue-generating applications and services. However, after a 3GPP release is finalized, there is a considerable lead time before the new features become commercially available, as it typically takes 18–24 months for compatible equipment to be ready and an additional 6–12 months for initial network deployments to commence (Spirent, 2024b).

Although the release of 5G specifications in 3GPP Release 15 (R15), finalized in June 2018, marked the official launch and provided foundational technologies for initial deployments—such as Enhanced Mobile Broadband (eMBB) and the Non-Standalone (NSA) architecture—other releases anticipated to drive transformative impacts have only recently been finalized or are still forthcoming (Figure 2.5).

Figure 2.5. Roadmap To 5G Revenue



Source: Spirent (2024b)

Notes:

- *Release 16 (R16): Finalized in 2020, this release focused on enhancing 5G capabilities for industrial and enterprise use cases. It introduced features such as Ultra-Reliable Low-Latency Communication (URLLC), Vehicle-to-Everything (V2X) communication, and power efficiency improvements.*
- *Release 17 (R17): Finalized in 2022, it expanded support for IoT, satellite communications (Non-Terrestrial Networks, NTNs), and Extended Reality (XR) technologies, paving the way for broader 5G adoption.*
- *Release 18 (R18): Finalized in 2024, it marked the beginning of 5G-Advanced, which focused on AI/ML integration, enhanced XR capabilities, and advanced NTN features.*

- *Release 19 (R19): Scheduled for finalization in 2026, it is expected to further evolve 5G-Advanced by enabling deeper AI/ML integration, improving energy efficiency, and supporting next-generation immersive applications.*

Observation #2. Governments play a pivotal role in accelerating the deployment and adoption of 5G technologies, particularly through efficient and effective spectrum allocation.

The adoption of technology by an economic agent, whether an individual or a business, is influenced by three main factors: awareness and belief, cost-benefit considerations, and enabling conditions. All three pillars are significantly shaped by a nation's vision, strategy, policy incentives, and coordination. In the context of 5G, the government's role becomes even more crucial, particularly regarding spectrum allocation policy. Spectrum serves as the backbone of wireless communication, and its efficient allocation is vital for the success of 5G networks. It is the responsibility of the government to release and allocate the necessary spectrum bands to support 5G deployment. These include the low band (below 1 GHz), mid band (ranging from 1 to 6 GHz), and high band or millimeter wave (mmWave), which spans from 24 to 100 GHz. Table 2.2 provides a summary of the main characteristics and performance indicators associated with each of these three types of 5G spectrum.

Table 2.2. Characteristics, typical allocation, and performance indicators for 5G by spectrum type

	Low bands (Sub-1 GHz)	**Mid bands** (1 GHz - 6 GHz)	**High bands** (24 GHz - 100 GHz; mmWave)
Key Features	- Excellent coverage and penetration - Suitable for rural and indoor areas	- Balance of coverage and capacity - Higher speeds than low-band	- Extremely high data rates - Ultra-low latency
Limitations	- Limited bandwidth - Slower data speeds	- Moderate range - Less penetration through obstacles	- Short range - Poor penetration - Requires dense deployment
Role in 5G	- Provides wide-area coverage - Supports basic connectivity and IoT applications	- Core spectrum for enhanced mobile broadband (eMBB) - Reliable capacity in urban areas	- Enables ultra-fast broadband - Powers latency-sensitive applications like AR/VR and IoT
Typical 5G bands	600 MHz 700 MHz 800 MHz	2.6 GHz 3.3 GHz, 3.5GHz 3.7 GHz, 4 GHz	24 GHz, 26 GHz, 28 GHz 39 GHz, 40 GHz 47 GHz, 50 GHz
Typical spectrum assignments	2x10MHz	80-100MHz	1,000 MHz recommended
Relative speeds	20% faster than LTE	6x faster than LTE	10x faster than LTE
Coverage (Typical cell radius)	Good (2–4 km)	Average (0.5–2 km)	Poor (100–500 m)
Cost to cover an area	Very low	Average	Very high
Antenna size	Large	Smaller	Individually small, collectively large

Source: Inputs from World Bank (2024) and 5G & Aviation - 5G Americas (accessed December 05 2024).

To establish an effective national policy for 5G spectrum allocation, policymakers should consider the GSMA (2022) recommendations, summarized into the following five key priorities:

i. Ensure Spectrum Availability and Harmonization: Distribute spectrum across low, mid, and high bands, with a focus on harmonized mid-band allocation (100

MHz per operator) and a goal of 2 GHz by 2030, to support diverse use cases and ensure global alignment.

ii. Emphasize Efficient Licensing Models: To enhance efficiency, synergy, and inclusivity, give priority to exclusively licensed spectrum for wide-area coverage, while also incorporating flexible spectrum-sharing models, such as leasing and the use of unlicensed bands.
iii. Encourage Strategic Spectrum Policies: To foster sustained 5G investment and development, implement long-term policies, including streamlined renewal processes, clear roadmaps, and affordable licensing.
iv. Control Spectrum Costs: Prevent inflated prices by reducing excessive reserve fees, annual charges, and ineffective auction designs that may impede broadband performance and growth.
v. Plan for Infrastructure and Backhaul Needs: Allocate adequate backhaul spectrum, support broader bandwidths, and encourage cost-effective licensing to facilitate the strong deployment of 5G networks.

Observation #3. AI and 5G are highly interdependent and mutually reinforcing. Recent groundbreaking advancements in AI, coupled with its rapid penetration, are set to profoundly shape the adoption of 5G, unlocking unprecedented benefits through the synergy of these two transformative technologies.

The transformative impact of AI on 5G deployment and adoption is evident through three key channels. First, AI enhances the performance, efficiency, and intelligence of 5G networks. Second, AI drives digital transformation across industries, increasing the adoption and appeal of 5G. Finally, integrating AI and 5G-enabled applications into devices like smartphones and wearables unlocks unprecedented benefits for 5G users.

(i) AI enhances the performance and intelligence of 5G networks (5G Americas, 2024)

- Performance Optimization: AI optimizes network performance, manages resources, predicts outages, and strengthens security through proactive monitoring and anomaly detection. It dynamically adjusts network parameters based on traffic patterns, prioritizing critical data to ensure ultra-low latency for

applications like autonomous vehicles and remote surgery. Additionally, AI enables self-optimizing networks, leveraging operational data to automatically improve performance, reduce latency, and enhance user experience.

- Enhanced Security: AI strengthens network security by identifying and addressing threats in real-time. It detects unusual patterns, thus preventing unauthorized access, fraud, and cyberattacks.
- Quality of Service (QoS): AI continuously monitors crucial performance metrics like latency, packet loss, and throughput. It optimizes network settings to guarantee consistent, reliable, and high-quality service delivery.
- Cost Efficiency: AI drives cost savings by streamlining operations, identifying churn risks, and boosting sales. These capabilities accelerate 5G adoption and market penetration.
- Personalized Customer Interactions: AI-powered tools enhance user experiences by providing personalized services, streamlining support with virtual assistants, and enabling human agents to concentrate on complex issues, ultimately boosting satisfaction and loyalty.

(ii) AI drives digital transformation across industries, enhancing the adoption and appeal of 5G

AI is a powerful catalyst for digital transformation across industries. It enhances the adoption and appeal of 5G by unlocking new possibilities and amplifying the benefits of advanced connectivity. Rapid advancements in AI, including groundbreaking innovations like Generative AI and Machine Learning, have significantly elevated the value of adopting digital solutions, a trend poised to accelerate in the coming years.

AI-driven technologies—like Generative AI, machine translation, and predictive analytics—are revolutionizing how we work and collaborate across sectors. These tools not only automate routine tasks and enhance data-based decision-making, but also break down language and cultural barriers, helping businesses connect and grow globally. For instance, farmers can now use generative AI in their native language to get real-time insights on market trends, pricing, suppliers, and buyers—empowering them to make smarter decisions and reach wider markets.

5G's pivotal role in this transformative landscape is its superior speed, ultra-low latency, and high data capacity, which provide the robust infrastructure necessary to

fully harness AI's potential. For instance, AI applications that require real-time data processing—such as autonomous vehicles, remote surgery, or industrial automation—depend on the reliability and responsiveness that 5G networks deliver. Without 5G, these applications would face performance bottlenecks, limiting their impact and scalability.

Moreover, integrating AI and 5G drives innovation across sectors. In healthcare, AI and 5G enable remote diagnostics and telemedicine, bringing quality care to underserved areas. In agriculture, AI-powered drones and sensors connected through 5G networks optimize resource use and crop yields. In manufacturing, 5G-supported AI systems improve operational efficiency, predict equipment failures, and reduce downtime.

The convergence of AI and 5G is not merely about enhancing technology—it's about reshaping how industries operate, innovate, and deliver value. By providing the infrastructure necessary to deploy and scale AI-driven applications, 5G transforms AI from a tool into an essential enabler of digital transformation. This powerful synergy accelerates the adoption of 5G, positioning it as the backbone of a smarter, more connected world.

(iii) 5G enables AI-embedded devices—such as smartphones, wearables, and other consumer electronics—to deliver unprecedented benefits to users.

The synergy between 5G and AI merges real-time connectivity and high-speed data transfer with intelligent automation, unlocking transformative opportunities across a wide range of sectors. Thanks to this integration, 5G adoption becomes more appealing to everyday users by providing practical, accessible solutions to real-world challenges. For instance, a farmer can use her smartphone to capture images of her crops and receive instant AI-powered advice on controlling pests or optimizing yields. This eliminates the need for costly or time-consuming expert consultations and enables her to take timely, informed actions, significantly enhancing productivity and sustainability.

Moreover, these applications extend beyond agriculture. In healthcare, wearable devices connected through 5G can monitor patients' vital signs in real-time and utilize AI to deliver early alerts about potential health issues, allowing for prompt intervention.

In education, students in remote areas can access interactive, AI-driven learning platforms without delays, levelling the playing field for quality education.

Observation #4. The vibrancy and robustness of the 5G ecosystem are crucial for driving the success of a nation's 5G deployment and adoption.

The 5G ecosystem represents a transformative shift from its 4G predecessor, which primarily focused on enhancing consumer experiences through faster internet speeds, to fostering innovation and value creation driven by synergy. This evolution brings unprecedented complexity, necessitating the seamless integration of diverse technologies and stakeholders to tackle sophisticated use cases.

The 5G ecosystem is a dynamic network of interdependent players, each essential to its development and deployment. Notably, as AI and 5G are disruptive technologies that rely significantly on advancements in chip technology, chipmakers play a pivotal role in the ecosystem, providing the foundational technology that powers devices and infrastructure. At the same time, the rapid penetration and combined impact of 5G and AI across nations elevate the importance of international and regional organizations, which now play an unprecedentedly critical role in ensuring coordination and collaboration.

Table 2.3 highlights the key stakeholders in the 5G ecosystem, with examples specific to the Singapore context for illustration.

Table 2.3. Key Stakeholders in the 5G ecosystem

Businesses	Examples (Specific to Singapore)
1. Network Operators	M1, SIMBA, Singtel, StarHub
2. Core Players, Enablers, and Contributors	
(i) Semiconductor and Chip Producers	Broadcom, Infineon Technologies, Qualcomm, STMicroelectronics
(ii) Equipment Manufacturers	Ericsson, Huawei, Nokia
(iii) Device Manufacturers, IoT Device Manufacturers	Huawei, Oppo, Samsung, ST Engineering
(iv) Software Vendors, System Integrators, and Technology Enablers	Cisco Systems Singapore, CrimsonLogic, DXC Technology, Fortinet Singapore, NCS, VMware Singapore
(v) Cloud and Data Service Providers	AWS, Google Cloud, Microsoft Azure, Singtel Cloud
(vi) Content and Application Developers	Animoca Brands (for 5G-ready content), Garena (Game), Wavemaker Partners (VC supporting 5G-enabled solutions)
3. Government agencies	Cyber Security Agency of Singapore (CSA), Infocomm Media Development Authority (IMDA), Ministry of Digital Development and Information (MDDI)
4. Universities & Research Institutes	ASTAR, NTU, NUS.
5. International and regional institutions for coordination and collaboration	ASEAN Secretariat, GSMA, ITU
6. Businesses/organizations	Hyundai Motor Group Innovation Centre Singapore (smart manufacturing), NUHS (Healthcare), PSA (Port), Weston Robot (unmanned surface vessels for river cleaning and inspection)
7. Individuals	5G-connected device users

Note: The example players in Singapore's 5G ecosystem are listed in alphabet order

Establishing a thriving 5G ecosystem is not just advantageous—it is crucial for the successful deployment, adoption, and lasting impact of 5G within a country. A robust ecosystem strengthens the efficiency and effectiveness of 5G implementation by addressing technical, regulatory, and market challenges. It minimizes deployment costs and risks, simplifies infrastructure expansion, and speeds up the launch of innovative applications.

A thriving 5G ecosystem plays a vital role in connecting diverse stakeholders—ranging from global tech leaders and chipmakers to equipment manufacturers, software providers, local startups, research institutions, and end-users. These collaborations drive innovation, facilitate knowledge exchange, and fast-track the development and adoption of cutting-edge 5G solutions. Additionally, they enable the localization and customization of technologies for industry-specific applications, which is essential for expanding 5G adoption and maximizing its economic and societal benefits.

Just as crucial, a thriving 5G ecosystem remains dynamic—constantly evolving by incorporating new players, business models, and technologies. This adaptability ensures its resilience and long-term relevance in an ever-changing digital landscape.

In this landscape, the government serves as a pivotal catalyst, actively shaping the 5G ecosystem through strategic investments, clear regulations, R&D support, public-private partnerships, and global collaboration. By embedding itself within the ecosystem, the government gains critical insights, enabling smarter policy decisions and more effective infrastructure planning. This dynamic, reciprocal engagement allows the public sector to craft adaptive, future-ready strategies that drive widespread 5G adoption, maximizing its impact across the economy and society.

In short, a vibrant 5G ecosystem is both the foundation and the accelerator for 5G development, and the role of government is indispensable in making that ecosystem thrive—for the benefit of innovation, competitiveness, and national digital transformation.

Observation #5. One can anticipate a major take-off 5G adoption between 2025 and 2030.

According to Spirent (2025), expectations for the second half of the 5G era (2025-2030) are high. After years of groundwork and growing pains, 5G is poised to deliver on its promise. With Standalone (SA) deployments expanding and 5G-Advanced gaining momentum, the technology is now positioned to drive real transformation across industries. Stakeholders are eager, end users are ready to be impressed, and demand is building fast, which will together unlock the full potential of 5G. Breakthrough applications—such as Technologies such as Fixed Wireless Access (FWA), private networks, RedCap, V2X, and AI-driven infrastructure are being

increasingly adopted. Integration with network APIs, low-altitude platforms, and non-terrestrial networks will further accelerate innovation.

Six factors are expected to drive the rapid take-off of 5G in the coming years:

i. Unprecedented Benefits from 5G and AI Integration: The maturity of 5G technology combined with groundbreaking AI advancements will unlock unparalleled benefits for users, driving mass market acceptance and robust monetization opportunities.
ii. Network Effects from Rapid User Growth: The increasing number of 5G users at both enterprise and individual levels creates network effects, where the value of adoption grows as the user base expands. China and India, with their aggressive 5G rollouts, will significantly amplify these effects while benefiting from substantial cost reductions due to economies of scale. Network effects are expected to grow exponentially with the emergence of 'killer apps' for everyday users—such as those that eliminate language barriers and allow people to communicate freely in their native languages.
iii. Development of 5G Infrastructure and Ecosystems: The evolution of 5G infrastructure, supported by robust coordination platforms and complementary technologies, applications, and services, will bolster innovation and strengthen the value proposition of 5G. This also fosters greater societal awareness and trust.
iv. Standardization and Regulatory Frameworks: Establishing systematic industry standards and regulatory systems will ensure compatibility, interoperability, and reliability across 5G networks and devices.
v. Enhanced User Experience: The refinement of 5G-enabled products and services, tailored to user needs, will significantly improve user experiences. Additionally, more sophisticated demands for 5G solutions will emerge, and they will be addressed.
vi. Cultural Integration of 5G: As 5G becomes an essential part of daily life and business operations, it will transition from a luxury to a necessity, fostering broader cultural acceptance and integration into social norms.

Section 3

Digital Transformation and 5G Readiness in ASEAN

This section explores digital transformation in ASEAN countries, focusing on their digital maturity and the development of their digital economies. It also examines the push and pull factors driving the urgency and strategic imperative for ASEAN to accelerate the deployment and adoption of 5G.

3.1. ASEAN's Digital Maturity

Recognizing the transformative potential and strategic importance of the digital revolution, ASEAN and its 10 member states have actively embraced digital technologies as a powerful lever for sustainable economic growth and social progress. These efforts, fueled by the rapid advancement and widespread adoption of digital tools, are closely aligned with the United Nations' Sustainable Development Goals (SDGs)—particularly SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 10 (Reduced Inequalities). By fostering digital innovation and accelerating the uptake of emerging technologies, ASEAN is charting a path toward a more vibrant, inclusive, resilient, and environmentally sustainable future across the region.

To realize these ambitions, both the bloc and its individual member states have developed national strategies with clear priorities and bold objectives to guide policy development and implementation. Table 3.1 summarizes the current versions of these strategies for illustration.

Table 3.1: ICT Strategies of ASEAN and its Member States (as of 2024)

Economy	Strategy Title	Aims/Focus/Priorities
ASEAN	**ASEAN Digital Masterplan 2025 (ADM 2025)**	Create a digitally connected, inclusive, and secure ASEAN by focusing on key areas such as digital infrastructure, digital literacy, cybersecurity, and digital integration. Prioritize on reducing digital divide, fostering innovation, and ensuring that digital transformation benefits all sectors of society.
Brunei	*Digital Economy Masterplan 2025*	Transform Brunei into a Smart Nation through digital innovation, enhancing ICT infrastructure, and developing a vibrant digital economy.
Cambodia	*Telecommunications and ICT Development Policy 2020-2025*	Expand ICT infrastructure, promote e-government services, and enhance digital literacy among citizens.
Indonesia	*Digital Indonesia Roadmap 2021-2024*	Target the acceleration of digital transformation across various sectors, including infrastructure development, digital governance, and human resource capacity building.
Lao PDR	*E-Government Development Plan 2018-2022*	Seek to improve public service delivery through ICT, develop digital infrastructure, and promote digital literacy.
Malaysia	*MyDIGITAL – Malaysia Digital Economy Blueprint*	Transform Malaysia into a digitally-driven, high-income nation by 2030, focusing on digital infrastructure, governance, and talent development.
Myanmar	*Myanmar Digital Economy Roadmap 2018-2025*	Developing digital infrastructure, promoting digital innovation, and enhancing digital skills among the workforce.
Philippines	*Philippine Digital Strategy 2022*	Building a digitally empowered and integrated nation by enhancing ICT infrastructure, promoting digital literacy, and supporting digital innovation.
Singapore	Smart Nation Singapore—Version 1.0 launched in 2014 and Version 2.0 refreshed in December 2024—is underpinned by three key strategies: the Digital Enterprise Blueprint (DEB), the Digital Government Blueprint	Singapore's Digital Enterprise Blueprint outlines Singapore's vision to become a nation of empowered enterprises and digitally skilled workers. Co-developed with ecosystem partners, it focuses on four priorities: adopting AI to Be Smarter, using integrated solutions to Scale Faster, strengthening cybersecurity to Be Safer, and Upskilling Workers to fully harness digital tools. (DEB, 2024)

	(DGB), and the Digital Connectivity Blueprint (DCB).	Singapore's Digital Government Blueprint (DGB) sets out 15 KPIs across three domains—Stakeholder Satisfaction, End-to-End Digital Services, and Digital Capabilities—to drive user-centric, efficient, and secure public services. Targets include 100% e-payment and pre-filled services, 90–95% of transactions completed digitally, and all public officers attaining basic digital literacy. These measures align with Singapore's vision of a government that is *"digital to the core, and serves with heart."* (DGB, 2023) Singapore's Digital Connectivity Blueprint (DCB) sets out five strategic priorities to enhance its digital infrastructure and global competitiveness: (i) expanding submarine cable capacity; (ii) delivering 10 Gbps domestic connectivity; (iii) securing critical compute infrastructure; (iv) advancing green data centers; and (v) scaling the use of the Singapore Digital Utility Stack (e.g., digital ID, payments, data exchange) for seamless digital services. (DCB, 2024)
Thailand	*Thailand Digital Economy and Society Development Plan (2018-2037)*	Developing digital infrastructure, promoting digital innovation, and enhancing digital skills to drive economic growth.
Vietnam	*National Digital Transformation Program by 2025, Orientation toward 2030*	Develop a digital government, economy, and society, with a focus on digital infrastructure, human resources, and cybersecurity.

Sources: ITU (2024c); authors' survey from government websites of ASEAN countries.

The digital maturity of ASEAN countries can be assessed by analyzing their adoption of basic digital applications and the quality of their supporting digital infrastructure. To facilitate this assessment, Table 3.2 provides statistics on the adoption of basic digital applications by populations and governments, while Table 3.3 highlights mobile and fixed broadband internet download speeds. Together, these tables reveal several key insights:

First, ASEAN as a region exhibits a mixed performance compared to the global average. Among the seven indicators of digital adoption outlined in Table 3.2, ASEAN surpasses the global median in three areas: individual internet usage penetration, ID ownership rate, and the e-government index. However, it falls short in fixed broadband

penetration, mobile internet penetration, and digital payment adoption, while aligning with the global average in monthly mobile broadband traffic per capita. At the same time, ASEAN outperforms the world median in fixed broadband download speeds but lags behind in mobile internet download speeds (Table 3.3). This emphasizes the urgent need for investment in mobile deployment infrastructure in at least 5 out of 10 ASEAN countries.

Second, ASEAN countries can be categorized into four distinct groups based on their digital maturity:

- *Group 1: Singapore and Malaysia,* the top performers, significantly exceed the world medians across most digital adoption measures (Table 3.2) and rank highly globally in both mobile and fixed broadband internet download speeds. Notably, Singapore emerges as a global leader alongside South Korea and the United States in both digital adoption and internet download speeds.
- *Group 2: Thailand, Vietnam, and Brunei,* which surpass the world and ASEAN medians in most digital adoption measures (Table 3.2) and in both metrics of internet download speeds (Table 3.3). Thailand stands out as the strongest performer in most areas, including as mobile internet penetration (71%), monthly mobile broadband traffic per capita (28 GB), digital payment adoption (92%), ID ownership (99%), e-government index (0.77), and fixed broadband download speeds (ranked sixth globally). Brunei leads in individual internet usage penetration (98%) and mobile internet download speeds (ranked 19th globally), while Vietnam excels in broadband penetration (22%).
- *Group 3: Indonesia and the Philippines,* which generally fall below the world medians in digital adoption measures and internet download speeds. However, Indonesia stands out by exceeding the world medians in two government-related digital adoption measures: ID ownership (97% vs. 94%) and the e-government index (0.72 vs. 0.66) (Table 3.2). Despite these strengths, Indonesia significantly lags behind both the world and ASEAN medians in mobile and broadband internet download speeds (Table 3.3), highlighting the urgent need for substantial investment to upgrade the country's digital infrastructure.

- *Group 4: Cambodia, Laos, and Myanmar,* the lagging performers, significantly fall below the world medians in most digital adoption measures (Table 3.2) and internet download speeds (Table 3.3). Despite being part of this group, Cambodia surpasses both the world and ASEAN medians in two digital adoption measures: mobile penetration and monthly mobile broadband traffic per capita

Third, although India remains well below the world and ASEAN medians in digital adoption measures (Table 3.2), it notably surpasses both the world and ASEAN medians in mobile internet speeds while continuing to lag in broadband internet speeds (Table 3.3). This underscores India's effective strategy of leveraging mobile technology to overcome its challenges in digital adoption.

Table 3.2: Digital Maturity of ASEAN Countries

Economy	Adoption by people					Adoption by governments	
	Individuals using the internet (% of population)	Fixed broadband subscriptions (per 100 inhabitants)	Unique mobile internet subscriptions (% of population)	Monthly mobile broadband traffic per capita (GB)	Use of digital payment (% of population ages 15+), 2021	ID ownership (% of population ages 15+), 2021	UN e-government index
Brunei Darussalam	98	20	48	NA	NA	NA	0.73
Cambodia	60	3	66	18.1	26	90	0.51
Indonesia	66	5	47	8.8	37	97	0.72
Lao PDR	62	2	46	2	21	55	0.38
Malaysia	97	12	67	28.6	79	96	0.77
Myanmar	44	2	37	0.1	40	88	0.5
Philippines	53	8	43	5.2	43	NA	0.65
Singapore	96	37	89	13.7	95	97	0.91
Thailand	88	18	71	28	92	99	0.77
Viet Nam	79	22	56	9.2	46	97	0.68
ASEAN (Median)	**73**	**10**	**52**	**9**	**43**	**97**	**0.70**
World (Median)	**66**	**18**	**56**	**9**	**58**	**94**	**0.66**
China	*76*	*41*	*79*	*14.4*	*86*	*100*	*0.81*
India	*46*	*2*	*49*	*9.6*	*35*	*NA*	*0.59*
Korea, Rep.	*97*	*45*	*94*	*17*	*98*	*97*	*0.95*
The US	*92*	*38*	*86*	*13.4*	*93*	*NA*	*0.92*

Source: World Bank (2024a).
Note: All values are for 2022 unless otherwise indicated.

Table 3.3: Internet Download Speed *(Updated as of September 2024)*

ASEAN countries listed in descending order by mobile download speeds

Country	Mobile download speed		Fixed broadband download speed	
	Mbps	Rank (#)*	Mbps	Rank (#)*
Singapore	127.8	11	324.5	1
Malaysia	105.8	14	128.5	39
Brunei	99.7	19	75.7	71
Thailand	54.9	50	233.7	6
Vietnam	54.8	51	153.3	32
Philippines	34.5	73	94.2	49
Laos	29.7	82	39.1	110
Indonesia	29.5	83	31.9	116
Myanmar	29.1	85	21.6	128
Cambodia	28.5	87	45.1	103
ASEAN (Median)	**44.6**		**84.9**	
World (Median)	**50.8**		**69.4**	
China	*105.2*	*15*	*180.6*	*22*
India	*91.7*	*26*	*63.5*	*84*
South Korea	*143.1*	*4*	*160.6*	*28*
United States	*108.0*	*13*	*246.3*	*5*

Source: Ookla, https://www.speedtest.net/global-index, September 2024

*Note: * Rankings are out of 113 economies for mobile and 159 economies for fixed broadband download speeds.*

3.2. 5G Deployment and Adoption in ASEAN

3.2.1. Salient issues in 5G deployment

As countries strive to drive digital transformation for economic growth and competitiveness through emerging critical technologies, 5G, coupled with AI, is becoming a transformative force, fostering efficiency, innovation, and disruptive creativity. However, deploying 5G is a complex and costly process, requiring communications service providers (CSPs)[3] in each country to adopt a strategic and practical approach to launching and expanding their 5G commercial networks.

[3] The term CSP is also used to refer to a 'Connectivity Service Provider' in the context of enterprise, Industrial IoT (IIoT), and private network deployments.

5G networks are deployed using two main architectures: Standalone (SA) and Non-Standalone (NSA), each with distinct advantages and challenges, particularly in spectrum allocation and usage.

- *Non-Standalone (NSA) 5G:*
  NSA deployment leverages existing 4G Long-Term Evolution (LTE) infrastructure, using the 4G core network to manage control signaling while 5G radios deliver faster data speeds. Its primary advantages include faster deployment and intermediate improvements in speed, capacity, and reliability compared to 4G. NSA focuses on the enhanced mobile broadband (eMBB) feature of 5G, making it an attractive option for early rollouts.
- *Standalone (SA) 5G:*
  SA deployment operates on a completely new 5G core network, independent of 4G infrastructure, to fully realize the capabilities of 5G technology. SA networks deliver all three key features of 5G: ultra-low latency (URLLC), high-speed connectivity (eMBB), and massive machine-type communication (mMTC). This architecture supports advanced use cases such as smart cities, autonomous vehicles, and industrial automation. However, it requires significant investment in new network components and infrastructure.

Consequently, most CSPs have initiated their 5G rollouts with NSA networks, leveraging their cost efficiency, faster deployment, and compatibility with existing infrastructure. As a result, the majority of commercially available 5G networks today are NSA. [4] The key reasons driving this approach are summarized in Table 3.4 below.

Table 3.4: Key Reasons for CSPs to Begin 5G Deployment with NSA Networks

Motive	Explanation
1. Cost Efficiency	NSA networks reduce initial investment by leveraging existing 4G infrastructure, avoiding the need for a complete overhaul of network components.
2. Faster Time-to-Market	NSA architecture allows CSPs to launch 5G services quickly, meeting market demand without waiting for full standalone (SA) network deployment.

[4] According to Ericsson (2024a), among 300 5G service providers, only 50 have launched standalone (SA) 5G networks.

3. Gradual Transition to SA	NSA serves as a stepping stone, enabling CSPs to refine operations, test 5G technologies, and progressively upgrade to standalone 5G over time.
4. Widespread Device Compatibility	Many early 5G devices are compatible with NSA networks, ensuring that consumers can access 5G services during the early stages of deployment.
5. Efficient Spectrum Utilization	NSA networks optimize the use of 4G and 5G spectrum resources, delivering improved speeds and latency while ensuring a seamless user experience.
6. Demand and Market Readiness	NSA networks meet current market needs, where demand for advanced standalone 5G applications is still limited, offering sufficient performance improvements.

Source: Compiled by the authors from reports provided by various CSPs.

While NSA is a practical solution for the initial stage of 5G deployment, its limitations must be acknowledged. It falls short of realizing the full potential of 5G, particularly in critical areas like network slicing, ultra-low latency, and massive IoT capabilities (GSMA, 2024b). Additionally, the dual connectivity approach requires managing both 4G and 5G networks simultaneously, increasing operational complexity. Furthermore, reliance on 4G infrastructure may limit spectrum availability for 5G, constraining its full performance.

More importantly, the deployment of SA 5G is essential for unlocking the true potential of 5G-Advance. SA 5G delivers the performance, scalability, and flexibility required for the next wave of technological innovation, enabling CSPs to support advanced use cases and seamlessly transition toward the future 6G era. Defined in the 3GPP Release 18 and beyond, 5G-Advance represents the evolution of 5G technology, enhancing performance, efficiency, and support for complex applications. Shifting from NSA to SA 5G is a crucial step for CSPs to transform 5G from an incremental improvement into a revolutionary leap beyond 4G.

Effective spectrum policy is a cornerstone of successful 5G deployment. Government decisions on spectrum allocation, availability, pricing, and management have a direct and lasting impact on network performance, coverage, and adoption. Both Non-Standalone (NSA) and Standalone (SA) 5G architectures face challenges related to spectrum efficiency—particularly in balancing coverage, capacity, and performance across low-, mid-, and high-frequency bands.

Each spectrum band presents distinct trade-offs. Low-band (<1 GHz) offers wide geographic coverage but limited capacity and speed. mmWave (>24 GHz) delivers ultra-high data rates and low latency but is constrained by short-range propagation and poor penetration. In contrast, the mid-band spectrum (1–6 GHz) has emerged as the sweet spot for 5G—delivering a compelling mix of capacity, coverage, and spectral efficiency, and making it the most versatile and widely applicable band for 5G deployment.

Mid-band spectrum offers four critical advantages. First, it provides an optimal balance between coverage and capacity, making it well-suited for urban, suburban, and rural areas with moderate-to-high user density. Second, it effectively supports key 5G features such as enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC), and network slicing—enabling applications ranging from high-definition streaming to smart infrastructure and industrial automation. Third, it enables cost-efficient, wide-area deployments, allowing CSPs to meet performance expectations while maximizing return on investment. Fourth, it ensures efficient spectrum utilization by combining favorable propagation characteristics with sufficient bandwidth, making it the most practical choice for large-scale, mass-market 5G rollouts. Consequently, mid-band spectrum auctions have become a strategic tool for governments—not only to advance connectivity goals but also to generate substantial public revenue.

That said, mmWave remains a strategic differentiator in targeted 5G deployments. While its propagation characteristics limit its suitability for nationwide coverage, mmWave's deployment in ASEAN's high-density industrial zones, logistics hubs, and innovation corridors offers a distinct performance edge. With its ability to support ultra-low latency, high throughput, and massive device connectivity, mmWave unlocks advanced use cases such as smart factories, digital twins, real-time robotics, and autonomous systems. Far beyond a mere speed enhancement, mmWave acts as a performance multiplier, enabling next-generation industrial services and accelerating ASEAN's broader goals for digital transformation and sustainable development. Appendix 1 outlines key elements of strategic approaches ASEAN countries can adopt to harness mmWave in building a future-proof industrial edge.

In summary, while Non-Standalone (NSA) architecture has been instrumental in the initial phases of 5G deployment, Standalone (SA) is essential for realizing the full

capabilities of 5G-Advanced. As ASEAN countries transition toward more advanced, mission-critical applications, forward-looking spectrum policy—particularly in the mid-band and mmWave bands—will serve as both a key enabler and a catalyst for technological innovation, industrial competitiveness, and inclusive economic growth across the region.

3.2.2. 5G Deployment and Adoption in ASEAN

The ASEAN region has emerged as a key player in the global adoption of 5G technology. Table 3.5 highlights the current status and plans for 5G deployment in ASEAN countries as of the end of 2024, offering several notable insights.

First, seven out of ten ASEAN countries have launched commercial 5G networks, while the remaining three—Laos, Cambodia, and Myanmar—are in the early stages of 5G deployment.

Second, Singapore leads the region, being the only ASEAN country to have successfully deployed 5G SA networks with 95% population coverage. Malaysia and Thailand are expected to transition to SA in the coming years (Malaysia aims for 2025). The Philippines has made significant progress in deploying 5G in urban areas and is preparing for an SA rollout. Vietnam and Indonesia, while less advanced in 5G deployment, are poised to make substantial progress starting in 2025 and beyond.

Third, despite varying levels of 5G deployment across ASEAN countries, all demonstrate meaningful progress in this area. Figure 3.1, which presents the spectrum assignments across the 10 ASEAN nations, supports this observation. All ASEAN countries, including Myanmar, have allocated substantial bandwidths for 5G, ranging from 394 MHz in Myanmar to 1,005 MHz in the Philippines. Notably, the majority of these allocations are in the mid-band spectrum (1–6 GHz), which is critical for balancing coverage and performance.

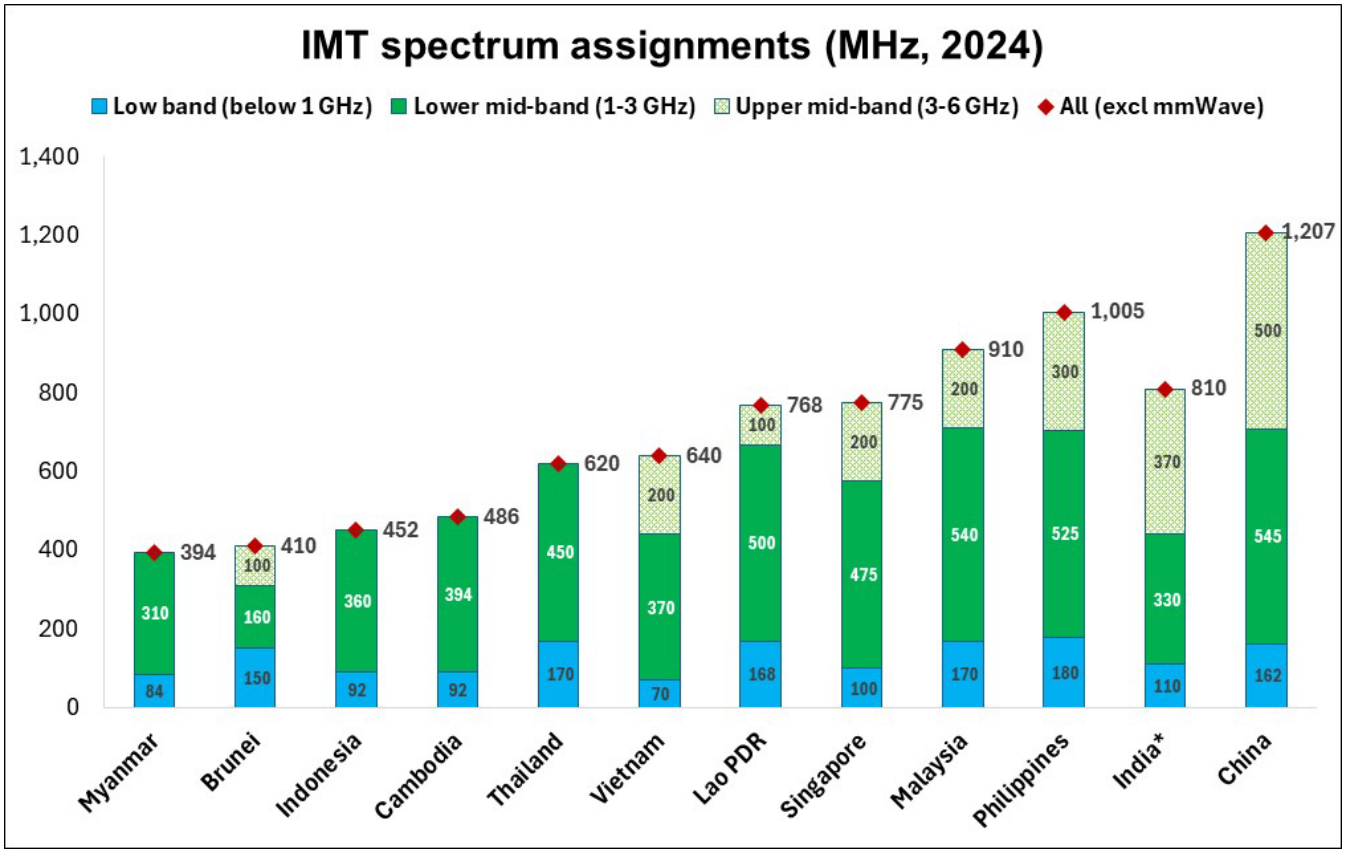
Table 3.5. 5G Deployment in ASEAN Countries

Country	Deployment Status	SA/NSA	Key Features/Plans
Singapore	Extensive 5G coverage achieved, 95% SA population coverage.	SA	Advanced capabilities, network slicing, and massive IoT support for Smart Nation initiatives.

Malaysia	Widespread NSA coverage managed by DNB, transitioning towards a dual network model.	NSA	Transition to SA expected by 2025, aiming to enhance advanced 5G features like ultra-low latency and IoT.
Thailand	NSA networks deployed, with plans to auction new spectrum for 5G-Advance.	NSA	Transitioning to SA to enhance network performance and advanced use cases.
Philippines	Extensive NSA coverage in urban areas by major operators, gradual transition to SA underway.	NSA	Enhancing service quality and enabling advanced applications with SA architecture.
Vietnam	Official commercial 5G launched in October 2024. Coverage rapidly expanding.	NSA	Aiming to support digital transformation and meet growing connectivity demands.
Indonesia	NSA 5G deployed in urban centers; coverage still expanding.	NSA	Focused on expanding coverage to rural areas and future transition to SA.
Brunei	Initial 5G rollout completed, trial services operational.	SA (Initial)	Supporting IoT, AI, and connectivity for key sectors like oil, gas, and smart cities.
Myanmar	Limited 5G progress due to political and economic challenges.	NSA (Early)	Early-stage deployments, primarily focused on trials and small-scale implementation.
Cambodia	Early-stage trials conducted in partnership with international firms.	NSA (Early)	Focus on urban areas, with plans for gradual expansion of infrastructure.
Laos	Limited deployment; early trials ongoing with international partnerships.	NSA (Early)	Targeted rollouts in urban centers, with a focus on future scalability.

Source: Authors with support from ChatGPT (OpenAI, 2025).

Figure 3.1. Spectrum Allocation in ASEAN Compared to China and India (2024)



Source: Authors, based on data from GSMA

To advance 5G deployment and adoption in ASEAN, Connectivity Service Providers (CSPs) across the region have played a pivotal role. Table 3.6 highlights their key initiatives, categorized into eight core areas of innovation and collaboration, as detailed below.

(i) Enhancing government capacity for digital transformation and disaster management

- Singtel (Singapore): Supported the Smart Nation program, utilizing 5G technology for IoT solutions in public housing, waste management, and energy efficiency.
- AIS (Thailand): Implemented 5G-enabled disaster management systems, offering real-time monitoring and response coordination for floods and earthquakes.

(ii) Pioneering advanced technologies

- Viettel (Vietnam): Achieved a global milestone by launching the world's first O-RAN 5G network with Qualcomm, setting a benchmark for open and flexible 5G infrastructure.

- Telkomsel (Indonesia): Introduced Indonesia's first 5G Smart Warehouse and Innovation Center in partnership with Huawei, revolutionizing logistics operations and demonstrating the potential of industrial 5G applications.

(iii) Establishing collaborative innovation hubs

- Singtel (Singapore): Partnered with Ericsson to create a co-innovation space for 5G applications in healthcare and manufacturing, advancing use cases in ports and airport management.
- MobiFone (Vietnam): Established a 5G Innovation Hub with Ericsson to co-create 5G solutions for consumers and enterprises.

(iv) Driving smart city and industrial solutions

- Singapore (M1 and StarHub): Explored 5G applications in port management, improving cargo tracking and operational efficiency.
- Malaysia: Leveraged 5G in airport management, optimizing passenger flow, security, and seamless connectivity, while advancing plantation supervision with real-time monitoring and automation.
- AIS (Thailand): Played a leading role in smart city development, partnering with Huawei and the Thai government to implement 5G-powered initiatives for public safety, transportation, and environmental monitoring. AIS also launched 5G Smart Hospitals, showcasing 5G's transformative role in healthcare.
- Unifi (Malaysia): Collaborated with global leaders to enhance 5G video streaming, earning recognition as a 5G Global Winner.

(v) Innovating in education

- Singtel (Singapore) partnered with EdTech companies to create 5G-powered platforms for personalized learning, incorporating AI-driven tools and immersive content delivery.
- True (Thailand): Integrated 5G into smart classrooms with Chulalongkorn University.
- AIS (Thailand) launched smart campus initiatives, integrating 5G-powered IoT and automation into universities like Mahidol University

(vi) Piloting smart agriculture and enhancing digital inclusion

- True (Thailand): piloted smart farming solutions using 5G for precision irrigation and crop monitoring.

- YTL Communications (Malaysia): Advanced smart agriculture through 5G RedCap Wi-Fi, improving rural connectivity and productivity.
- Dtac (Thailand): Focused on rural inclusion, deploying 5G in underserved areas in collaboration with the Thai government to foster economic empowerment.
- DITO (Philippines): Expanded 5G coverage to 61 provinces by 2024 and introduced affordable 5G-powered home Wi-Fi solutions, bridging the rural connectivity gap.

(vii) Fostering cross-industry collaboration

- M1 and StarHub (Singapore): Introduced a shared 5G radio access network, reducing costs and enhancing performance.
- DNB (Malaysia): Partnered with Ericsson to implement a single wholesale 5G network, optimizing deployment and resource utilization across industries like ports and logistics.
- XL Axiata & Indosat Ooredoo Hutchison (Indonesia): Contributed to the 5Gnow.id platform, a hub with Nokia, ZTE, and Qualcomm, providing updates and fostering innovation.

(viii) Supporting local manufacturing and supply chain modernization

- Vinaphone (Vietnam): Partnered with Nokia to locally produce 5G equipment, supporting digital infrastructure while fostering Vietnam's manufacturing sector.
- Dtac (Thailand): Launched smart retail solutions, digitizing supply chains and showcasing the transformative impact of 5G in commerce and logistics.

Table 3.6. Deployment and Innovation Initiatives by 5G Operators in ASEAN

Country	Initiatives by Operator
Brunei	• DST collaborated with Huawei for 5G infrastructure development and testing, focusing on deploying 5G for enterprise solutions, smart logistics and energy sectors, facilitating early trials of industrial IoT applications.
Cambodia	• Smart Axiata partnered with Huawei for 5G pilot programs and infrastructure upgrades, engaging with the Cambodian government to roll out 5G trials in Phnom Penh.
Indonesia	• Telkomsel collaborated with Huawei to launch Indonesia's first 5G Smart Warehouse and Innovation Center in West Java, revolutionizing logistics operations. • XL Axiata and Indosat Ooredoo Hutchison contributed to the 5Gnow.id platform, a collaborative hub with Nokia, ZTE, and Qualcomm, offering real-time updates on 5G deployment and use-case developments. • Telkomsel, XL Axiata, and Indosat Ooredoo Hutchison engage in a joint research with Kominfo, ITB, and Telkom University on industrial 5G applications for healthcare and manufacturing. They also established the xG Research Center to explore advanced 5G and 5.5G use cases.
Laos	• Lao Telecom partnered with Huawei to conduct early-stage 5G trials and develop a roadmap for nationwide deployment, focusing on 5G applications for education and e-government services.
Malaysia	• DNB (Digital Nasional Berhad) partnered with Ericsson to implement Malaysia's single wholesale network model. • YTL's Yes 5G: Collaborated with Qualcomm to optimize 5G RedCap Wi-Fi for home networks. • Unifi: Engaged with global leaders to enhance video streaming performance, becoming a 5G Global Winner in this category.
Myanmar	• MyTel: - Partnered with Viettel to gain expertise in deploying 5G infrastructure. - Collaborated with Huawei to implement smart city solutions, focusing on urban connectivity. • MPT conducted 5G trials with Huawei for urban network upgrades.
Philippines	• DITO Telecommunity: - Partnered with Huawei to introduce RedCap Wi-Fi, delivering high-speed home connectivity. - Expanded 5G coverage to 61 provinces by 2024, emphasizing digital inclusion. - Collaborated with Ericsson and Nokia to enhance AR/VR experiences for education and gaming. • NOW Telecom: - Secured funding from the U.S. Trade and Development Agency to develop and pilot 5G networks in Metro Manila.
Singapore	• Singtel: - Collaborated with Ericsson to create a co-innovation space for 5G

	applications in sectors like healthcare and manufacturing. - 5G Standalone (SA): Partnered with Nokia for comprehensive SA deployment. • M1 & StarHub: - Introduced a shared 5G radio access network through their joint venture, Antina. - Launched customizable mobile plans powered by cloud-based systems.

Table 3.6. Deployment and Innovation Initiatives by 5G Operators in ASEAN (Cont')

Thailand	• AIS - Partnered with Huawei, Ericsson, and ZTE to deploy Thailand's 5G network, achieving approximately 85% population coverage by 2022. - Collaborated with the Thai government to develop 5G-powered smart city initiatives in areas such as Bangkok and Chiang Mai, focusing on public safety, environmental monitoring, and smart transportation. - Partnered with Huawei to implement 5G private networks for industrial clients in sectors such as manufacturing, logistics, and energy, promoting efficiency and automation. - Launched 5G Smart Hospitals in collaboration with Siriraj Hospital, utilizing 5G for real-time remote consultations, advanced imaging, and AI diagnostics. • True - Collaborated with Ericsson and Nokia to enhance 5G infrastructure and introduce advanced applications such as cloud gaming, virtual reality (VR), and augmented reality (AR) solutions. - Established partnerships with universities, including Chulalongkorn University, to implement 5G in education through smart classrooms and virtual learning environments. - Introduced 5G-powered immersive tourism experiences, using AR/VR technologies to enhance visitor engagement in cultural and historical sites. - Partnered with the Thai Ministry of Agriculture to pilot 5G solutions for smart farming, including precision irrigation and automated crop monitoring. • Dtac (pioneer in environmental sustainability and rural digital inclusion through targeted 5G solutions) - Worked with Nokia and Ericsson to accelerate 5G rollout and improve mid-band spectrum efficiency, ensuring robust connectivity in urban and suburban areas. - Launched 5G-enabled smart retail solutions to digitize supply chains and enhance customer experiences in collaboration with local businesses. - Deployed 5G IoT sensors for environmental monitoring, focusing on air quality and waste management in major cities. - Partnered with the Thai government to extend 5G coverage to rural areas, focusing on digital inclusion and economic empowerment.

Vietnam	• Viettel - O-RAN Leadership: Launched the world's first O-RAN 5G network with Qualcomm's platforms. - Global Expansion: Plans to extend O-RAN deployments internationally. • MobiFone - Innovation Hub: Established a 5G co-creation space in partnership with Ericsson • Vinaphone - Localized Manufacturing: Partnered with Nokia to produce 5G equipment locally in Bac Giang province.

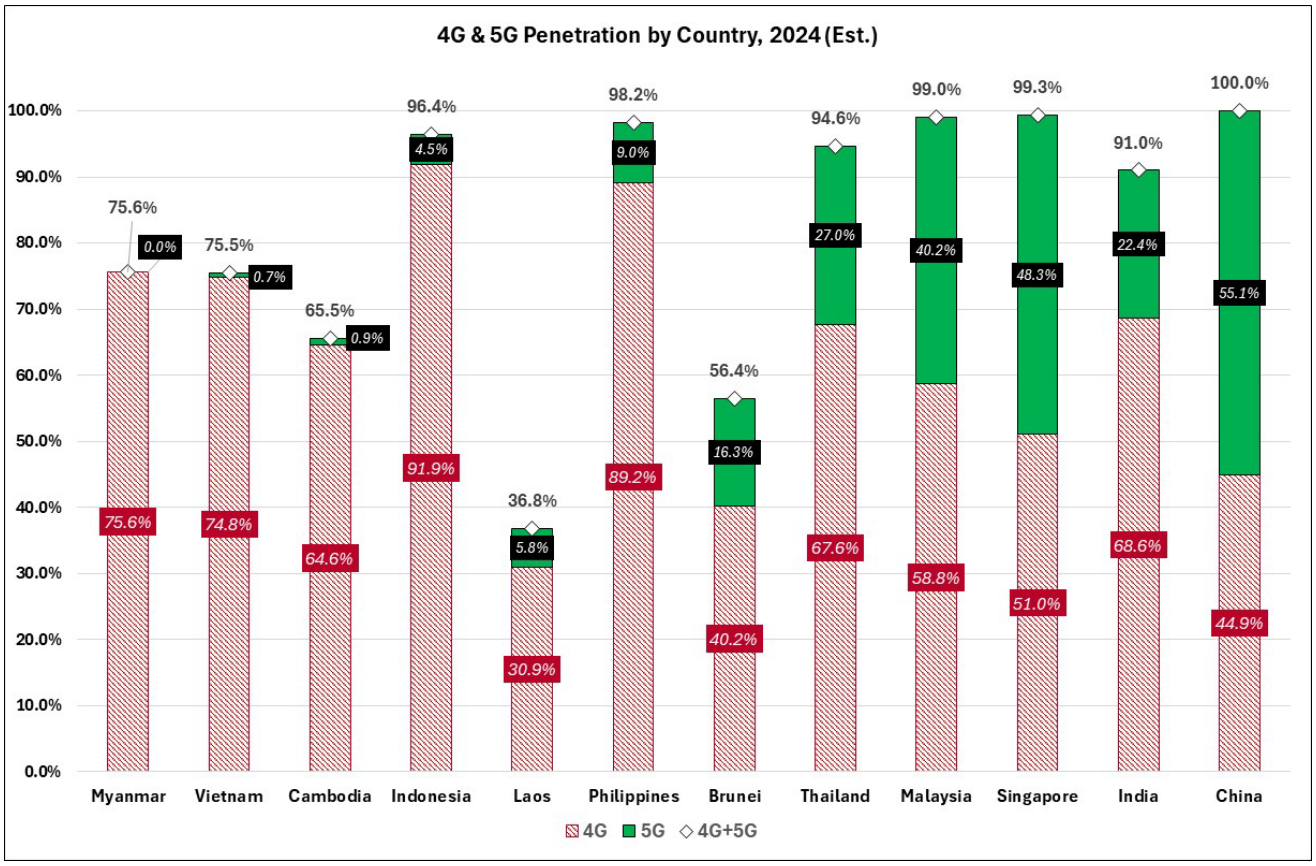
3.2.3. 5G penetration

5G adoption in a country is shaped first by supply-side factors and then by demand-side dynamics. On the supply side, 5G service providers face critical challenges, including regulatory hurdles, substantial infrastructure investment costs, and spectrum allocation complexities. On the demand side, adoption is influenced by factors such as perceived benefits, ease of use, compatibility, market dynamics, and competitive pressures, as outlined in technology acceptance models like TAM (Davis, 1989) and TOE (Tornatzky & Fleischer, 1990).

For 5G specifically, these factors are further driven by the availability and ongoing performance improvements of 5G-enabled devices, the readiness of plug-and-play platforms, and the richness of innovative applications that enhance user experience and utility.

By the end of 2024, 5G penetration, defined as the proportion of 5G subscriptions within total mobile phone subscriptions, was highest in Singapore (48.3%), followed by Malaysia (40.2%) and Thailand (27.0%) (Figure 3.2). Compared to China and India—the two regional giants with significant 5G deployment initiatives—these top three ASEAN countries surpassed India (22.4%) but fell behind China (55.1%). Notably, the remaining seven ASEAN countries performed below India in 5G penetration rates.

Figure 3.2. Penetration of Advanced Mobile Technologies (4G and 5G) in 2024: ASEAN vs. China and India



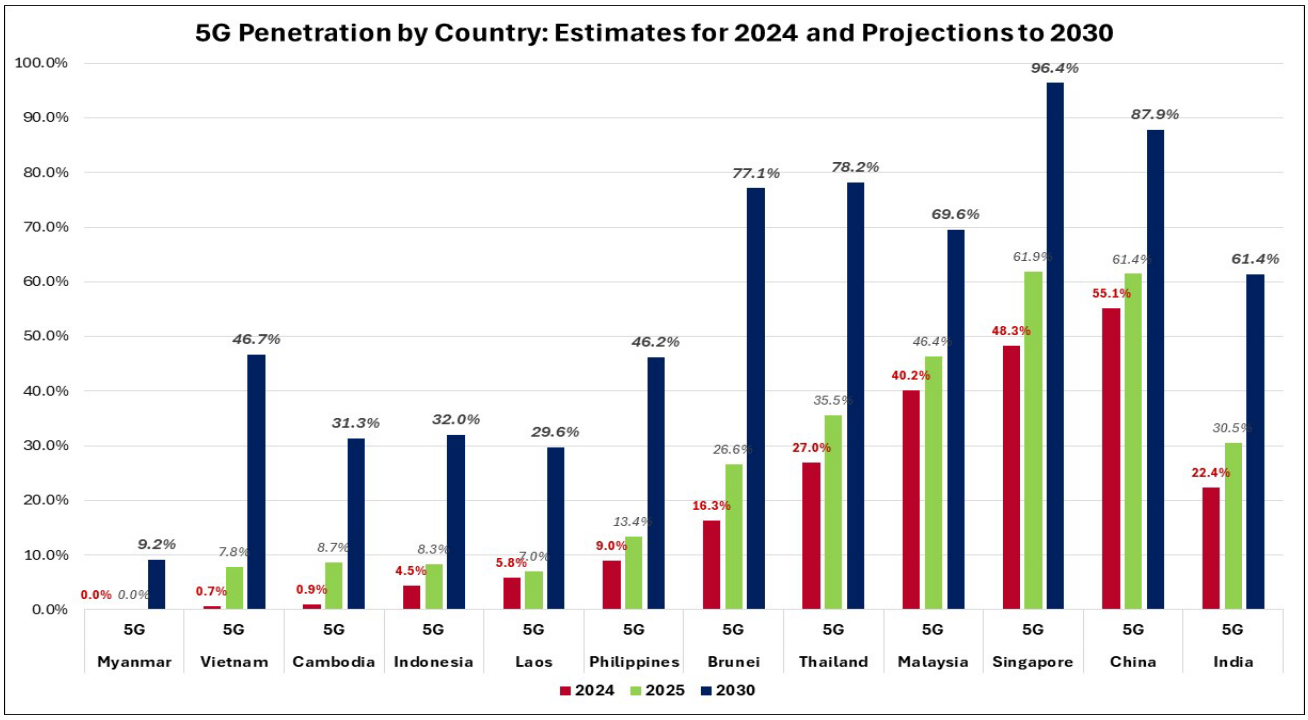
Source: Authors, based on data from GSMA.
Note: The penetration of a mobile technology (4G or 5G) refers to its share of total mobile subscriptions in the country.

5G deployment and adoption are expected to accelerate significantly between 2025 and 2030. By 2030, the 5G penetration rate in Singapore is projected to reach 96.4%, surpassing China's rate of 87.9%. The next three leading countries—Thailand (78.2%), Brunei (77.1%), and Malaysia (69.6%)—are expected to outperform India (61.4%) but remain below China (Figure 3.3).

Among the remaining ASEAN nations, Vietnam is projected to lead with a penetration rate of 46.7%, closely followed by the Philippines at 46.2%. Meanwhile, Indonesia's projected rate is relatively modest at 32%, comparable to Cambodia (31.3%) and Laos (29.6%). Although Myanmar remains a laggard, its penetration rate is expected to reach nearly 10% by 2030.

It is important to note that these projections may not fully account for the evolving dynamics of 5G policy reforms and adoption in countries like Malaysia, Vietnam, and Indonesia. Moreover, rapid advancements and the integration of 5G across various sectors are likely to amplify the benefits of adoption. As such, the penetration rates in Figure 3.3 should be viewed as conservative, lower-bound estimates.

Figure 3.3. Projected Penetration Rates of 5G towards 2030: ASEAN vs. China and India



Source: Authors, based on data from GSMA.
Note: The penetration of a mobile technology (4G or 5G) refers to its share of total mobile subscriptions in the country.

3.2.4. Global recognitions of 5G performance by ASEAN operators

As ASEAN emerges as a vibrant hub for 5G adoption, the region's CSPs have garnered significant recognition for their achievements in 5G performance and innovation. Global accolades awarded to 5G operators by Opensignal—an independent analytics company specializing in 'quantifying the mobile-network experience'—provide compelling evidence of these efforts and successes.

In its 2024 recognition, Opensignal examined the 5G experience of users across the first 180 days of the year, using five key measures: '5G Availability,' '5G Download

Speed,' '5G Games Experience,' '5G Voice App Experience,' and '5G Video Experience.'

Based on these metrics, Opensignal awarded the top-performing operators the title of 5G Global Winners, while the runners-up were designated as 5G Global Leaders. Additionally, acknowledging the rapid pace of change in 5G performance, Opensignal introduced a category for year-on-year improvement, recognizing the top performers in this area as 5G Global Rising Stars.

This comprehensive evaluation serves as a clear benchmark for assessing 5G performance and showcases the exceptional efforts and achievements within the ASEAN region. To enhance the relevance of its recognitions, Opensignal categorizes countries into two groups based on land area: the 'large land mass' group for countries with areas exceeding 50,000 km² and the 'small land mass' group for those with smaller areas.

In these global rankings ASEAN operators have demonstrated significant advancements in 5G performance, earning notable recognitions across the five key 5G performance measures. Table 3.6 highlights the following standout observations.

5G Availability

In the large land mass group, four Malaysian operators—U Mobile, Maxis, Digi, and Yes—are recognized as 5G Global Leaders, a testament to the effectiveness of Malaysia's single wholesale 5G network (DNB). From Thailand, AIS is also a 5G Global Leader, reflecting its leadership in providing robust 5G connectivity. In the Philippines, DITO and Yes are recognized for their growing 5G availability.

In the small land mass group, Singapore's operators—M1, StarHub, and Singtel—stand out as 5G Global Leaders, leveraging 5G Standalone (SA) technology.

5G Download Speed

Three Malaysian operators—Unifi, Digi, and Maxis—are recognized as 5G Global Leaders in the large land mass group, showcasing impressive speeds supported by Malaysia's 5G infrastructure. From the Philippines, DITO is also a 5G Global Leader in this category.

In the small land mass group, Singapore’s three operators—Singtel, M1, and StarHub—are recognized as 5G Global Leaders, delivering consistently high download speeds.

5G Games Experience

In the large land mass group, U Mobile from Malaysia is the sole 5G Global Winner, scoring 90.4 points on a 100-point scale. Maxis, Digi, Celcom, and Unifi, also from Malaysia, are recognized as 5G Global Leaders. Thailand’s AIS and the Philippines' Smart are also recognized as 5G Global Leaders.

In the small land mass group, Singapore’s Singtel is a 5G Global Winner, with M1 and StarHub recognized as 5G Global Leaders. Indonesia’s Telkomsel is also among the Global Leaders, reflecting its growing capabilities in gaming experiences on 5G networks.

5G Video Experience

In the large land mass group, Unifi from Malaysia is among the 11 5G Global Winners, joined by Thailand’s AIS as a Global Leader. The Philippines' DITO is also recognized as a Global Leader for its robust video streaming capabilities.

In the small land mass group, Singapore’s M1 is a 5G Global Winner, with Singtel and StarHub named Global Leaders.

5G Voice App Experience

In the small land mass group, Singapore’s Singtel and StarHub are recognized as 5G Global Leaders, with M1 closely following as a Rising Star. From the large land mass group, Malaysia’s Digi is recognized as a Rising Star for this category.

In summary, the results highlight that a diverse range of ASEAN operators, not only from Singapore—an advanced city-state—but also from developing countries such as Malaysia, Thailand, the Philippines, and Indonesia, have excelled globally. These operators have earned multiple recognitions across key performance categories, underscoring their leadership in 5G innovation and user experience. Their achievements are summarized by country below:

Singapore: Singtel, StarHub, and M1 consistently recognized across multiple categories. Singtel leads in 5G Coverage Experience, while StarHub has secured the most awards for Mobile Network Experience.

Malaysia: U Mobile, along with Maxis, Digi, and Unifi, demonstrates exceptional performance, particularly in 5G Availability and Games Experience, supported by the country’s shared 5G infrastructure.

Thailand: AIS emerges as a strong performer in 5G Availability and Video Experience, reflecting the country’s growing 5G capabilities.

The Philippines, DITO and Smart are recognized for their achievements in 5G Availability, Download Speed, and Video Experience, highlighting the nation’s progress in 5G adoption.

Indonesia, Telkomsel is recognized as a 5G Global Leader in Games Experience, showcasing Indonesia's potential in the 5G space despite being in the earlier stages of adoption.

Table 3.7. Globally Recognized 5G Operators by Performance, 2024

Measures	Large Land Mass Group			Small Land Mass Group		
	Global Winner	Leaders	Rising Stars	Global Winner	Leaders	Rising Stars
5G Availability	T-Mobile - USA	Jio - India; Vodafone - Australia; WOM - Chile; ***U Mobile - Malaysia;*** ***AIS - Thailand;*** ***Maxis - Malaysia;*** DNA - Finland; ***Digi - Malaysia;*** ***DITO - Philippines;*** ***Yes - Malaysia***	Rakuten - Japan; TIM - Italy; Digi Mobil - Romania; ***Telkomsel - Indonesia;*** ***Digi - Malaysia***	T-Mobile - Puerto Rico	***M1 - Singapore;*** stc - Kuwait; ***StarHub - Singapore;*** Ooredoo - Kuwait; KT - South Korea; Zain - Kuwait; Singtel - Singapore; Batelco - Bahrain; SK telecom – S. Korea; Telekom.mk - N. Macedonia; Etisalat - Bahrain; FarEasTone - Taiwan	Partner - Israel; Orange - Belgium; Proximus - Belgium; ***M1 - Singapore***; Vodafone - Czechia
5G Download Speed	Vivo - Brazil	Claro - Brazil; ***Unifi - Malaysia;*** ***Digi - Malaysia;*** Orange - France; 2Degrees - New Zealand; TIM - Brazil; ***Maxis - Malaysia;*** One NZ - New Zealand; ***DITO - Philippines***	Orange - Poland; T-Mobile - Poland; Play - Poland; AT&T - USA; Verizon - USA	LG U+ - South Korea; SK telecom - South Korea	KT - South Korea; Ooredoo - Qatar; Telia - Denmark; Telenor - Denmark; ***Singtel - Singapore;*** Claro - Guatemala; HT - Croatia; A1 - Bulgaria; ***M1 - Singapore;*** ***StarHub - Singapore***	Claro - Puerto Rico; Telekom Slovenije - Slovenia; Vodafone - Ireland; Telia - Denmark; A1 - Slovenia

Table 3.7. Globally Recognized 5G Operators by Performance, 2024 (Continued)

Measures	Large Land Mass Group			Small Land Mass Group		
	Global Winner	Leaders	Rising Stars	Global Winner	Leaders	Rising Stars
5G Games Experience	***U Mobile - Malaysia***	SoftBank - Japan; ***Telkomsel - Indonesia;*** Telekom - Germany; eu - Japan; ***Celcom - Malaysia; Maxis - Malaysia; XL - Indonesia; Unifi - Malaysia;*** Vodafone - Germany; ***Digi - Malaysia***	Zain - Saudi Arabia; Digi Mobil - Romania; ***Smart - Philippines; Indosat - Indonesia;*** Mobily - Saudi Arabia	***Singtel - Singapore*** ; csl - Hong Kong	O2 - Czechia; SK telecom - South Korea; KT - South Korea; Vodafone - Czechia; ***StarHub - Singapore;*** Slovak Telekom - Slovakia; ***M1 - Singapore;*** T-Mobile - Czechia; LG U+ - South Korea; O2 - Slovakia; 3 - Hong Kong	Ooredoo - Qatar; Tigo - Guatemala; du - UAE; Zain - Kuwait; A1 - Slovenia
5G Video Experience	DNA - Finland	Tele2 - Norway; Telenor - Norway; Telia - Norway; Elisa - Finland; ***Unifi - Malaysia;*** Telia - Finland	AT&T - USA; Orange - Poland; Vodafone - Spain; EE - UK; Telia - Finland	Telia - Denmark	HT - Croatia; Telekom Slovenije - Slovenia; Telenor - Denmark; Magenta - Austria; A1 - Slovenia; ***M1 - Singapore;*** 3 - N. Macedonia; ***Singtel - Singapore***	Liberty - Puerto Rico; Claro - Puerto Rico; du - UAE; LG U+ - South Korea; KT - South Korea
5G Voice App Experience	SoftBank - Japan; au - Japan	DNA - Finland; U Mobile - Malaysia; Telkomsel - Indonesia; Digi Mobil - Romania; Orange - Poland; Digi - Malaysia; XL - Indonesia; 3 - Indonesia	Digi Mobil - Romania; ***Smart - Philippines;*** Vodafone - UK; Telcel - Mexico; Bell - Canada	Vodafone - Czechia; T-Mobile - Czechia; O2 - Czechia; Yettel - Hungary	Orange - Slovakia; Magenta - Austria; Slovak Telekom - Slovakia; Vodafone - Hungary; ***Singtel - Singapore;*** A1 - Slovenia; ***StarHub - Singapore;*** csl - Hong Kong; O2 - Slovakia	du - UAE; Tigo - Guatemala; HT - Croatia; SK telecom - South Korea; Vodafone - Ireland

Source: Compiled by the authors from Opensignal (2024), available at https://www.opensignal.com/2024/10/5g-global-mobile-network-experience-awards-2024

3. ASEAN’s Readiness for 5G

ASEAN's readiness as a region can be assessed from three key perspectives: the rankings of its member states in the GSMA Intelligence 5G Connectivity Index, the strength of its 5G enablers, and its preparedness for AI—an essential driver and catalyst for 5G and beyond. This analysis offers valuable insights into the current state and potential dynamics of 5G deployment and adoption across ASEAN countries.

3.3.1. ASEAN Country Rankings in the GSMA Intelligence 5G Connectivity Index

The GSMA (Global System for Mobile Communications Association) is a globally recognized authority representing the interests of mobile operators and the broader telecommunications industry. With a membership of over 750 operators and 400 companies in adjacent industries, the GSMA plays a pivotal role in shaping the future of connectivity. Through its research arm, GSMA Intelligence, it provides in-depth, data-driven insights and analyses on global mobile trends, including 5G readiness and adoption. Widely regarded for its robust methodology and evidence-based approach, the GSMA's assessments are trusted by governments, policymakers, and industry leaders worldwide, making it a credible source for evaluating 5G development and connectivity performance.

The GSMA Intelligence 5G Connectivity Index (5GI) serves as a critical tool for evaluating and driving 5G development globally. Recognizing the transformative potential of 5G, the 5GI aims to enhance network coverage, adoption, and market development by offering a comprehensive view of 5G progress in various markets. The index tracks key indicators across coverage, network performance, affordability, adoption, and market development, facilitating comparative analysis and providing actionable insights for decision-makers. By tailoring connectivity and economic priorities to local market contexts, the 5GI aligns strategies with specific national needs, enabling countries to maximize the benefits of 5G.

The 5GI framework combines two dimensions -- 5G infrastructure and 5G services, divided into six pillars encompassing 17 indicators (Table 3.8). These indicators measure both enablers—such as network infrastructure and spectrum—and outcomes, including adoption and market development. By integrating enablers and outcomes, the 5GI offers a holistic assessment of 5G readiness and performance, aiding governments and organizations in making informed decisions, prioritizing investments, and planning strategic initiatives for 5G deployment.

Table 3.8: The 5GI Framework

Infrastructure		Services	
Pillars	**Indicators**	**Pillars**	**Indicators**
I. Spectrum	1. Low-band spectrum 2. Mid-band spectrum 3. mmWave spectrum	**IV. Affordability**	1. 5G data affordability 2. 5G device affordability
II. Network	4. 5G base stations 5. 5G coverage 6. 5G standalone	**V. Adoption**	3. 5G subscriber penetration 4. 5G device shipments 5. 5G FWA penetration
III. Experience	7. Download speeds 8. Upload speeds 9. Latencies 10. Video quality	**VI. Market Development**	6. Data traffic per user 7. Revenue growth

Source: compiled from GSMA (2024b)

The 5GI 2023 global rankings include only five ASEAN countries—Indonesia, Malaysia, the Philippines, Singapore, and Thailand—as the remaining five countries (Brunei, Vietnam, Cambodia, Laos, and Myanmar) had not launched commercial 5G networks by the end of 2023.

The performance of these ASEAN countries in the 5GI 2023 rankings is summarized in Table 3.9, while their distribution across the two key dimensions—Infrastructure and Services—is illustrated in Figure 3.4. Several notable observations, drawn from Table 3.9 and Figure 3.4, are detailed below.

First, Singapore leads ASEAN in the 5GI 2024 rankings, securing the 13th position globally with a score of 52, making it the highest-ranking ASEAN country. This score places Singapore ahead of advanced economies such as Switzerland (51), Australia (50), Germany (48), and Japan (48). Furthermore, Singapore is positioned in the top-right quadrant of Figure 3.4, indicating a score exceeding 50 in both key dimensions of 5GI—‘5G Connectivity’ and ‘5G Services’—highlighting its strong readiness in both areas. However, it should be noted that Singapore lags behind Hong Kong and South Korea in the overall 5GI rankings and underperforms Hong Kong in both 5GI dimensions.

Second, Thailand ranks as the second-highest ASEAN country but trails far behind Singapore. Globally, it holds the 28th position with a score of 39. Thailand's relatively lower score on '5G Services' suggests a need to prioritize improvements in this dimension to enhance its overall 5G readiness (Figure 3.4).

Third, Malaysia demonstrates moderate performance among ASEAN countries, ranking 31st globally with a score of 34. This ranking reflects Malaysia's efforts to implement a wholesale 5G network model, but it also highlights areas for improvement in both key dimensions, '5G Connectivity' and '5G Services.'

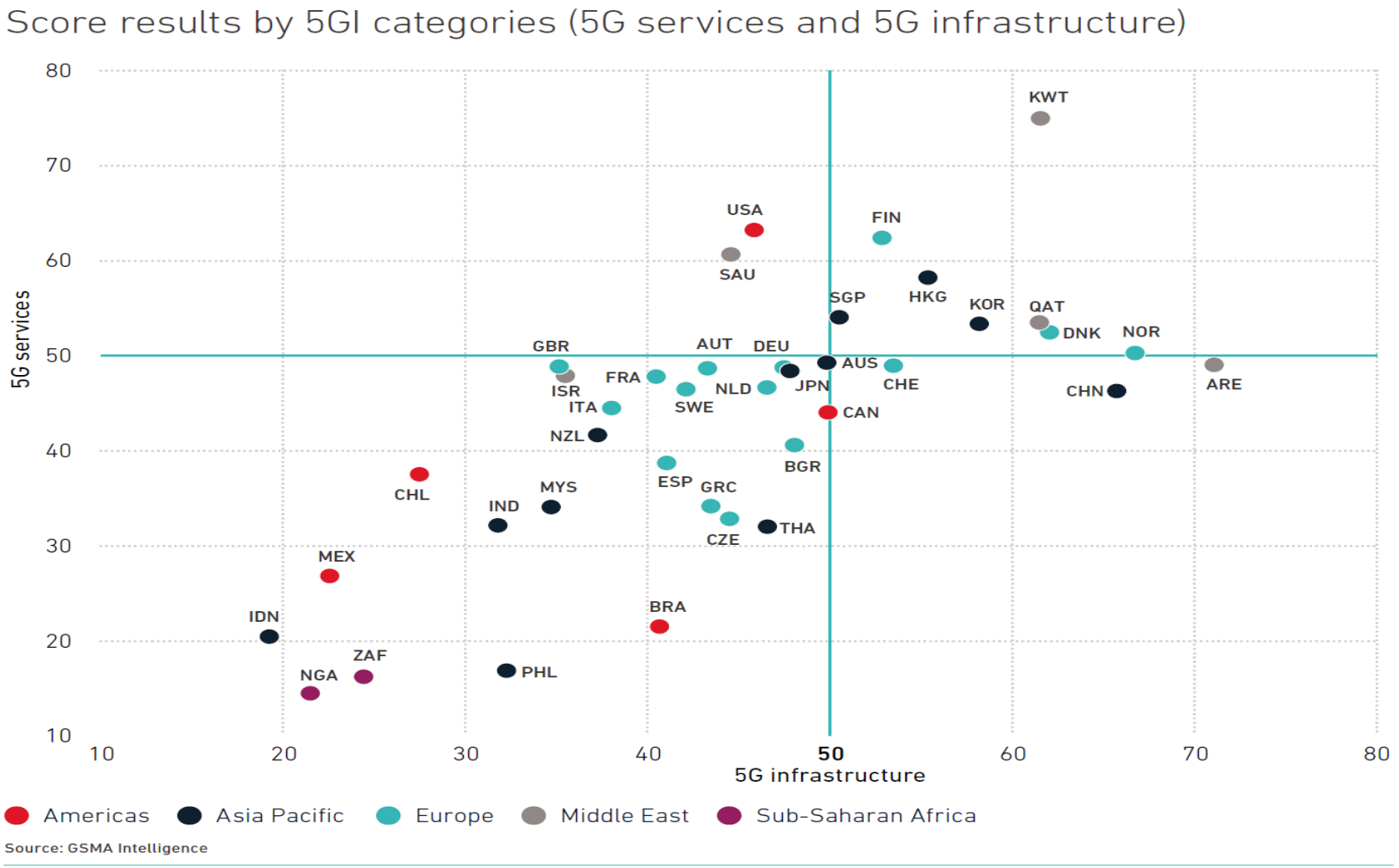
The Philippines and Indonesia rank 36th and 38th globally, respectively, falling behind comparable developing economies such as India (33rd), Brazil (34th), and Mexico (35th). Both countries are among the lowest performers in both dimensions, indicating significant challenges in infrastructure development and service adoption. For improvement, the Philippines should urgently prioritize advancements in '5G Services,' while Indonesia must prioritize both key 5GI dimensions equally.

Table 3.9: ASEAN Countries in the Global Rankings by 5GI 2023

Rank	Country	5GI Score	Region
1	Kuwait	68	Middle East
2	UAE	59	Middle East
3	Norway	58	Europe
4	Finland	57	Europe
5	Qatar	57	Middle East
6	Denmark	57	Europe
7	Hong Kong SAR, China	57	Asia Pacific
8	South Korea	56	Asia Pacific
9	Mainland China	55	Asia Pacific
10	US	54	Americas
11	Singapore	52	ASEAN
12	Saudi Arabia	52	Middle East
13	Switzerland	51	Europe
14	Australia	50	Asia Pacific
15	Germany	48	Europe
16	Japan	48	Asia Pacific
17	Canada	47	Americas
18	Netherlands	47	Europe
19	Sweden	46	Europe
20	Austria	46	Europe
21	Bulgaria	44	Europe
22	France	44	Europe
23	UK	42	Europe
24	Israel	41	Middle East
25	Italy	41	Europe
26	Spain	40	Europe
27	New Zealand	39	Asia Pacific
28	Thailand	39	ASEAN
29	Greece	39	Europe
30	Czechia	38	Europe
31	Malaysia	34	ASEAN
32	Chile	32	Americas
33	India	32	Asia Pacific
34	Brazil	30	Americas
35	Mexico	25	Asia Pacific
36	Philippines	23	ASEAN
37	South Africa	20	Asia Pacific
38	Indonesia	20	ASEAN
39	Nigeria	18	Sub-Saharan Africa

Source: GSMA (2024b)

Figure 3.5: ASEAN Countries in the Global Distribution by the Two Dimensions of the 5GI 2023



Source: GSMA (2024b)

3.3.2. 5G Enablers

The 5G Enablers Framework, introduced by the International Telecommunication Union (ITU) in 2024, provides a structured approach to assessing the key factors driving 5G deployment and adoption. Covering multiple dimensions essential for 5G readiness and impact, the framework evaluates:

- Affordability – The economic accessibility of 5G services.
- Infrastructure – The strength and scalability of network capabilities.
- Spectrum – The availability and efficiency of spectrum allocation.
- Consumer Readiness – Adoption rates and user adaptability.
- Content & Services – The availability of relevant applications.
- Cybersecurity Index – The robustness of 5G security standards.
- e-Government Score – The role of digital governance in 5G enablement.
- Gender Equality – Ensuring inclusive 5G access and opportunities.
- Mobile Latencies – Measuring network performance and responsiveness.

By integrating technical, economic, and societal factors, the framework provides a holistic view of a country's 5G preparedness, helping stakeholders identify gaps, optimize strategies, and accelerate deployment for maximum impact.

The performance of the 10 ASEAN countries, alongside China, India, and South Korea for comparison, is detailed in Table 3.10. Key observations from the table include the following:

- Singapore is a global leader across nearly all dimensions, scoring close to 100 in most categories except for Spectrum (72.0), which is below the Philippines (87.8) and Thailand (75.9). On other dimensions, Singapore outperforms all ASEAN countries, with scores comparable to or exceeding advanced nations like South Korea and Japan. Notable strengths include Gender Equality (100%), Cyber Security Index (98.5%), and Consumer Readiness (93.6%).
- Thailand ranks second in ASEAN for the Infrastructure Index (82.1%), trailing Singapore but surpassing China (88.0%) and India (61.8%). Its scores in Consumer Readiness (86.0%) and Content and Services (86.5%) demonstrate strong demand-side enablers, positioning it as a regional leader in 5G adoption.

- Malaysia presents a balanced 5G readiness profile, excelling in Affordability (64.8%), Cyber Security (98.1%), and Content and Services (76.4%). Although its Infrastructure Index (73.9%) slightly lags behind Thailand, Malaysia shows significant potential for advancing 5G deployment but remains behind China (88.0%) and South Korea (87.9%).
- The Philippines leads ASEAN in Spectrum (87.8%), surpassing China (57.4%), India (61.8%), and even South Korea (48.6%). However, it falls short in Content and Services (59.4%) and Cyber Security (77.0%), which could hinder the effective utilization of its spectrum advantage.
- Indonesia and Vietnam exhibit growth potential despite notable limitations. Indonesia shows strength in Affordability (70.6%) and Cyber Security (94.9%), providing a foundation for future 5G expansion. Vietnam, while challenged by Infrastructure (62.8%), demonstrates promise in Content and Services (76.8%) and Cyber Security (94.6%), reflecting its growing digital capabilities and user engagement.
- Smaller ASEAN nations such as Brunei, Laos, and Cambodia face significant gaps in Spectrum (22.7%–33.9%), Cyber Security (19.1%–56.1%), and e-Government scores, which fall well below the ASEAN median. These deficiencies underline the need for targeted investments in digital infrastructure and policy reforms to address their developmental challenges.

Table 3.10. ASEAN's 5G Enablers

ASEAN countries listed in descending order by infrastructure index

Country	5G Enablers								
	Affordability	Infrastructure	Spectrum	Consumer Readiness	Content and Services	Cyber Security Index	e-Gov. Score	Gender Equality	Mobile latencies
Singapore	99.1	90.9	72.0	93.6	89.0	98.5	96.2	100.0	92.7
Thailand	59.4	82.1	75.9	86.0	86.5	86.5	77.6	98.8	89.7
Malaysia	64.8	73.9	70.1	81.5	76.4	98.1	76.3	92.5	88.0
Philippines	47.0	73.3	87.8	76.8	59.4	77.0	63.0	100.0	86.4
Brunei	77.7	64.3	22.7	82.2	62.7	56.1	58.7	100.0	93.0
Indonesia	70.6	64.2	33.9	66.7	70.2	94.9	76.4	68.1	86.1
Vietnam	61.3	62.8	30.1	74.3	76.8	94.6	64.8	86.5	88.6
Myanmar	49.6	62.7	32.2	56.7	36.2	36.4	30.7	50.8	84.4
Lao PDR	42.7	60.0	31.5	71.8	41.4	20.3	30.1	100.0	84.0
Cambodia	45.9	58.1	29.3	53.6	51.3	19.1	43.6	41.5	85.8
Timor-Leste	53.0	53.0	29.6	59.7	30.4	4.3	39.3	61.1	82.4
ASEAN (Median)	**59.4**	**64.2**	**32.2**	**74.3**	**62.7**	**77.0**	**63.0**	**92.5**	**86.4**
China	76.7	88.0	57.4	80.2	78.3	92.5	88.8	74.7	88.5
India	62.4	61.8	61.8	54.3	67.2	97.5	79.3	40.5	79.7
South Korea	64.6	87.9	48.6	94.0	91.8	98.5	98.3	98.9	87.8
Japan	85.4	83.3	75.9	86.1	87.8	97.8	90.9	73.7	81.4

Source: ITU (2024a)

3.3.3. AI Readiness

The AI Readiness Framework, introduced by Oxford Insights in 2023 (Oxford, 2023), provides a robust methodology for evaluating nations' preparedness to leverage artificial intelligence (AI) technologies effectively. This framework assesses AI readiness across multiple critical dimensions, including governance, infrastructure, innovation, and societal impact, integrating both qualitative and quantitative metrics. Key focus areas include government strategy and policies, AI infrastructure investment, availability of skilled talent, and ethical considerations in AI deployment. Recognized as a global benchmark, the framework enables policymakers and stakeholders to identify opportunities and challenges, design effective strategies, and maximize AI's transformative potential while mitigating risks.

AI Readiness and 5G Synergy

AI readiness is vital for 5G readiness and performance, while they are highly synergistic and mutually reinforcing. Artificial intelligence enhances the operational efficiency and scalability of 5G networks. AI-driven solutions optimize network management, reduce latency, and enable dynamic resource allocation, which are essential for delivering high-speed, low-latency connectivity. Furthermore, AI powers innovative applications like autonomous vehicles, smart cities, and industrial IoT, all of which leverage 5G capabilities. Nations with strong AI readiness are better positioned to maximize 5G investments, ensuring transformative economic and societal benefits. The interplay between AI and 5G will define the next wave of connectivity-driven innovation.

The 2024 AI Readiness performance of ASEAN countries reveals a diverse and uneven landscape, with frontrunners like Singapore and Malaysia well ahead of others in key dimensions. Table 3.11 provides comparative insights into ASEAN’s AI readiness alongside major Asian economies such as China, India, and South Korea.

Singapore continues to stand out as a global AI leader, ranking 2nd globally with an overall score of 84.2. It excels in Government Readiness (91.0) and Data Infrastructure (93.1)—figures that surpass even those of South Korea and the United States. Its Technology Sector score of 68.7 positions it well ahead of regional peers and underscores its strong innovation environment. To maintain this leadership,

Singapore will need to continue investing in frontier technologies, regulatory agility, and global partnerships to set the benchmark for AI development in ASEAN and globally.

Malaysia ranks 24th globally with a score of 71.4, affirming its position as ASEAN's second-strongest performer. Its Government Readiness score of 82.5 surpasses both China (72.9) and India (73.3), reflecting the strength of its national AI policy and institutional frameworks. However, Malaysia's Technology Sector score of 54.2 indicates room for improvement, particularly compared to China (63.0) and South Korea (62.6). By addressing ecosystem gaps and fostering more active private-sector engagement, Malaysia could strengthen its position as a regional AI hub.

Thailand ranks 35th globally with a total score of 66.2. It performs strongly in Data Infrastructure (77.9) and Government Readiness (75.8), placing it above India and on par with Indonesia in institutional readiness. However, its Technology Sector score of 44.8 lags behind both Malaysia (54.2) and Indonesia (48.1), pointing to the need for deeper investment in AI entrepreneurship, industry adoption, and research capabilities.

Indonesia closely follows Thailand at 38th globally with a score of 65.9, reflecting a broadly balanced performance. The country shows notable strength in Government Readiness (79.9)—higher than Thailand, Vietnam, and even China—and steady progress in Data Infrastructure (69.6). Its Technology Sector score of 48.1 suggests emerging private sector engagement in AI, though continued support is needed to accelerate R&D and digital talent development.

Vietnam ranks 51st globally with a score of 61.4, showing steady improvement across all dimensions. Its Government Readiness (75.0) and Data Infrastructure (65.9) approach the ASEAN median. However, its Technology Sector score (43.4) remains a structural constraint, underscoring the need to enhance local innovation ecosystems, promote AI startups, and facilitate deeper collaboration between academia and industry.

The Philippines is ranked 56th globally with a score of 58.5. It performs reasonably well in Government Readiness (74.5) and Data Infrastructure (62.5) but faces significant challenges in its Technology Sector (38.6). Strengthening this domain

through digital skills programs, targeted innovation policies, and incentives for AI adoption will be essential to unlock growth potential.

Brunei shows relatively stronger infrastructure, ranking 66th globally with a total score of 55.4. Its Data Infrastructure (74.6) is notable, but Government Readiness (45.9) and Technology Sector (45.9) highlight the need for more coherent strategies and institutional development.

Lower-performing ASEAN countries such as Cambodia (36.6), Lao PDR (36.1), Myanmar (34.3), and Timor-Leste (33.7) remain at the bottom of the global ranking. These countries all score under 30 in Government Readiness and below 34 in the Technology Sector, indicating critical capacity deficits. Without significant foundational investments in digital infrastructure, institutional capability, and human capital, these nations risk further marginalization in the AI era.

Outside ASEAN, China ranks 23rd globally with a score of 72.0. While strong in Technology Sector (63.0) and Data Infrastructure (80.2), its Government Readiness score (72.9) is now surpassed by several ASEAN countries, including Singapore and Malaysia. India, ranked 46th, shows moderate performance with a score of 62.8, led by Technology Sector (50.3) but held back by relatively weaker Data Infrastructure (64.8).

South Korea, ranked 3rd globally, remains a global leader in AI readiness with Government Readiness (84.6) and Data Infrastructure (92.7)—scores comparable to Singapore. The country's Technology Sector score (62.6) reflects a mature innovation landscape, heavily supported by coordinated public-private R&D investment.

In summary, the 2024 AI Readiness Index underscores the urgent need for tailored national strategies across ASEAN. While Singapore and Malaysia set the regional benchmark, Thailand and Indonesia are making strong gains and can achieve global competitiveness by closing gaps in their tech ecosystems. Vietnam and the Philippines require strategic investment in innovation capacity, while Brunei shows potential through infrastructure readiness. The rest of ASEAN—including Cambodia, Lao PDR, Myanmar, and Timor-Leste—must focus on foundational capacity building to avoid deepening the digital divide.

By drawing lessons from regional leaders and global exemplars like South Korea, ASEAN countries can shape inclusive, forward-looking AI ecosystems that fuel long-term competitiveness and sustainable growth.

Table 3.11. ASEAN in the Global AI Readiness Index, 2024

ASEAN countries listed in descending order by the readiness index

Country	Global Rank	Total score	Government	Technology Sector	Data and Infrastructure
Singapore	2	84.2	91.0	68.7	93.1
Malaysia	24	71.4	82.5	54.2	77.6
Thailand	35	66.2	75.8	44.8	77.9
Indonesia	38	65.9	79.9	48.1	69.6
Viet Nam	51	61.4	75.0	43.4	65.9
Philippines	56	58.5	74.5	38.6	62.5
Brunei	66	55.4	45.9	45.9	74.6
Cambodia	133	36.6	29.2	29.3	51.4
Lao PDR	137	36.1	28.1	28.8	51.4
Myanmar	143	34.3	24.2	33.9	44.7
Timor-Leste	146	33.7	27.0	26.7	47.3
ASEAN (Median)	**65**	**52.0**	**65.4**	**37.8**	**56.6**
China	23	72.0	72.9	63.0	80.2
India	46	62.8	73.3	50.3	64.8
South Korea	3	80.0	84.6	62.6	92.7
The US	1	87.0	89.3	80.9	90.9

Source: Oxford (2025)

Section 4

5G-AI Development in ASEAN: Insights from Surveys and Stakeholder Interviews

4.1. 5G-AI Deployment: From Expectations to Reality

The development of 5G in Asia, beginning with South Korea's groundbreaking commercial launch in December 2018, has revealed fascinating dynamics and key insights—many of which are increasingly intertwined with the rapid evolution of artificial intelligence (AI). This section aims to enhance our understanding of the ongoing patterns of 5G development in ASEAN countries and its prospects through 2030, while also highlighting the emerging role of AI as a powerful enabler of network optimization, intelligent service delivery, and value creation. Drawing from surveys and stakeholder interviews—the primary focus of this section—we first examine the salient issues that illustrate both the challenges and transformative potential of 5G and AI integration in ASEAN.

The Gap Between Expectations and Reality in 5G Rollouts

A review of 5G development across Asia reveals a complex transition from ambitious projections to on-the-ground realities. The Mobile Economy – Asia Pacific 2019 report by GSMA anticipated that nearly half of APAC economies would launch commercial 5G networks by 2019 or 2020, with the remainder expected to follow by 2025 (Table 4.1). However, by the end of 2024, most ASEAN countries had fallen behind the expected deployment schedule—a pattern mirrored in other APAC nations.

Nevertheless, this initial lag has not necessarily translated into long-term stagnation. As highlighted in Table 4.2, which compares actual and projected 5G and 4G penetration rates, updated 2024 projections suggest a steeper upward trajectory in 5G adoption than previously forecasted. Crucially, the deployment of AI-driven tools—such as predictive analytics for network traffic, smart resource allocation, and automated infrastructure management—has begun to accelerate rollout timelines and enhance the value proposition of 5G in several countries.

For instance, Malaysia reached a 5G penetration rate of 40.2% in 2024, far surpassing the 2025 target set in GSMA's 2019 forecast—even though the country launched 5G commercially a year later than planned. The integration of AI in managing spectrum, optimizing network load, and supporting industrial use cases (e.g. smart logistics, manufacturing) has likely contributed to this rapid progress.

India, too, despite a two-year delay in its 5G launch (2022 instead of 2020), achieved a 22.4% penetration rate in 2024—significantly outpacing the original 7% projection for 2025. AI-powered telecom analytics and policy pushes toward digital transformation have enabled faster scaling of infrastructure and services.

Vietnam, following a cautious yet calculated 'smart follower' approach, launched commercial 5G in 2024—four years later than initially expected. However, early signs point to accelerated growth, fuelled in part by the use of AI in urban planning, public service delivery, and agricultural tech pilots aligned with 5G deployment.

Importantly, the updated 2024 projections for 4G penetration also reflect the shifting technological priorities. Countries aggressively transitioning to 5G—such as Malaysia, China, and India—show significantly lower 4G projections for 2025 compared to 2019, indicating a reallocation of investment and focus. In contrast, nations such as Indonesia, the Philippines, and Vietnam exhibit higher 4G projections in 2024, reflecting a more cautious or resource-constrained pivot to next-generation connectivity.

This divergence suggests that countries further along the 5G path are already harnessing AI to drive efficiencies and new use cases, allowing them to reduce dependence on legacy 4G systems. Conversely, those still prioritizing 4G may face mounting pressure to adopt AI-enhanced strategies to avoid long-term digital divides.

Table 4.1: Year of 5G Commercial Launch in Asian Economies – Actual (by End of 2024) vs. Anticipated (in Early 2019)

Economy	Year of First 5G Commercial Launch		
	Anticipated (in Early 2019)	Actual (by End of 2024)	Actual vs. Anticipated Year Gap (+ for Earlier, - for Later)
ASEAN			
Thailand	2021-2025	2020	+1
Brunei Darussalam	2021-2025	2023	0
Indonesia	2021-2025	2021	0
Malaysia	2020	2021	-1
Singapore	2020	2021	-1
Philippines	2019	2021	-2
Vietnam	2020	2024	-4
Cambodia	2021-2025	Not yet	?
Myanmar	2021-2025	Not yet	?
China-India			
China	2020	2019	+1
India	2020	2022	-2
Other APAC Economies			
New Zealand	2020	2019	+1
Taiwan	2020	2020	0
Japan	2020	2020	0
Hong Kong	2019	2020	-1
Australia	2019	2020	-1
Sri Lanka	2020	Not yet	-5 or more
Bangladesh	2021-2025	Not yet	?
Pakistan	2021-2025	Not yet	?

Source: GSMA (2019); Wikipedia (2025); Note: South Korea's CSPs launched their first 5G commercial networks in December 2018.

Table 4.2: 5G Penetration – Actual vs. Projected (2018, 2024, and 2025)

Country	5G				4G			
	Actual		GSMA Projections for 2025 in		Actual		GSMA Projections for 2025 in	
	2018	2024	2019	2024	2018	2024	2019	2024
Indonesia	0%	4.5%	6.0%	8.3%	44.0%	91.9%	79.0%	88.9%
Malaysia	0%	40.2%	20.0%	46.4%	59.0%	58.8%	79.0%	53.0%
Philippines	0%	9.0%	10.0%	13.4%	20.0%	89.2%	64.0%	85.3%
Vietnam	0%	0.7%	6.0%	7.8%	8.0%	74.8%	36.0%	80.6%
China	0%	55.1%	28.0%	61.4%	76.0%	44.9%	72.0%	38.6%
India	0%	22.4%	7.0%	30.5%	39.0%	68.6%	77.0%	65.4%

Source: GSMA (2019); GSMA-Database (2024, December).

4.2. Perceptions about 5G Development in ASEAN: Findings from a Survey

To gain a broad understanding of the prospects and drivers of 5G development in ASEAN, we conducted an expert opinion survey covering eight of the region's ten countries: Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam.

Following the approach used in various international reports—such as the *Global Competitiveness Report* by the World Economic Forum, the *IMD Competitiveness Yearbook* by the International Institute for Management Development (IMD), and the *Logistics Performance Index* by the World Bank—our survey targeted a small sample of experts and professionals with relevant knowledge, using a simple questionnaire to gather their opinions on key issues of interest.

The questionnaire comprised two main questions. The first focused on expectations regarding the pace of 5G penetration and its economic impact during 2025–2030 in respondents' respective countries, along with views on AI and the broader dynamics of digital transformation. The second question explored the perceived significance of six key players within the 5G ecosystem that influence 5G penetration. In total, the questionnaire included 12 items—six related to each of the two questions (see Appendix 2 for details).

The survey was independently conducted online in each of the eight countries during December 2024 and January 2025, using the Google Forms platform. Due to various constraints, the primary focus was placed on four countries—Vietnam, Indonesia, Thailand, and Singapore—where we had direct access to stakeholders and experts

within the 5G ecosystem, referred to as *core respondents*. To expand each country's sample size to 30 or more participants, core respondents were invited to assist in recruiting *non-core respondents*, including government officials and professionals from their networks.

For Malaysia, the Philippines, Cambodia, and Myanmar, we primarily relied on government officials and professionals within our reach. Although these respondents and their networks were not directly involved in the 5G ecosystem, they considered themselves sufficiently knowledgeable to answer the survey questions.

As of the cutoff date on January 29, 2025, the survey had received a total of 413 valid responses. Table 4.3 presents the sample sizes and corresponding Cronbach's alpha coefficients for each of the eight countries. In all cases, the Cronbach's alpha values exceed the conventional threshold of 0.70, which is widely regarded as the minimum standard for construct validity in social science and technology adoption research (Nunnally, 1978; George & Mallery, 2003; DeVellis, 2016). Accordingly, the survey results can be considered sufficiently reliable for drawing insights into the questions explored in each country. Additional details on this validity test are provided in Appendix 2B.

Table 4.3. Survey Sample Size and Cronbach's Alpha by Country

Country	Core respondents*	Sample size (all respondents)	No. of Items	Cronbach's Alpha
Indonesia	30	30	12	0.7621
Cambodia	2	34	12	0.7750
Myanmar	1	33	12	0.9292
Malaysia	2	70	12	0.7926
Philippines	2	45	12	0.7787
Singapore	12	45	12	0.8563
Thailand	15	72	12	0.9365
Vietnam	20	84	12	0.8727

Note: Core respondents refer to stakeholders or experts actively involved in the 5G ecosystem within the surveyed country who participated in our interviews. Non-core respondents include government officials or professionals invited through the networks of core respondents or the survey team.

Given the limitations of our survey sampling, it is appropriate to compare average scores across indicators within each country. However, caution should be exercised when comparing scores for the same indicator across countries, as respondent

samples may vary in terms of their knowledge and experience with 5G-AI development.

With this caveat in mind, we calculate an aggregated score for each indicator across ASEAN to enable rough comparisons between individual countries and the regional average. To ensure equal weighting among the eight surveyed countries, each respondent is assigned a weight inversely proportional to their country's sample size—i.e., respondents from larger samples are given lower weights.

The survey results provide key policy insights on two critical aspects: (i) expectations for the penetration pace and economic impact of 5G, along with two major digital advancements—AI and broader trends of digital transformation (DX)—over the next five years (2025–2030); and (ii) the perceived importance of key ecosystem players in driving 5G development within a country.

Expected penetration and economic impact of 5G, DX, and AI (2025-2030)

The rapid advancement of digital technologies is reshaping the economic landscape of ASEAN Member States (AMS), though expectations around the penetration and impact of Digital Transformation (DX), Artificial Intelligence (AI), and 5G vary significantly across countries. In this survey, digital transformation (DX) is defined as the efforts of governments, businesses, and individuals to adopt emerging technologies—such as digital solutions, cloud computing, AI, the Internet of Things (IoT), and 5G—to enhance work processes, increase productivity, and improve outcomes. These efforts collectively advance the development of the digital economy, digital society, and digital government.

As shown in Figure 4.2, the survey results highlight six key insights that reveal both common trends and regional disparities.

First, Thailand, Singapore, and Malaysia lead in DX expectations, anticipating above-average adoption and economic impact. Singapore, in particular, stands out with the highest economic impact score (~4.4), driven by its Smart Nation Strategy and AI-powered governance. These findings suggest that more digitally advanced economies foresee greater benefits from DX, leveraging government-led initiatives and strategic investments.

AI adoption is another major focus across AMS, with Singapore, Vietnam, and Malaysia expressing the highest expectations (~4.2–4.3). In contrast, Myanmar and the Philippines report slightly lower scores, indicating slower adoption. Indonesia aligns with the ASEAN average (~3.9–4.0), suggesting a steady integration of AI into key industries. The widespread optimism surrounding AI highlights its role as a key driver of automation and digital services, with leading nations investing heavily in AI-powered growth. It should be noted that 5G plays an increasingly critical role in accelerating AI adoption and driving digital transformation by providing the high-speed, low-latency connectivity needed to support data-intensive applications. Its ability to enable real-time data transmission, edge computing, and seamless device-to-device communication makes it a foundational infrastructure for AI-powered innovations across sectors such as manufacturing, healthcare, transportation, and smart cities. By unlocking new possibilities for automation, analytics, and intelligent services, 5G acts as a catalyst for deeper, more integrated digital transformation efforts.

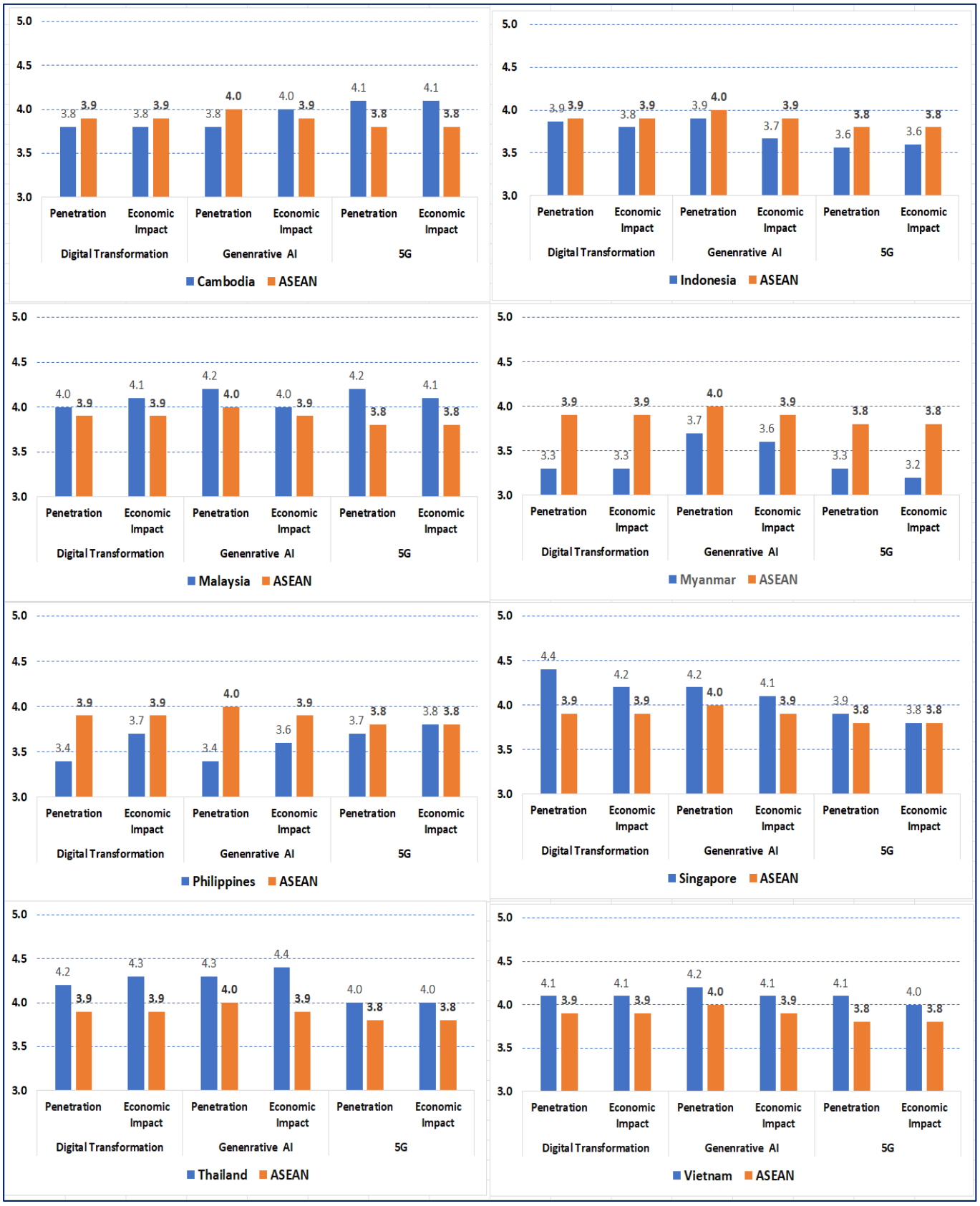
Expectations for 5G deployment, however, are more varied. Vietnam, Malaysia, and Thailand report above-average confidence (~4.1), while Singapore, despite its advanced telecom infrastructure, remains close to the ASEAN average (~4.0). Myanmar and the Philippines (~3.3–3.6) anticipate a slower rollout, reflecting deployment challenges. Vietnam's 'Smart Follower' strategy, which prioritizes timely adoption and rapid expansion, is particularly notable—having launched commercial 5G in October 2024, the country aims for over 99% coverage by 2030. These findings suggest that countries with strong telecom policies expect significant economic gains from 5G, while others face barriers to implementation.

Beyond individual technology trends, the Philippines presents a distinctive pattern: respondents expect a greater economic impact from DX, AI, and 5G than their penetration rates suggest. This indicates that the country could unlock substantial benefits by accelerating its digital adoption efforts. Conversely, Myanmar reports the lowest overall expectations, though scores remain above 3.0, indicating cautious optimism despite ongoing economic challenges.

Finally, a broader ASEAN-wide trend emerges—DX and AI generate stronger confidence in economic impact than 5G. While AI and digital transformation are seen as immediate growth drivers, 5G's full potential remains uncertain due to varying levels of network readiness and policy prioritization.

Overall, the findings reflect ASEAN's evolving digital landscape, where more advanced economies are leading in digital transformation (DX) and AI adoption, while expectations and progress around 5G remain uneven. As ASEAN Member States (AMS) continue to refine their digital strategies, addressing these disparities will be critical to ensuring an inclusive and transformative digital future for the region.

Figure 4.2: Survey Results on Expected DX, AI, and 5G Penetration and Economic Impact (2025–2030) – AMS vs. ASEAN Average



4.2.1. Perceived Importance of Key Ecosystem Players in 5G Development

Figure 4.3 presents survey results on respondents' perceptions of the key players driving 5G development in their countries. These include Technology Providers, Industry (CSPs), Government, Vendors, International/Regional Organizations, and Universities.

First, Technology Providers, Industry, and Government are perceived as the most influential players in 5G development across ASEAN, with regional average scores of 4.5, 4.5, and 4.4, respectively (on a scale of 1-5). This pattern is consistently observed across countries: Indonesia (4.7, 4.8, and 4.6), Thailand (4.7, 4.6, and 4.5), Malaysia and the Philippines (both scoring 4.6, 4.7, and 4.5), Vietnam (with 4.5 across all three stakeholders), and Singapore (4.2, 4.5, and 4.4).

This finding highlights the essential roles these three stakeholders play in driving 5G development. Technology Providers supply the innovations embedded in 5G products and services, CSPs develop and operate the necessary network infrastructure, and Government plays a crucial role in shaping the regulatory framework, allocating spectrum, and driving policy direction. Given their pivotal influence, effective collaboration among these stakeholders is essential, with governments ideally leading coordination efforts to ensure a harmonized approach to 5G deployment.

Second, universities and international or regional organizations are perceived as secondary contributors to 5G development, with ASEAN-wide average scores of 3.9 and 4.0, respectively. This trend is particularly evident in Singapore, Vietnam, the Philippines, and Indonesia, where their perceived importance scores range between 3.3 and 4.0. However, in Malaysia, Thailand, Myanmar, and Cambodia, their perceived importance exceeds 4.0, indicating a stronger role in these markets. This pattern likely reflects two underlying dynamics. In Malaysia and Thailand, universities are highly active in national digital strategies, engaging in applied research, public-private partnerships, and capacity-building programs that support 5G and emerging technologies. In contrast, in Myanmar and Cambodia—where government capacity, resources, and institutional coordination may be more limited—universities are seen as filling critical gaps by providing technical expertise, policy advocacy, and workforce development. As a result, universities in these countries are perceived as playing a more central role in shaping and supporting 5G-related initiatives.

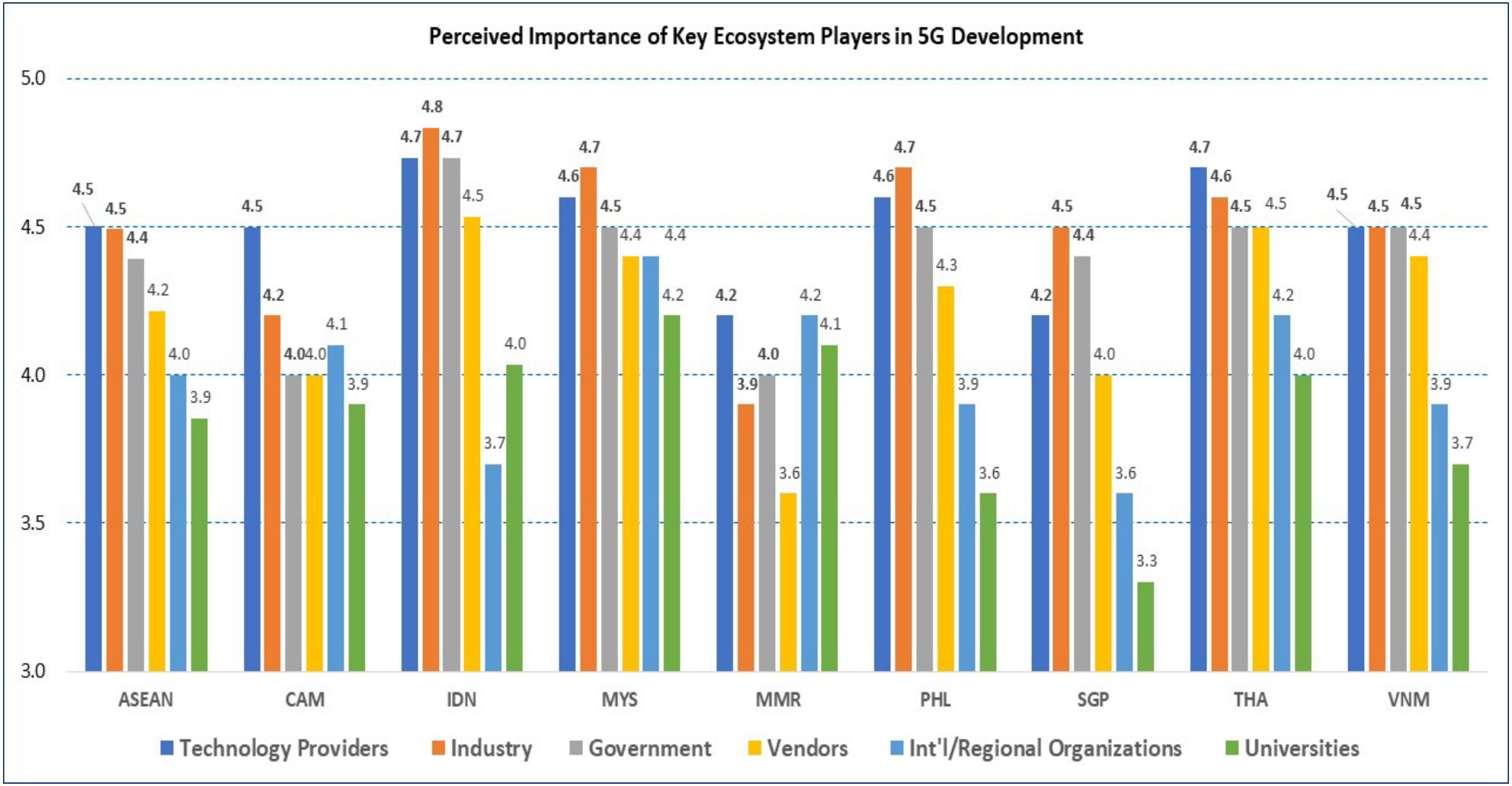
This suggests that while Universities and International/Regional Organizations are not yet recognized as primary drivers of 5G development, they hold significant potential, particularly in economies that have relied heavily on international assistance, such as Cambodia and Myanmar. Their involvement in research, policy advocacy, and cross-border collaboration can enhance knowledge sharing and capacity building, supporting the broader 5G ecosystem.

Third, Vendors are considered important but not as critical as Technology Providers, CSPs, or Government. Their perceived importance scores reach or exceed 4.0 in most ASEAN countries, including Indonesia, Thailand, Malaysia, Vietnam, the Philippines, and Singapore. While vendors play a key role in supplying 5G network equipment and infrastructure, their influence is still regarded as secondary.

This finding suggests that vendors could strengthen their role in 5G development by positioning themselves more strategically as technology providers and fostering closer collaborations with CSPs and government agencies. By doing so, they could contribute more effectively to the expansion and acceleration of 5G networks across ASEAN.

Overall, this analysis underscores the necessity of strong multi-stakeholder collaboration, where governments, industries, and technology providers take the lead while ensuring meaningful participation from universities, international organizations, and vendors to drive sustainable 5G development in the region.

Figure 4.3: Survey Results on the Role of Key Ecosystem Players in 5G Development – AMS vs. ASEAN Average



4.3. Key Insights from Expert and Stakeholder Interviews

This subsection presents key findings from in-depth interviews with stakeholders across selected ASEAN countries, including Vietnam, Singapore, Indonesia, Malaysia, and Thailand. Guided by a structured questionnaire comprising 13 questions provided in Appendix 3, these interviews offer valuable insights into strategic choices and key Insights on the critical factors shaping 5G development.

4.3.1. Four insights on strategic choices

Insight #1: In 5G deployment, adopting a 'smart follower' strategy may be a more viable option for developing countries, as indicated by interviews with senior government officials and telecom executives in Vietnam.

The interviewees supported this perspective with several key arguments. First, it significantly reduces equipment costs. Due to rapid technological advancements and economies of scale, smart followers benefit from declining investment costs in technical infrastructure, especially base stations, antennas. For instance, the unit cost of a typical base transceiver station (BTS) has sharply declined, dropping from over $100,000 in early 2020 to less than $25,000 by late 2024. Furthermore, In early deployments, 5G equipment was highly specialized and costly. Over time, technologies like Open RAN (O-RAN) have reduced hardware costs for late adopters.

Second, smart followers can mitigate risks in 5G deployment by avoiding the challenges and uncertainties faced by pioneers. By learning from early adopters, they can steer clear of potential failures related to untested technologies, regulatory hurdles, and market education challenges. Additionally, they can rapidly adopt best practices, minimizing costly mistakes and optimizing deployment efficiency.

Third, the development of end-user devices takes time to fully align with 5G. This process involves not only the maturation of the manufacturing ecosystem to ensure both performance and affordability but also the availability of 5G-enabled applications on these devices.

Throughout our interviews with key stakeholders in Vietnam’s 5G ecosystem—including senior government officials, regulators, and communication service providers (CSPs)—there was a clear consensus that it is no longer the time to pursue a fast-follower strategy. Instead, Vietnam is setting ambitious targets for 5G network expansion as a central pillar of its digital transformation agenda. By 2025, the country

aims to achieve 5G coverage across all cities, provinces, high-tech zones, R&D centers, industrial parks, transport hubs, ports, and international airports.

Looking ahead to 2030, Vietnam aims to extend 5G coverage to over 99% of its population, with projections exceeding 90 million 5G connections by that time. Since early 2025, the government has actively promoted 5G infrastructure development through targeted incentives designed to accelerate deployment by telecom operators. For instance, companies that establish at least 20,000 operational 5G base stations by the end of 2025 are eligible for subsidies covering 15% of equipment costs. These initiatives underscore Vietnam's ambition to become a regional leader in 5G adoption, laying the foundation for a dynamic digital economy and enhancing its appeal to foreign investors in the telecommunications sector.

Insight #2: 5G is set to transform enterprises, much like how 4G revolutionized consumer markets. This suggests that enterprises should be the primary focus of 5G deployment for operators to achieve meaningful, large-scale success. This insight is based on interviews with a major telecom vendor, as well as multiple experts and business leaders in ASEAN.

Interviewees provide the following arguments for this insight.

First, unlike 4G, which primarily enhanced consumer experiences through faster mobile internet, 5G is built for ultra-reliable, low-latency, and high-capacity applications. These capabilities unlock mission-critical use cases in industries such as manufacturing, healthcare, logistics, and smart cities—where automation, real-time data processing, and advanced connectivity drive efficiency and innovation. Additionally, 5G serves as the backbone for Industry 4.0, enabling AI-driven automation, robotics, real-time monitoring, and edge computing. These technologies optimize production, improve supply chains, and support autonomous operations, making 5G an essential driver of industrial transformation.

Second, enterprises provide a stronger business case than consumers. The consumer 5G market is price-sensitive, with adoption limited by incremental speed improvements and high device costs. In contrast, enterprises view 5G as a strategic necessity to enhance automation, reduce costs, and gain a competitive edge in an increasingly digital global economy. Sectors such as manufacturing, logistics, and healthcare have clear and immediate 5G use cases—such as private networks, predictive

maintenance, and smart infrastructure—which ensure a more predictable and scalable deployment path. This makes enterprise adoption a more sustainable and profitable strategy for telecom operators, delivering faster return on investment.

Third, a key lesson from 4G's consumer-centric growth is the pivotal role of killer apps—such as video streaming and social media—that fundamentally reshaped consumer behaviour. Similarly, for 5G to achieve widespread adoption, operators, governments, and other stakeholders must focus on delivering high-impact solutions that transform industries and business operations. Beyond automation, 5G will enable large-scale IoT deployment, real-time monitoring, and AI-powered decision-making—enhancing industrial efficiency, unlocking new revenue streams, driving economic growth, and strengthening global competitiveness.

Highlighting this lesson, a business leader in Singapore noted that his logistics company is eager to adopt 5G but seeks a plug-and-play model that would simplify integration and reduce risk. This reflects a broader industry need for accessible, ready-to-deploy 5G solutions that accelerate adoption and maximize business value.

Insight #3: A strong foundation in digital transformation is essential for a country to fully harness the benefits of 5G deployment and adoption. For resource-constrained countries, prioritizing digital transformation across sectors—alongside deliberate efforts to promote 5G development—could be a more efficient and effective strategy. This insight is drawn from the interviews with policymakers, experts, and business leaders in Indonesia, Singapore, and Vietnam.

There are several key arguments supporting this insight.

First, 5G requires a digitally ready ecosystem. Without robust IT infrastructure, cloud adoption, and digital business models, 5G risks becoming an underutilized investment. Industries such as manufacturing, healthcare, logistics, and agriculture can only unlock 5G's full potential when integrated with automation, IoT, and AI-driven solutions. Businesses—especially SMEs—must first develop digital capabilities before effectively leveraging 5G-powered technologies.

Second, prioritizing digital transformation maximizes impact in resource-constrained countries by directing limited resources toward building foundational capabilities and delivering immediate value. Investing in digital skills training, enterprise IT adoption, and cloud infrastructure ensures industries are prepared to leverage 5G effectively,

turning deployment into tangible economic benefits rather than costly, underutilized infrastructure. In contrast, premature 5G rollout—without industry and institutional readiness—risks low adoption and wasted investment.

Third, prioritizing digital transformation enables a phased, cost-effective approach to 5G deployment. Strengthening DX first reduces investment risks by maximizing existing technologies such as 4G, FTTH, and cloud-based solutions. This allows countries to gradually upgrade infrastructure while ensuring industries are digitally mature and ready to transition seamlessly to 5G when the ecosystem is fully prepared.

Finally, a DX-first approach ensures that 5G adoption is purpose-driven and aligned with national priorities and strategic goals, particularly in economic growth, productivity, and sustainability. A strong digital foundation allows time to develop country-specific 5G applications in key sectors such as manufacturing, education, healthcare, smart cities, and agriculture. This ensures that when 5G is deployed, there is clear demand, well-defined use cases, and a meaningful impact across industries.

Insight #4: ASEAN's geopolitical neutrality uniquely positions the region as a rising manufacturing hub for 5G and 6G technologies. This perspective emerged from expert insights gathered in Indonesia, Vietnam, and Malaysia. Below are their key arguments.

First, ASEAN's geopolitical neutrality stands out as a strategic asset amid intensifying U.S.-China tensions, evolving trade dynamics, and global supply chain realignments. As major tech firms seek to reduce overreliance on any single country, ASEAN offers a stable and non-aligned environment for high-tech manufacturing. Coupled with cost competitiveness and a favourable geographic location, the region is increasingly viewed as a viable, neutral ground for telecom manufacturing—particularly in next-generation infrastructure such as 5G and the forthcoming 6G.

Second, ASEAN's existing industrial and export-oriented strengths, together with its neutral geopolitical approach, offer the region a unique potential to become a strategically located, politically neutral, and cost-competitive hub for both manufacturing and services in the telecom sector. Particularly, ASEAN nations like Vietnam, Malaysia, and Thailand already serve as critical players in the existing global electronics and telecom supply chain. This will enable them to rapidly develop capabilities to become key contributors to the global telecom infrastructure supply chain. More specifically,

- Vietnam with increasing investments from global tech giants like Foxconn, Pegatron, and Intel make Vietnam a rising hub for telecom equipment manufacturing. Ericsson has already established a 5G Innovation Hub in Vietnam, supporting the local ecosystem.
- Malaysia has a strong semiconductor industry with key players like Broadcom and Infineon, making it a strategic hub for telecom component manufacturing.
- Thailand & Indonesia benefit from expanding telecom infrastructure with a special focus on 5G, making them attractive for 5G & 6G-related investments

Third, beyond manufacturing, ASEAN is emerging as a leader in 5G-driven enterprise solutions, cloud computing, and AI services. Major cloud providers like AWS, Google Cloud, and Microsoft Azure are investing billions of dollars in data centers in Malaysia and Thailand to support AI-powered and 5G-enabled industries as these countries emerge as data center hubs. Additionally, countries like Singapore and Malaysia are advancing telecom R&D, collaborating with universities and global firms on 6G network development.

Regarding AI, governments across ASEAN have recently made significant investments to advance artificial intelligence (AI) initiatives, recognizing AI's potential to drive economic growth and innovation.

Here are some notable developments illustrating Insight #4:

Malaysia:

- Chip Design Investment: In March 2025, Malaysia announced a $250 million agreement with Arm Holdings to acquire chip design blueprints over ten years. This initiative aims to produce indigenous chips within the next decade, addressing the growing demand for AI and data centers. The deal includes training for 10,000 engineers and the development of local chip companies, each projected to generate $1.5 to $2 billion annually.
- Data Center Expansion: Malaysia is investing heavily in data centers, particularly in Johor province, which is emerging as Southeast Asia's fastest-growing data center market. This strategy seeks to modernize the economy and create job opportunities, although concerns have been raised about the environmental impact and resource consumption associated with these facilities.

Indonesia:

- Sovereign Wealth Fund for AI: In February 2025, Indonesia established Danantara Indonesia, a new sovereign wealth fund with an initial investment of $20 billion. The fund is set to finance projects in metal processing, AI development, renewable energy, and food production, aiming to boost economic growth from 5% to 8%.

Singapore:

- Economic Zone Collaboration: In January 2025, Singapore and Malaysia officially launched the Johor-Singapore Special Economic Zone (JSSEZ), inspired by China’s Shenzhen SEZ. Designed to attract investment in high-growth sectors like artificial intelligence and advanced technology manufacturing, the initiative is projected to generate up to $26 billion annually for Malaysia’s economy by 2030 and create 20,000 skilled jobs.

Thailand:

- Digital Economy Promotion: Thailand's Digital Economy Promotion Agency (DEPA) is actively supporting AI development. In January 2025, DEPA outlined plans to position Thailand as a global technology and supply chain hub, focusing on promoting digital talent and job creation through tax incentives and initiatives like the Thailand Digital Catalog, which compiles digital services and products for public and private sectors.

Regional Initiatives:

- ASEAN AI Governance: ASEAN has launched initiatives such as the ASEAN Guideline on AI Governance and Ethics and established the ASEAN Working Group on AI (WG-AI) to promote collaborative efforts and ethical AI use across member states. These efforts aim to create a cohesive framework for AI development and deployment in the region.

These investments and initiatives underscore ASEAN countries' strategic efforts to leverage their geopolitical neutrality in fostering AI development, positioning the region as an emerging hub in the global AI landscape.

4.3.2. 10 insights on the critical factors shaping 5G development

Insight #1: Advancing AI-Driven 5G Development Requires a Holistic, Coordinated Policy Framework

The effective promotion of AI-driven 5G development demands a comprehensive and well-orchestrated policy approach that addresses key factors across four core pillars: (i) essential infrastructure; (ii) economic viability and market demand; (iii) user and enterprise readiness, and (iv) an enabling environment.

Interviewees emphasized that a comprehensive, well-coordinated approach is essential to advancing meaningful and effective 5G development. As outlined in Table 4.3, the key factors across the four foundational pillars collectively shape a country's capacity to deploy, adopt, and scale 5G in synergy with artificial intelligence (AI). While still in its early stages, AI is rapidly emerging as a game-changing force—accelerating 5G innovation, enhancing network performance, and unlocking new value across sectors.

Interviewees emphasized that expanding and upgrading digital infrastructure, including spectrum availability, fiber-optic backbones, and edge computing capabilities, is foundational to enabling real-time AI applications and seamless 5G connectivity.

Economic viability and market alignment are equally crucial. For CSPs, enterprises, and consumers to invest in 5G-AI adoption, the benefits—ranging from efficiency gains to new business opportunities—must clearly outweigh associated costs. This requires robust investment strategies, compelling AI-integrated use cases, and scalable monetization models.

On the readiness front, closing digital and AI literacy gaps, improving access to affordable 5G-AI devices, and supporting SMEs and startups in adopting intelligent technologies are critical for inclusive growth and industry transformation.

A supportive enabling environment—anchored in agile regulation, cross-sector partnerships, and AI-responsive governance—is essential for accelerating

deployment. Regulatory clarity, cybersecurity frameworks, and AI ethics safeguards will help de-risk investment and foster trust.

In sum, a strategic, phased, and coordinated national approach that integrates infrastructure, economic logic, user readiness, and governance—with AI as a cross-cutting enabler—will be vital to realizing the full socioeconomic potential of 5G. This approach will position ASEAN countries to lead in the next wave of inclusive, AI-powered digital transformation.

Table 4.3: Key Factors Shaping 5G-AI Development

Core Pillar	Key Factors
(i) Essential Infrastructure	• Spectrum Availability and Allocation (including for AI-intensive applications) • Fiber-Optic Backbone to support AI-enabled data transfer at scale • Small-Cell Deployment to support dense, AI-enabled urban networks • **Edge Computing Infrastructure for AI inference and real-time decision-making** • Rural and Remote Connectivity for inclusive AI-enabled services (e.g., smart agriculture) • **AI-assisted Network Planning and Optimization** to improve efficiency of infrastructure rollouts
(ii) Economic viability and market demand	• Capital Expenditure (CapEx) and OpEx for 5G-AI infrastructure • Return on Investment (ROI) from AI-driven services (e.g., predictive maintenance, AI analytics) • Affordability of 5G-AI solutions for enterprises and consumers • Network Sharing and Cost Optimization using AI for dynamic resource allocation • High Spectrum Acquisition Costs and associated risks For CSPs: • Costs: AI platform integration, edge/cloud upgrades, compliance • Benefits: New AI service verticals (e.g., AI-as-a-service), enhanced monetization through analytics For Enterprises: • Costs: AI adoption and workforce training • Benefits: Enhanced automation, intelligent operations, personalized customer experiences For Consumers: • Costs: Access to AI-enabled apps and services • Benefits: AI-powered mobile experiences, smart farming, health diagnostics, personalized education
(iii) User and Enterprise Readiness	• Availability of 5G-Compatible and AI-Capable Devices (e.g., smart sensors, wearables) • Digital and AI Literacy among consumers and the workforce • Enterprise Demand for AI-powered 5G Applications • SME and Startup Integration in 5G-AI value chains • Consumer Willingness to Adopt AI-enabled Services (e.g., voice assistants, smart mobility) • Readiness of AI platforms, data infrastructure, and edge AI integration within businesses
(iv) Enabling Environment	• Regulatory Framework and Spectrum Policy including AI ethics and accountability • Government Incentives and Public-Private Partnerships for 5G-AI innovation hubs • Cybersecurity and AI-Specific Data Protection Protocols (e.g., bias mitigation, algorithmic transparency) • Standardization of AI and 5G protocols, interoperability, and data sharing • Infrastructure Deployment Regulations inclusive of AI-powered monitoring and compliance tools • National AI strategies aligned with 5G roadmaps for coordinated tech advancement

Insight #2: Government Leadership, Strategic Support, and Governance Are Crucial for 5G Development

Countries like Thailand and Singapore illustrate how a clear national 5G roadmap and high-level coordination accelerate deployment. Thailand established a 5G Steering Committee, chaired by the Prime Minister, to ensure alignment across ministries and industry stakeholders. In Singapore, the Infocomm Media Development Authority (IMDA) played a pivotal role in shaping regulations and providing financial incentives for 5G trials. Additionally, other government agencies, such as the Land Transport Authority (LTA), have supported new applications, including self-driving vehicle trials for logistics.

Vietnamese interviewees emphasized the importance of legal and regulatory reforms to facilitate 5G deployment. For example, the Law on Telecommunications No. 24/2023/QH15, enacted on November 24, 2023, and effective July 1, 2024, mandates telecommunications infrastructure sharing—including base transceiver station (BTS) sites—among service providers. This reform addresses a major challenge for CSPs, aiming to optimize resources, minimize environmental impact, lower operational costs, and enhance service quality.

In Indonesia, interviewees highlighted governance challenges, including fragmented oversight, slow spectrum auctions, and regulatory bottlenecks, which have delayed 5G deployment. These issues underscore the need for a cohesive national strategy to accelerate and streamline the rollout.

Insight #3: Spectrum policy is critical to 5G development, with well-designed auction mechanisms and targeted incentives proving to be the most effective approach.

A well-defined spectrum policy is a cornerstone of successful 5G deployment, influencing network expansion, service quality, and the overall competitiveness of a country's digital economy. Key factors such as spectrum availability, allocation strategy, pricing mechanisms, and governance determine how effectively operators can roll out 5G services.

Thailand conducted a transparent spectrum auction in 2020, raising USD 3.2 billion and allocating multiple frequency bands, including 700 MHz, 2600 MHz, and 26 GHz. Although the high spectrum prices caused some concerns, stakeholders

acknowledged that the auction ensured fair market competition and attracted significant operator investments.

Malaysia initially adopted a Single Wholesale Network (SWN) model under Digital Nasional Berhad (DNB), which limited competition but ensured nationwide coverage. However, this approach met resistance from private operators. In response, Malaysia recently transitioned toward a dual-network model in 2024, balancing competition and efficiency.

In Indonesia, the uncertain spectrum allocation model—debating between an auction and a beauty contest—has slowed investment. As a result, the limited availability of dedicated 5G spectrum has delayed 5G deployment. An industry executive noted: *"Until now, the implementation of 5G is still limited to existing frequencies like 1800 MHz, 2100 MHz, and 2300 MHz, which are also used for 4G. This has resulted in a less extensive 5G rollout. Additionally, high regulatory costs for operators have made them hesitant to invest in 5G deployment. In the future, we hope the release of mid-band frequencies like 2.6 GHz and 3.5GHz, along with incentive policies such as spectrum fee reductions and flexible payment schemes, will accelerate 5G development in Indonesia."*

Regarding the spectrum allocation model, he expressed a clear preference for auctions over Calls for Proposal (CFPs), commonly referred to as 'beauty contests.' He explained:

> *"In beauty contests, telecom operators submit proposals that are evaluated based on a weighted scoring of technical and financial criteria. However, the technical evaluation can be highly subjective. In Indonesia, the market is dominated by a few large operators with extensive networks and infrastructure, giving them a clear advantage in such evaluations. This makes it difficult for new entrants to compete fairly. The playing field remains uneven, and beauty contests further disadvantage emerging players in securing access to spectrum or projects."*

In Vietnam, which conducted its first successful spectrum auction in over 15 years, there has been a strategic shift in how spectrum is assigned. This auction was essential for 5G commercialization and long-term digital infrastructure development. Notably, the auctions were transparent, fair, and competitive.

The auctioned bands were:

- 2500-2600 MHz (B1) – Suitable for both 4G and 5G.
- 3700-3800 MHz (C2) and 3800-3900 MHz (C3) – Exclusively for 5G.

Each CSP (Communications Service Provider) could bid for only one 100 MHz block (B1, C2, or C3). The licenses are valid for 15 years, with a minimum deployment obligation of deploying at least 3,000 BTS within two years.

The auction results, as shown in Table 4.4 below, establish a solid foundation for Vietnam to make rapid advancements in 5G developments in 2025, with the aim to achieve 99% population coverage by 2030.

Table 4.4 Auction Results of 5G Band Auctions in Vietnam.

Band	Auction Date	Winning Operator		
			Winning Bid (VND Billion)	Approx. USD (Million)
B1 (2500-2600 MHz)	Mar-24	Viettel	7,533	300
C2 (3700-3800 MHz)	Mar-24	VNPT	2,581	103
C3 (3800-3900 MHz)	Jul-24	MobiFone	2,581	103

A key observation from Vietnam is that its communication service providers (CSPs) have shown a clear preference for lower mid-bands—specifically B1—over higher mid-bands such as C2 and C3. This preference is driven by two main factors: (i) **lower investment costs**, as B1 requires fewer base transceiver stations (BTS) per square kilometer compared to higher bands, and (ii) **strategic reliance on existing 4G infrastructure**, with B1 offering a smoother and more cost-effective integration into legacy networks. This approach reflects Vietnam's phased strategy for 5G deployment, prioritizing broad, cost-efficient coverage before transitioning to higher-capacity, high-frequency networks.

In contrast, countries with more advanced 5G ambitions—such as Switzerland—prioritize higher mid-bands like C2 and C3 to support ultra-fast, low-latency applications. Within ASEAN, Singapore has taken a forward-leaning stance by allocating spectrum across both the 3.5 GHz and mmWave bands (26 GHz and 28

GHz), enabling the delivery of ultra-fast 5G in high-demand zones such as business districts and industrial hubs.

Looking ahead to 2025–2030, the mmWave bands will be pivotal in unlocking the full promise of 5G. These high-frequency bands offer significantly greater bandwidth than sub-6 GHz alternatives, making them ideal for supporting massive IoT deployments and data-intensive use cases like real-time automation, smart manufacturing, and augmented or virtual reality. In dense urban and industrial environments, where demand for high-capacity, low-latency connectivity is highest, mmWave can deliver the performance needed to drive digital transformation. For ASEAN economies aiming to develop smart cities and next-generation industries, the strategic allocation and deployment of mmWave spectrum will be critical.

Insight #4: Industry-Specific 5G-AI Applications Show Promise Despite Significant Challenges

The monetization of 5G-AI should be more strategically focused on enterprises, where industry-specific applications demonstrate tangible benefits. While early-stage pilots highlight 5G-AI's potential in smart cities, industrial automation, logistics, healthcare, and agriculture, achieving scalability, regulatory alignment, and sustainable revenue models remain a challenge. Furthermore, ASEAN enterprises are closely observing proven 5G-AI use cases from global businesses to guide their adoption strategies.

An Indonesian interviewee highlighted the importance of global companies in driving 5G adoption, stating: "*5G implementation in Indonesia will largely depend on use cases introduced by global manufacturers setting up operations here. For instance, an electronics manufacturer in Batam is leveraging IoT and 5G for smart warehousing. Similar trends are emerging across industries—whether in manufacturing, mobile phones, or oil and gas. If global operations integrate 5G, they will likely bring the technology to Indonesia as well. To enable this, we need assurance in connectivity, security, and data protection. However, I am confident that as the market matures, 5G adoption will naturally accelerate.*"

At the same time, several notable 5G use cases are already being explored across ASEAN, demonstrating the transformative impact of 5G across industries.

<u>Smart Cities & Communities</u>

- Singapore:

- Under its Smart Nation Initiative, AI-driven traffic control and surveillance systems powered by 5G are reducing congestion and improving urban security.
- With support from IMDA, Weston Robot has deployed 5G-enabled electric autonomous surface vessels for river cleaning and inspection using real-time video analytics. Remotely operated via 5G connectivity, these unmanned vessels significantly enhance operational efficiency, reduce dependence on manual labour, and lower carbon emissions by up to 80%

- Malaysia: The Kuala Lumpur Smart City Blueprint includes 5G-powered AI traffic monitoring and predictive crime analytics in Johor Bahru and Penang.
- Thailand: 5G-AI flood early warning systems integrate real-time IoT sensor data in disaster-prone regions to enhance emergency response.

<u>Industrial Automation</u>

- Singapore:
  - Smart Factory: The Hyundai Motor Group Innovation Center Singapore (HMGICS) leverages 5G-AI and advanced automation to revolutionize EV manufacturing. Partnering with Singtel, it employs a private 5G network for real-time data, digital twin simulations, and quality control. A cell-based production system replaces traditional conveyor belts, enhancing flexibility with AI and robotics. HMGICS also offers customizable EV options and VR factory tours, setting a new standard for smart manufacturing and Industry 4.0.
  - Jurong Innovation District (JID) serves as a 5G-powered smart factory testbed, deploying AI-driven robotics and IoT sensors in semiconductor manufacturing.
- Malaysia: Penang Electronics Hub integrates 5G-AI for predictive maintenance, automation, and supply chain tracking, benefiting companies like Intel and Infineon.
- Thailand: In the Eastern Economic Corridor (EEC), 5G-enabled robotics and AI-based inspections are optimizing Toyota’s automotive production.

- Vietnam's industrial zones are using 5G-powered IoT sensors for predictive machine maintenance.
- Viettel deployed 5G private networks in Samsung’s factories to support robotic automation in Bac Ninh.

Healthcare & Telemedicine

- Singapore:
    - Maritime Telemedicine Services: M1 Limited, in collaboration with Fullerton Health, has introduced 5G-enabled telemedicine services tailored for the maritime sector. This initiative facilitates live teleconsultations between seafarers aboard vessels and shore-based healthcare professionals. Additionally, 5G-powered drones are employed to deliver medications directly from shore to ship crews, ensuring timely medical support even while at sea.
    - 5G-Enabled Medical Booths ("Medbots"): Republic Power, under the auspices of IMDA 5G Innovation Programme, has deployed unmanned medical booths equipped with 5G connectivity. These "Medbots" support remote health screenings and facilitate video consultations, offering enhanced user experiences. They represent Asia's first 5G-enabled unmanned pre-screening and teleconsultation medical booths, featuring advanced hygiene and safety systems.
    - Mixed Reality-Based Holomedicine: The National University Health System (NUHS) has leveraged 5G technology to implement Mixed Reality-based Holomedicine in operating theatres. This application enhances patient care by providing surgeons with augmented reality visualizations during procedures, leading to improved surgical outcomes and redefining the healthcare experience.
- Thailand: Siriraj 5G Smart Hospital utilizes robotic-assisted surgeries, AI diagnostics, and remote patient monitoring to improve healthcare accessibility.
- Malaysia: The National Heart Institute (IJN) has implemented 5G-supported AI imaging, accelerating cardiovascular diagnostics.

Logistics & Supply Chain

- Singapore: Advancing Autonomous Vehicle Trials for Logistics - The Land Transport Authority (LTA) is collaborating with businesses to trial self-driving vehicles for goods transportation on public roads. Additionally, IMDA is exploring the possibility of permitting driverless trucks to operate at night (12:00 AM – 5:00 AM). This initiative aims to enhance logistics efficiency, address labor shortages, and reduce traffic accidents by leveraging off-peak hours for safer and more efficient transportation.
    - In October 2024, FairPrice announced it had successfully passed the first milestone in the "AV Milestone Testing Regime", a safety assessment process for autonomous vehicles. The regime consists of three stages that must be completed before public road deployment, which are (i) Simulation tests; (ii) Closed-course testing; and (iii) On-road testing to ensure safety and regulatory compliance.
    - An executive from a major logistics company in Singapore voiced strong support for government plan to experiment on self-driving trucks for nighttime container transport between ports and warehouses. This solution is highly anticipated, as Singapore—one of the busiest ports globally—faces a severe truck driver shortage. Additionally, nighttime driving has a lower safety record compared to daytime operations, making autonomous trucks a safer and more efficient alternative.
- Indonesia: In March 2024, Telkomsel and Huawei launched Indonesia's first 5G Smart Warehouse and 5G Innovation Centre in Bekasi Regency, West Java.
    - This facility showcases IoT, big data analytics, and AI-driven automation for enhanced operational efficiency.
    - Features include digital twins for real-time inventory management, autonomous guided vehicles (AGVs), and intelligent security systems using video and infrared sensors.
    - The initiative aligns with Indonesia's Golden Vision 2045, emphasizing digital transformation in logistics.

<u>Smart Agriculture & Rural Connectivity</u>

- Thailand: 5G-powered smart farms in Chiang Rai and Nakhon Ratchasima employ IoT sensors and AI-driven irrigation to optimize water use and crop yield.
- Malaysia: Farms in Sabah and Sarawak utilize 5G drones for crop monitoring and automated pesticide application, reducing labor costs and improving efficiency.

Maritime & Port Operations

- Singapore:
    - Port Operations Automation: A 5G mmWave trial in collaboration with PSA, Singtel, and M1 demonstrated 50% latency reduction, enabling the scaling of Automated Guided Vehicles (AGVs) and Rubber Tire Gantry cranes (aRTG) at Tuas Mega Port.
- Malaysia: The Port Klang Smart Logistics Project integrates 5G IoT tracking and AI analytics to reduce customs processing times.
- Thailand: Laem Chabang Port is piloting real-time AI navigation for ship docking and supply chain optimization.

Despite early successes, industry-specific 5G applications remain in the experimental phase, requiring scalability, regulatory alignment, and sustainable monetization models to achieve long-term impact.

Insight #5: Fixed Wireless Access (FWA) is becoming a compelling solution across ASEAN countries to provide high-speed internet, particularly in areas where traditional fibre infrastructure is limited.

In Thailand, Advanced Info Service (AIS) has rapidly expanded its 5G FWA services, achieving over 80% population coverage. Major cities such as Bangkok and Chiang Mai have benefited from this rapid rollout, which facilitates widespread access to high-speed internet and supports economic growth through digital transformation across various sectors. Similarly, Malaysia's Telekom Malaysia (TM) offers Unifi Air, a service targeting areas without fibre infrastructure. The quick deployment of high-speed internet and affordability of this service have improved accessibility and provided a cost-effective alternative to traditional broadband, particularly in underserved regions.

In Indonesia, Indosat Ooredoo Hutchison (IOH), in collaboration with Nokia, is deploying FWA as part of its 4G and 5G network expansion across both urban and rural areas. This initiative improves connectivity for millions, particularly in underserved communities, while supporting economic development and fostering digital inclusion.

In the Philippines, Globe Telecom has launched 5G FWA services in key urban areas, including Metro Manila, Cebu, and Davao. Globe's efforts have significantly improved access to high-speed internet, strengthened digital inclusion, and positioned the company as a regional leader in FWA services.

These FWA deployments across ASEAN demonstrate how 5G technology is being leveraged to bridge the digital divide, provide fast and reliable connectivity, and drive digital transformation in both urban and remote areas, ultimately supporting economic growth and promoting greater access to digital services across the region.

Insight #6: Until 5G killer use cases emerge, monetizing 5G for individual consumers remains a significant challenge.

Until killer 5G use cases emerge, monetizing 5G for individual consumers remains a significant challenge. Unlike 4G, which rapidly drove revenue through mobile broadband, video streaming, and app-based services, 5G lacks an immediate, compelling use case that justifies premium pricing. Most users perceive only marginal improvements in their daily mobile experience, making it difficult for CSPs to charge higher fees.

Compounding this challenge is the widespread adoption of Fiber-to-the-Home (FTTH), which directly competes with 5G for high-speed connectivity. FTTH offers stable gigabit speeds comparable to 5G, but with consistent performance and fewer limitations—unlike 5G, which is affected by obstacles like walls, weather, and network congestion. In regions with strong FTTH penetration, consumers and enterprises see little incentive to switch to 5G for fixed broadband, as FTTH already meets their needs for video streaming, gaming, and remote work.

From a cost perspective, FTTH is also more economical for consumers over time. Fixed broadband plans typically offer unlimited data at lower costs, whereas 5G plans often come with premium pricing or data caps, further reducing its appeal as a home internet alternative.

In Vietnam, where 20 million households have FTTH connectivity, this challenge is particularly pronounced. As noted by a senior executive of a major CSP, his company's FTTH revenue is growing and has already surpassed mobile service revenue, which is in decline. This underscores a broader trend—without breakthrough applications, 5G struggles to differentiate itself in markets where fiber is already fulfilling consumer and enterprise needs.

However, some interviewees anticipate that AI-powered 5G applications could drive adoption. Potential killer apps include AI-driven agricultural advisory services, where farmers can receive tailored recommendations by uploading photos of their crops via mobile devices. Another promising use case is real-time AI-powered translation, allowing users to seamlessly communicate with foreigners in their native language through automatic translation apps on 5G-enabled smartphones. If such applications gain traction, they could help unlock new consumer demand and monetization opportunities for 5G.

Insight #7: Bridging the Digital Divide to Drive 5G Adoption

In many developing markets, the digital divide remains a critical barrier to 5G adoption. However, countries like Thailand and Vietnam offer valuable models for overcoming affordability and accessibility constraints through policy-driven, people-centered strategies.

Thailand's success in driving mass 5G adoption was no accident. Recognizing that cost and public perception were major hurdles, the Thai government led coordinated efforts with telecom operators and device manufacturers to make 5G both affordable and relevant. Subsidized smartphone financing was introduced through 0% interest installment plans, device trade-ins, and entry-level 5G smartphones, bringing the technology within reach for students, low-income workers, and rural populations.

Yet affordability alone wasn't enough. Many consumers viewed 5G as a luxury, not a necessity. To shift this mindset, the government launched nationwide awareness campaigns, showcasing real-world applications in smart cities, healthcare, and digital agriculture. Public demonstrations, rural workshops, and targeted media campaigns helped communities understand how 5G could enhance education, e-commerce, and connectivity.

Simultaneously, Thailand prioritized infrastructure expansion in underserved areas. Public–private partnerships (PPPs) accelerated base station deployment, while regulatory incentives ensured affordable 5G service packages in rural regions. Partnerships with universities enabled 5G-powered smart classrooms, further bridging the digital education gap. These comprehensive efforts helped Thailand emerge as one of Southeast Asia's 5G frontrunners.

While Thailand emphasized 5G adoption, Vietnam pursued a complementary strategy: a phased transition from 2G to 4G as a foundation for 5G readiness. In 2022, the government set a firm deadline to shut down 2G by September 2024, enabling spectrum reallocation and pushing users toward mobile broadband.

To support low-income users during this transition, telecom providers launched extensive device upgrade programs. Viettel committed VND 300 billion (USD 12.2 million) to provide subsidized 4G smartphones to 700,000 people, while MobiFone and VinaPhone offered trade-in deals, free SIM exchanges, and bundled incentives. Partnerships with major retailers like The Gioi Di Dong (Mobile World) and FPT Shop further improved access through discounts and installment plans, reducing the financial burden on users.

Vietnam's approach reflects a strategic, policy-led digital transition. By combining infrastructure development, affordability measures, and user education, Vietnam laid a strong foundation for rapid 5G uptake. Just as it successfully migrated millions from 2G, Vietnam can replicate this momentum to broaden 5G adoption—especially if it adopts Thailand's integrated approach to public awareness and localized innovation.

Together, the experiences of Thailand and Vietnam underscore a key lesson: 5G adoption in developing economies requires more than network rollout—it demands inclusive policy design, affordability solutions, and grassroots engagement.

Insight #8: Global Collaborations Are Key to Accelerating 5G Deployment and Innovation in ASEAN

Global partnerships are crucial for accelerating 5G deployment and building a sustainable, innovation-driven ecosystem. ASEAN nations have actively engaged with leading tech providers, telecom giants, and infrastructure companies to foster technology transfer, drive innovation, and attract investment in critical 5G applications.

In Singapore, the government and communication service providers (CSPs) have positioned the city-state as a regional hub for 5G innovation by collaborating with global technology leaders. IBM and the government are working on AI-powered cybersecurity solutions for 5G networks. Singtel and Ericsson are advancing 5G standalone (SA) networks, testing applications in smart ports and autonomous transport. Meanwhile, Huawei is providing smart city infrastructure, and NEC is leading a 5G Open RAN pilot, promoting vendor diversity and innovation.

In Thailand, the government and CSPs are leveraging partnerships with global telecom vendors and cloud providers to accelerate industry-focused 5G adoption. AIS has teamed up with Huawei and Ericsson to expand 5G infrastructure in Bangkok and industrial zones. AWS supports cloud-based 5G applications, including IoT for precision farming and AI-driven supply chains. True Corporation and ZTE are piloting 5G smart hospitals, enabling remote surgery and AI-assisted diagnostics.

In Malaysia, the government, with Ericsson's support, has embraced a wholesale 5G model to provide affordable, nationwide 5G access for businesses and consumers. The Digital Nasional Berhad (DNB) initiative awarded Ericsson a USD 2.6 billion contract to develop and manage the country's single wholesale 5G network, improving cost efficiency for private operators.

In Indonesia, a multi-sector approach to 5G partnerships is driving innovation in smart cities, agriculture, and financial services. Indosat Ooredoo has partnered with Cisco and Qualcomm to develop 5G applications for smart agriculture and logistics. Telkomsel and Nokia are deploying 5G in Jakarta and industrial hubs, while Telkom Indonesia and Google Cloud are exploring 5G-powered edge computing for e-commerce and fintech. Huawei is providing 5G solutions for mining, logistics, and energy companies.

In Vietnam, international partnerships are key to localizing 5G technology and accelerating network expansion. Viettel has partnered with Qualcomm to develop Vietnam's first domestically produced 5G chipset, reducing reliance on imported technologies. In collaboration with Qualcomm, Viettel is also embracing O-RAN, creating an open, flexible 5G network that supports its global expansion. Additionally, Viettel is working with Ericsson to explore network slicing, enterprise applications, and Industry 4.0 use cases. Meanwhile, VNPT is collaborating with Nokia to expand its 5G

infrastructure using AI-driven network management solutions, enhancing operational efficiency.

Interviewees across ASEAN emphasize the vital importance of global partnerships in shaping a competitive, forward-looking 5G ecosystem. By leveraging international expertise, ASEAN nations are ensuring that their 5G networks deliver unprecedented value amid the rapid evolution of digital technologies.

Insight #9: A Strong Regulatory Framework Is Essential for Building Trust and Security in 5G Networks.

Most interviewees highlighted cybersecurity as a top priority for ensuring resilient and secure 5G networks.

- Singapore enforces strict data protection laws and mandates vendor diversity to mitigate risks associated with reliance on a single supplier.
- Malaysia has implemented local cybersecurity standards to safeguard critical 5G infrastructure.
- Singaporean interviewees underscored the importance of data privacy regulations in maintaining consumer trust in 5G services.
- Vietnamese interviewees emphasized national security, advocating for indigenous technology development to reduce foreign dependency.

Insight #10: Regional Coordination and Cross-Border Cooperation Are Crucial for 5G Harmonization and Accelerating Adoption

Singapore, Malaysia, and Thailand have aligned their 5G spectrum with the globally recommended 3.5GHz band, allowing seamless integration of telecom services and better roaming experiences for businesses and consumers.

Vietnam and Indonesia are also working toward standardized spectrum planning, preventing interference in border regions, and improving network efficiency.

Singapore and Malaysia are exploring 5G-enabled smart logistics and cross-border transportation systems, enhancing trade efficiency at the Johor-Singapore Causeway, one of the busiest land border crossings in the world.

Collaboration between Singtel and Telekom Malaysia aims to improve cross-border network handovers, ensuring that users experience uninterrupted 5G services when traveling between the two countries.

Thailand and Vietnam are working together to develop 5G-powered industrial zones, particularly for smart manufacturing and logistics.

- Companies operating in the Eastern Economic Corridor (EEC) in Thailand and Vietnam's industrial parks benefit from harmonized 5G standards, enabling automated production lines, AI-powered supply chains, and remote monitoring across borders.
- Telecom providers like AIS (Thailand) and Viettel (Vietnam) are engaging in cross-border agreements to ensure network interoperability for businesses operating in both markets.

Governments and telecom operators in Indonesia, Malaysia, and the Philippines are collaborating to enhance 5G-enabled shipping routes, using IoT sensors and AI-driven analytics to improve maritime logistics efficiency. Smart ports in Jakarta, Manila, and Port Klang are implementing 5G-powered real-time cargo tracking and AI-driven customs processing, reducing delays and enhancing regional trade.

Singapore's Cyber Security Agency (CSA) has collaborated with ASEAN neighbours to create a regional 5G security roadmap, ensuring common standards for threat detection and response. Vietnam, Malaysia, and Thailand are also working to align data privacy regulations, creating a standardized framework for handling cross-border 5G data transfers in compliance with international security standards.

Section 5

5G as the Foundation for AI-Driven Transformation and the Evolution to 6G

The rapid deployment of 5G networks has laid the foundation for the next wave of digital transformation, acting as the backbone for AI-driven innovation and a crucial bridge to 6G. As AI applications increasingly rely on ultra-fast, low-latency communication, 5G's advanced infrastructure enables real-time automation, edge computing, and next-generation AI capabilities.

Recognizing 5G's pivotal role in accelerating AI-driven transformation and shaping the path to 6G is essential for policymakers and business leaders. By prioritizing 5G deployment and adoption, they can unlock new technological frontiers, enhance digital capabilities, and drive sustained innovation.

This section explores 5G's transformative impact through key use cases and real-world applications, demonstrating its role as the backbone of an intelligent, hyper-connected future.

5.1. 5G as the enabler of AI-Driven Transformation

As AI advances with groundbreaking innovations, 5G serves as a crucial enabler, unlocking its full potential across industries. Its transformative impact is particularly evident in three use cases: 5G-Enhanced Edge AI, 5G-reinforced synergy between Edge AI and Cloud AI, and 5G Broadcast (5GB).

Each of these focuses demonstrates how 5G accelerates AI-driven innovation, driving the development of smarter, more responsive, and more efficient digital ecosystems, as detailed below.

Use Cases #1: 5G Empowers Edge AI: Enhancing Real-Time Decision-Making

Edge AI refers to the implementation of artificial intelligence algorithms directly on edge devices—such as sensors, Internet of Things (IoT) devices, and embedded systems—enabling real-time data processing and analysis without constant reliance on centralized cloud infrastructure. This approach allows for immediate responses, reduced latency, enhanced data privacy, and decreased bandwidth usage, making it particularly valuable in applications like autonomous vehicles, smart cities, and industrial automation.

With its low latency, high speed, reliable connectivity, and energy-efficient AI-powered IoT, 5G—particularly Private 5G—plays a pivotal role in unlocking the full potential of Edge AI by enabling real-time decision-making, seamless data exchange, and optimized AI-driven automation, as summarized in Table 5.1.

Table 5.1: 5G Boosts the Power of Edge AI

5G Capability	How It Enhances Edge AI	Example Applications	The Role of Private 5G
Ultra-Low Latency for Real-Time AI Processing	5G's sub-millisecond latency allows AI models to process data instantly at the network edge, reducing delays in mission-critical applications. Essential for autonomous vehicles, smart manufacturing, and AR/VR, where every millisecond counts.	Autonomous Driving – Edge AI enables real-time object detection and collision avoidance, while 5G ensures instant communication with smart infrastructure to optimize traffic flow.	Automated Ports & Logistics – Private 5G ensures zero-latency connectivity for AI-powered robotic cranes and autonomous transport systems, optimizing efficiency without network congestion.
Higher Bandwidth to Support AI Workloads on Edge Devices	5G's high-speed connectivity (up to 10 Gbps) enables the smooth transmission of high-resolution video, sensor data, and AI model updates to Edge AI devices. Eliminates bottlenecks in data transmission, allowing AI applications to function more efficiently.	Smart Factories – AI-powered robots rely on Edge AI for local decision-making, while 5G ensures real-time communication between machines and cloud-based monitoring systems.	AI-Driven Warehousing – Private 5G allows autonomous forklifts, robotic pickers, and AI-driven inventory management to communicate in real time without interference.
Improved Energy Efficiency for AI-Powered IoT Networks	5G optimizes power consumption, enabling AI-powered IoT sensors to operate at scale without excessive energy use. Supports smart cities, healthcare systems, and industrial automation by reducing energy demands.	Precision Agriculture – Edge AI-powered drones and sensors analyze soil quality in real time, while 5G enables instant coordination between multiple devices for optimized farming.	Smart Hospitals – Private 5G ensures secure, real-time AI-powered patient monitoring, allowing doctors to receive instant health updates while maintaining strict data privacy.

Use Case #2. 5G Enables and Fosters the Synergy Between Edge AI and Cloud AI

Edge AI and Cloud AI complement each other, creating a hybrid AI architecture where Edge AI handles real-time, localized processing, while Cloud AI provides large-scale

computation, model training, and analytics. 5G serves as a critical enabler, strengthening the synergy between these two AI systems, as outlined in Table 5.2.

Table 5.2: The Role of 5G as a Critical Enabler of the Synergy between Edge AI and Cloud AI

Synergy Channel	How It Works	Example Applications	Role of 5G
Cloud AI for Training, Edge AI for Execution	Cloud AI trains deep learning models on massive datasets using high-performance computing. Edge AI deploys lightweight versions of these models on devices for real-time execution.	Telemedicine – Cloud AI trains diagnostic models, while Edge AI in portable medical devices enables real-time health monitoring and instant decision-making.	5G enables real-time synchronization between Cloud AI and Edge AI, ensuring instant model updates and seamless execution on medical devices.
Edge AI for Immediate Decisions, Cloud AI for Big Data Insights	Edge AI processes real-time inputs locally, handling facial recognition, predictive maintenance, and fraud detection. Cloud AI aggregates data from multiple edge devices, refining AI models and generating long-term insights.	Retail Analytics – Edge AI detects customer behavior inside stores, while Cloud AI analyzes data across multiple locations to optimize store layouts and marketing strategies.	5G ensures ultra-low latency data exchange, allowing instant AI-powered decision-making in stores while enabling fast cloud-based insights across retail chains.
Hybrid AI for Optimized Workload Distribution	Non-time-sensitive tasks (e.g., AI model training, historical data analysis) are offloaded to Cloud AI. Time-sensitive tasks (e.g., AR/VR rendering, real-time cyber threat detection) are processed on Edge AI.	Smart Transportation Systems – Edge AI enables real-time traffic control, while Cloud AI processes historical traffic patterns to optimize city-wide infrastructure planning.	5G provides the high-speed, low-latency connectivity necessary for Edge AI to make split-second traffic decisions, while Cloud AI analyzes city-wide data in real time.

The critical role of 5G in empowering Edge AI and enabling its synergy with Cloud AI is ushering in a transformative era where AI-powered systems become more autonomous, scalable, and intelligent than ever before. This convergence enables instant decision-making, seamless data exchange, and optimized AI deployment, revolutionizing industries and reshaping the way technology interacts with the real world.

As AI applications become increasingly embedded in smart systems such as healthcare, manufacturing, logistics, transportation, and defense, zero-latency responsiveness will be crucial for real-time diagnostics, autonomous mobility, and security operations. The fusion of 5G and AI ensures that these mission-critical systems operate with unparalleled speed and efficiency. Simultaneously, AI's scalability will expand across industries, driving industrial automation, smart cities, and personalized digital assistants, making AI an integral part of everyday life.

Beyond performance, the synergy between Edge AI and Cloud AI strengthens cybersecurity, allowing real-time threat detection at the edge while cloud intelligence analyzes global attack patterns to proactively defend against emerging risks. This self-optimizing AI ecosystem will continuously learn and refine itself—Edge AI delivering immediate, localized insights while Cloud AI drives large-scale intelligence and innovation.

At the core of this transformation, 5G acts as the backbone, bridging the gap between localized real-time AI processing and cloud-scale intelligence. By providing ultra-low latency, high-speed connectivity, and reliable network infrastructure, 5G fuels a future where AI is more responsive, efficient, and accessible across industries. As this revolution accelerates, businesses, policymakers, and innovators must embrace this shift, leveraging the power of Cloud-Edge AI and 5G to build a smarter, more connected world.

Use Cases #3: 5G Broadcast (5GB) Revolutionizes Mobile Content Distribution

5G Broadcast (5GB) is poised to revolutionize mobile content distribution by enabling efficient, high-quality transmission to a vast number of users simultaneously. Unlike traditional unicast streaming, which sends individual data streams to each user and can strain network resources, 5G Broadcast employs a one-to-many transmission model. This approach allows content to be delivered to all users within a broadcast area without additional network load, ensuring consistent quality regardless of the number of recipients. (Rohde-schwarz, 2025)

This technology is particularly advantageous in scenarios such as live sports events or concerts, where large audiences consume the same content concurrently. By broadcasting the content once to all users, 5G Broadcast reduces network congestion

and enhances the viewing experience with seamless, real-time streaming. (Qualcomm, 2025)

Moreover, 5G Broadcast supports the distribution of linear media content over extensive areas, utilizing high-power transmitters to cover radii of up to 60 kilometers. This capability makes it ideal for delivering services like live television and radio broadcasts directly to mobile devices without requiring a SIM card or cellular subscription. Ors (2025)

In addition to entertainment, 5G Broadcast holds significant potential for public safety and emergency communications. It enables the dissemination of critical information, such as emergency alerts and disaster notifications, to all enabled devices within the broadcast area, ensuring that vital messages reach the public promptly and reliably. (Enensys, 2025)

As the technology matures, 5G Broadcast is expected to become a cornerstone in the evolution of media delivery, offering a robust and scalable solution for content providers and network operators to meet the growing demand for high-quality mobile media consumption. Table 5.3 below highlights the key advantages and emerging applications of 5G Broadcast.

Table 5.3: 5G Broadcast -- Key Advantages and Emerging Applications

Advantage / Application	How It Works	Example Use Cases
Network Efficiency & Scalability	One-to-many broadcasting eliminates redundant unicast streams, reducing network congestion.	Live Sports & Concerts – Ensures high-quality streaming for thousands of attendees in a stadium without overloading the network.
High-Quality Content Delivery	Enables buffer-free, high-resolution video streaming, even in high-density areas.	Mobile TV & Live News Feeds – Delivers real-time broadcasts of major events without network lag.
Uninterrupted Public Service Communication	Does not rely on SIM cards, making it ideal for nationwide emergency alerts and disaster notifications.	Emergency Broadcasts – Authorities can instantly notify citizens of extreme weather, security threats, or evacuation procedures.
Data-Free Access for End Users	Viewers can access zero-rated premium content without consuming mobile data plans.	Educational & Government Outreach – Provides free educational programming and public health updates.
Seamless Integration with Edge AI	AI-powered real-time analytics enhance personalized content recommendations via 5G Broadcast-enabled smart devices.	Smart Cities – Digital billboards and public screens display real-time traffic updates, environmental alerts, and local news.
Emergency Response & Public Safety	Ensures emergency alerts reach everyone, even in low-signal areas, without relying on mobile data.	Disaster Warnings – Authorities can deliver instant evacuation instructions during earthquakes or tsunamis.
Mobile Learning & Public Information Services	Enables large-scale e-learning and real-time public service announcements.	Nationwide Education – Governments distribute interactive courses to remote schools without requiring individual internet connections.
Smart Cities & Connected Vehicles	Transmits real-time traffic, weather, and transit updates to digital billboards and vehicle infotainment systems.	Smart Transportation – 5G Broadcast delivers live congestion updates to digital road signs, guiding drivers to alternative routes.

5.2. 5G as the Bridge to 6G: The Evolution of Next-Generation Networks

The evolution from 5G to 5G-Advanced (5G-A) and ultimately to 6G marks a major leap in wireless communication technologies. 6G (Sixth-Generation Wireless Technology) is envisioned to surpass conventional networking by functioning as a

distributed neural network, seamlessly integrating sensors, devices, infrastructure, and AI-driven intelligence systems into a unified ecosystem.

The key enhancements of 6G compared to 5G and 5G-A are summarized in Table 5.4.

Table 5.4. Key Features of 6G Compared to 5G and 5G-A

Feature	5G	5G-Advanced (5G-A)	6G
Standardization	3GPP Release 15 (2018)	3GPP Release 18 (2024)	Expected around 2030
Peak Data Rate	Up to 10 Gbps	Enhanced beyond 10 Gbps	Up to 1 Tbps
Latency	~1 ms	Reduced further	Sub-millisecond (<0.1 ms)
Spectrum Bands	Sub-6 GHz, mmWave (24.25–52.6 GHz)	Expanded mmWave, potential sub-THz	Terahertz (THz) frequencies (100 GHz–10 THz)
Key Technologies	eMBB, mMTC, URLLC, Network Slicing	AI/ML Optimization, Enhanced MIMO, Integrated Sensing and Communication	AI-Native Networks, Holographic Communications, Integrated Sensing, Imaging, and Positioning
Energy Efficiency	Improved over 4G	Further enhancements	Focus on zero-energy devices
Use Cases	High-speed internet IoT Autonomous vehicles	Advanced XR applications Smart cities, Industrial automation	Fully autonomous systems, Brain-computer interfaces, Digital twins

Sources: testbed (2025); Ericsson (2025); Arxiv (2025)

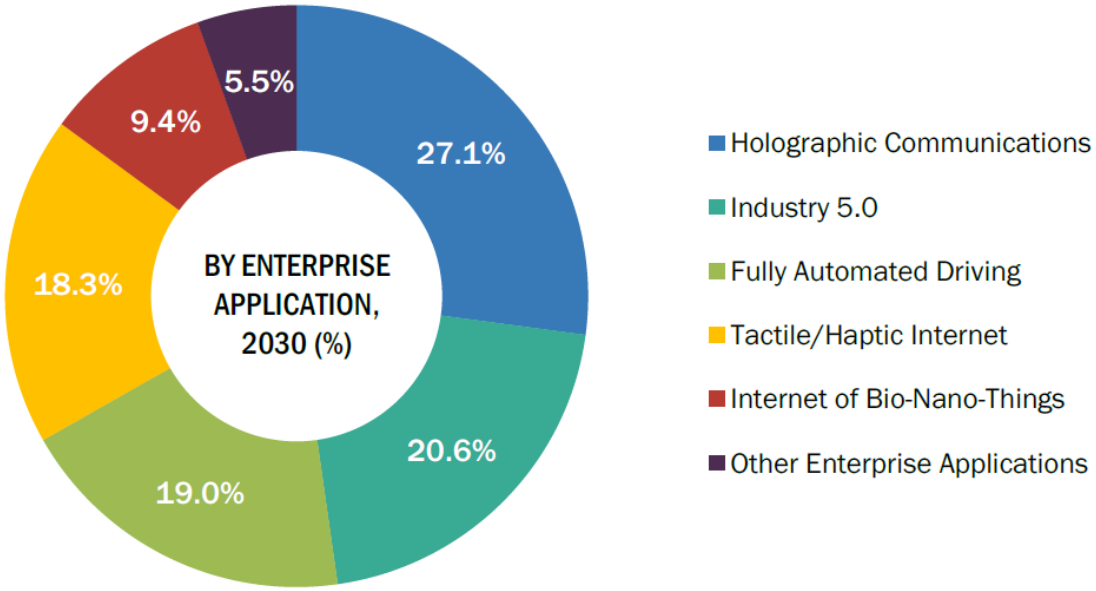
As outlined in Table 5.4, 6G will enable applications that are either significantly limited or entirely unattainable with 5G, including:

- Holographic Communications – Facilitates real-time, high-resolution holograms, transforming virtual meetings, remote healthcare, and entertainment experiences.
- Tactile Internet & Haptic Feedback – Supports real-time touch transmission, enabling remote physical interactions in surgery, education, gaming, and industrial robotics.
- Fully Autonomous Driving – 6G's ultra-low latency and AI-driven networks will allow for instant decision-making in autonomous vehicles, significantly improving safety and efficiency.

- Industry 5.0 – Enhances intelligent manufacturing, predictive maintenance, and AI-driven process control, leading to highly adaptive and autonomous industrial systems.
- Internet of Bio-Nano-Things – Integrates biotechnology, AI, and nanotechnology, enabling real-time health monitoring, nano-robotic drug delivery, and personalized medicine.

According to a recent market research report by M&M (2024), holographic communication and Industry 5.0 are projected to be the leading 6G applications by market share in 2030, accounting for 27.1% and 20.6%, respectively (Figure 5.1).

Figure 5.1: Projected Market Share of 6G by Application in 2030



Source: M&M (2024)

To advance toward 6G, the widespread deployment and optimization of 5G and 5G-Advanced (5G-A) serve as a crucial foundation for its development.

Table 5.5 highlights the key contributions of 5G in laying the groundwork for 6G.

Table 5.5: 5G Contributions 5G to 6G Advancement

Key Area	5G Contribution	6G Evolution
Spectrum Expansion	Introduces mmWave frequencies (24 GHz–100 GHz) and spectrum efficiency techniques.	Expands into terahertz (THz) spectrum (100 GHz–10 THz) for ultra-high-speed communication.
Network Densification	Deploys small cells and dense network infrastructure to improve capacity and coverage.	Further densifies networks with AI-powered base stations and satellite-terrestrial integration.
AI-Driven Network Optimization	Uses AI and machine learning for network management and predictive analytics.	Becomes AI-native, allowing full AI-based automation, resource allocation, and cybersecurity.
Edge Computing & Cloud-Native Architecture	Implements edge computing to reduce latency and enable real-time data processing.	Advances AI-driven edge intelligence and fully distributed computing architectures.
Integrated Sensing & Communication (ISAC)	Introduces environmental sensing capabilities within communication networks.	Expands into high-resolution imaging, localization, and digital twin applications.
Ultra-Reliable Low-Latency Communication (URLLC)	Achieves sub-1ms latency for mission-critical applications like remote surgery and autonomous driving.	Reduces latency to below 0.1ms, enabling holographic communication and brain-computer interfaces (BCI).
IoT & Massive Connectivity	Supports massive IoT (mMTC), connecting millions of devices per km².	Introduces ambient IoT and energy-harvesting IoT systems, enabling fully autonomous smart environments.
Security & Quantum-Resilient Networks	Enhances AI-driven cybersecurity and encryption.	Integrates quantum-safe cryptography and AI-based security for next-generation cyber resilience.

Sources: testbed (2025); Ericsson (2025); Arxiv (2025)

Section 6

Strategic Policy Recommendations

6.1. Recommendation #1: 5G AI-Driven Development Strategy (2025-2030)

Each ASEAN country, along with the region as a whole, should establish a comprehensive and forward-looking 5G AI-Driven Development Strategy with a practical roadmap for 2025–2030. This strategy should serve as a cornerstone of a broader initiative to harness AI-powered digital transformation for sustainable economic growth, industrial competitiveness, and technological leadership.

To ensure impactful and sustainable 5G-AI development, the strategy and roadmap should:

- Define a strong value proposition that aligns with both national priorities and ASEAN's regional digital development agenda.
- Identify strategic priority areas for 5G-enabled AI deployment across key sectors such as manufacturing, healthcare, agriculture, urban development, and education.
- Establish clear action plans with measurable milestones to ensure effective implementation and long-term success.

As part of this effort, ASEAN should launch the ASEAN 5G-AI Innovation Challenge, a flagship regional initiative to raise awareness, support SMEs, and accelerate the development of 5G-enabled AI solutions. This challenge would:

- Encourage startups, SMEs, and research teams to develop real-world applications of 5G-AI across strategic sectors.
- Provide technical mentorship, access to test-beds, and opportunities to pilot solutions in partnership with telecom providers and digital innovation hubs.
- Promote regional collaboration and knowledge-sharing, with a final pitch and demo day aligned with major ASEAN digital economy forums.

The Innovation Challenge can serve as both a capacity-building mechanism and a policy testbed, helping governments, enterprises, and regulators better understand the needs and opportunities within the emerging 5G-AI ecosystem. Integrating such initiatives into the broader 5G AI-driven development strategy will enhance regional

competitiveness and position ASEAN as a global leader in next-generation digital innovation.

To craft a robust and future-proof 5G development strategy, policymakers and communications service providers (CSPs) should recognize that 5G is more than just an incremental upgrade in network speed—it is a transformational enabler of AI-driven digital innovation and a stepping stone toward 6G.

With its ultra-high speed, low-latency, massive connectivity, and intelligent networking capabilities, 5G serves as the technological backbone for next-generation applications, fuelling advancements in smart cities, autonomous mobility, industrial automation, immersive digital experiences, and AI-powered ecosystems.

However, to fully unlock 5G's potential, stakeholders should go beyond infrastructure deployment and focus on long-term value creation and ecosystem development. An effective 5G development strategy should be anchored in the following three core strategic priorities:

1. Strengthening the synergy between 5G and AI-driven digital transformation to maximize its industry-wide impact and accelerate technological innovation.
2. Positioning enterprise 5G adoption as a primary driver to unlock its full benefits, boosting productivity, efficiency, and economic growth.
3. Creating a mutually reinforcing cycle between 5G infrastructure investment and 5G-enabled value-added services, ensuring sustainable and scalable adoption.

By focusing on these strategic priorities, policymakers and industry leaders can ensure that 5G deployment translates into widespread industry adoption, economic growth, and technological leadership. The key rationales and corresponding actions for each of these three priorities are outlined in Table 6.1 below.

Table 6.1. Three Core Strategic Priorities for AI-Driven 5G Development Strategy

Priority	Why This Matters	Key Actions	Expected Impact
1. Strengthening the Synergy Between 5G and AI-Driven Transformation	5G is a foundation for AI-driven transformation. Integrating 5G with AI, cloud computing, and IoT enhances automation, optimizes decision-making, and enables smarter ecosystems.	- Develop AI-powered 5G networks for intelligent automation.	- Increased industrial efficiency through AI-driven automation.
		- Encourage AI-5G integration in key sectors like healthcare, logistics, and smart cities.	- Accelerated innovation in autonomous systems, real-time analytics, and digital services.
		- Invest in 5G-enabled edge computing to support real-time AI processing.	- Greater economic value creation as AI-driven 5G solutions reshape industries.
2. Positioning enterprise 5G adoption as a key driver to unlock its full benefits	Enterprise and industrial 5G adoption will have greater economic impact than consumer adoption. Industries using 5G-powered automation, robotics, and IoT will achieve higher productivity and cost efficiency.	- Prioritize enterprise 5G applications in high-impact industries like manufacturing, logistics, finance, energy, mining, and healthcare.	- Boosted productivity through smart manufacturing, automation, and real-time analytics.
		- Support private 5G network deployment for high-security, high-performance business operations.	- Higher ROI for enterprises, leading to sustained economic growth.
		- Provide financial incentives and regulatory support to accelerate business adoption of 5G.	- Stronger ASEAN digital economy with enhanced global competitiveness.
3. Creating a mutually reinforcing cycle between 5G connectivity and 5G-enabled value-added services	5G infrastructure alone is not sufficient; driving 5G adoption by promoting 5G-enabled value-added services is essential to maximize the returns on 5G investment and enhance its overall impact.	- Foster public-private partnerships (PPPs) to expand 5G deployment while ensuring accessibility.	- Optimized use of 5G infrastructure investments, preventing underutilization.
		- Develop national 5G roadmaps that align network expansion with business and consumer demand; incentivize both the development and adoption of high-value, 5G-enabled services.	- Stronger innovation ecosystem, enabling businesses to adopt and create 5G-powered solutions.
		- Enable SMEs and startups to leverage 5G services for growth and innovation.	- Sustainable 5G growth, ensuring a scalable and inclusive digital transformation.

To effectively implement the AI-driven 5G development strategy, each ASEAN country should establish a practical action roadmap for 2025–2030. Below is a proposed roadmap, structured into three key phases.

Phase 1 (2026-2027): Full 5G Rollout & AI Adoption Acceleration

- The majority of ASEAN member states complete full deployment of 5G standalone (SA) networks.
- Governments implement AI-driven solutions for network automation, spectrum management, and cybersecurity.
- ASEAN introduces a unified regional governance framework for AI and 5G technologies.

Phase 2 (2027–2028): AI-Powered Smart Cities & Industry 4.0 Adoption

- ASEAN cities integrate AI-driven smart infrastructure powered by 5G digital twins, autonomous traffic management, and public service AI bots.
- AI-enhanced solutions become mainstream in manufacturing, logistics, and precision agriculture.
- AI-powered fintech & blockchain solutions expand across ASEAN markets.

Phase 3 (2028–2030): Regional AI-5G Convergence & Expansion

- Cross-border AI-driven trade, finance, and logistics networks enhance supply chain automation.
- ASEAN aligns digital economy regulations to promote inclusive and responsible AI-5G adoption.
- Research & investment in 6G integration & quantum AI computing.

6.2. Recommendation #2: Establishing a Dedicated National Agency for 5G-AI Deployment and Adoption

To drive effective and coordinated 5G-AI deployment, each ASEAN country should designate a **dedicated national agency** with a clear mandate to lead strategy, oversee implementation, and accelerate adoption across all sectors. This agency should serve as the **central coordinating body** to ensure alignment between national 5G-AI strategies, economic priorities, technological advancements, and industry needs.

A **centralized, empowered approach to 5G-AI governance** is essential for enabling sustainable digital transformation, laying the groundwork for future 6G development, and enhancing national and regional competitiveness in next-generation technologies. This agency should assume the following five key functions:

1. *Strategic Planning & Policy Development*
   Formulate and update a national 5G-AI roadmap, defining clear objectives, regulatory guidelines, and incentive mechanisms for enterprises and SMEs.
2. *Spectrum Allocation & Infrastructure Expansion*
   Ensure efficient spectrum management (including mid-band and mmWave), support private 5G deployment and facilitate public-private partnerships for cost-effective network rollout.
3. *Industry Adoption & Digital Transformation*
   Accelerate 5G-AI adoption in high-impact sectors such as manufacturing, logistics, ports, healthcare, education, and energy—focusing on both enterprise and SME use cases.
4. *Regulatory Oversight & Trust Frameworks*
   Develop legal, cybersecurity, and data governance frameworks to safeguard trust, ensure fair competition, and foster innovation.
5. *Monitoring & Performance Evaluation*
   Establish KPIs to track progress, measure economic and social impact, and ensure agile policy adjustments based on real-world outcomes.

The agency should pursue its mission with a clear sense of urgency, recognizing **5G-AI as a strategic window of opportunity**—one that must be seized or risk being missed. The convergence of 5G and AI presents a **historic moment for ASEAN** to develop a new generation of globally competitive, homegrown digital companies. These firms have the potential to lead innovations across a range of high-impact sectors, including:

- Smart manufacturing and Industrial IoT (IIoT)
- AI-powered health related diagnostics
- Precision agriculture and climate-resilient technologies
- Logistics optimization and smart mobility
- Immersive learning and workforce development

A core enabler of this ecosystem is the **extensive deployment of private 5G networks**, which provide secure, high-performance, low-latency infrastructure tailored to enterprise and industrial needs. Private 5G is especially critical for **startups and SMEs** seeking controlled environments to develop, test, and scale AI-driven innovations. ASEAN's diverse economies and industrial clusters position the region as a natural **testbed for private 5G-AI deployment**, provided that governments ensure access to:

- Affordable, scalable infrastructure
- Spectrum (especially mid-band and mmWave)
- Testbeds, edge-cloud resources, and commercialization support
- Regulatory clarity and private sector incentives

Without deliberate action, ASEAN risks falling behind. A lack of coordinated 5G policy, spectrum access, and private network readiness could:

- Undermine the competitiveness of ASEAN-based firms
- Limit local value creation in digital transformation
- Slow innovation, industrial upgrading, and AI adoption
- Fragment regional digital markets and weaken ASEAN's global standing

Learning from Regional Leaders: Singapore, Malaysia, and Thailand:

Experiences from ASEAN frontrunners offer valuable insights into successful 5G governance models:

- **Singapore**: The Infocomm Media Development Authority (IMDA) champions an enterprise-driven, innovation-focused model built on strong public-private collaboration.
- **Malaysia**: Digital Nasional Berhad (DNB) oversees infrastructure rollout via a Single Wholesale Network (SWN) to optimize cost-efficiency and access.
- **Thailand**: The National Broadcasting and Telecommunications Commission (NBTC) guides implementation through a national 5G Steering Committee that ensures multi-stakeholder coordination.

Five Strategic Priorities for the 5G-AI Lead Agency

i. Define a clear mandate and strong institutional leadership to align national policies, investment flows, and regulatory frameworks under a unified vision.

ii. Drive inclusive collaboration across government, industry, academia, and the innovation ecosystem to accelerate 5G-AI adoption and solution development.

iii. Adapt governance models to national contexts, whether through enterprise-led (Singapore), centralized wholesale (Malaysia), or multi-stakeholder coordination (Thailand) approaches.

iv. Mobilize private sector participation through targeted fiscal incentives, regulatory facilitation, and co-investment programs that de-risk innovation.

v. Strengthen regional cooperation by harmonizing standards, enabling cross-border scaling, and integrating ASEAN into global digital value chains.

A well-structured and empowered 5G-AI lead agency will be critical to unlock ASEAN's digital potential—fuelling inclusive growth, fostering industrial competitiveness, and preparing the region for the next wave of digital innovation. Further details on comparative models and implementation lessons are provided in Table 6.2.

Table 6.2. Comparative Summary of Best Practices

Country/Agency/ *Governance Model*	**Impact & Successes**	**Lessons for ASEAN**
Singapore IMDA *Enterprise-Driven, Industry-Led 5G Innovation*	❖ Singapore achieved 95% 5G standalone coverage by end 2022, exceeding the regulatory target of end 2025. ❖ 5G-powered smart ports (Tuas Megaport) use AI-driven automation, enhancing maritime logistics efficiency. ❖ 5G-enabled blockchain solutions in digital banking enhance financial security and operational efficiency.	➢ Government-Led, Industry-Driven Approach: IMDA plays a proactive role in setting 5G policies, spectrum allocation, and regulatory frameworks, while actively engaging industry players to drive innovation. ➢ Enterprise-Focused 5G Strategy: Singapore prioritizes 5G adoption in high-value industries such as finance, logistics, manufacturing, and smart mobility, ensuring economic impact and commercial viability. ➢ Public-Private Co-Funding Model: IMDA co-funds 5G testbeds and enterprise adoption pilots, reducing risks for businesses and accelerating industry uptake. ➢ Dual-Layer Network Strategy: Singapore deploys both Standalone (SA) and Non-Standalone (NSA) 5G networks, ensuring fast consumer rollout while supporting next-gen enterprise applications.
Country/Agency *Governance Model*	Impact & Successes	Key Insights for ASEAN
Malaysia DNB *Centralized Deployment via Single Wholesale Network (SWN)*	❖ DNB's wholesale model reduces infrastructure costs, making 5G deployment more efficient and scalable. ❖ 5G-powered smart manufacturing initiatives improve automation, AI-driven analytics, and industrial efficiency. ❖ As of the end of 2024, Malaysia's 5G network had achieved 82.4% population coverage, surpassing its target of 80%.[5]	➢ Government-Controlled 5G Infrastructure Deployment: DNB is fully owned by the government and oversees nationwide 5G rollout under a Single Wholesale Network (SWN) model, ensuring cost efficiency and infrastructure sharing. Malaysia recently transitioned toward a dual-network model in 2024. ➢ Eliminating Market Fragmentation: Instead of multiple telecom operators building separate networks, DNB provides wholesale 5G access to all mobile network operators (MNOs), reducing redundant investments. ➢ Regulatory Oversight & Industry Consultation: The Malaysian Communications and Multimedia Commission (MCMC) works with DNB to ensure transparent regulatory policies, pricing models, and service quality standards. ➢ Ensuring Affordability & Digital Inclusion: The government's cost-controlled model enables lower 5G service prices, ensuring affordable access for consumers and businesses.

[5] Source: Malaysia leads in 5G rollout with 82.4pc coverage, adoption doubles, says deputy communications minister. Malay Mail, 28 February 2025. Available at: https://www.malaymail.com/news/malaysia/2025/02/28/malaysia-leads-in-5g-rollout-with-824pc-coverage-adoption-doubles-says-deputy-communications-minister/168285

Thailand NTBC *Multi-Stakeholder National 5G Steering Committee*	❖ Thailand was the first ASEAN country to achieve nationwide 5G coverage, reaching 80% of the population within two years. ❖ 5G-powered smart cities in Bangkok and Phuket enhance traffic management, public safety, and urban efficiency. ❖ Thailand's smart hospitals leverage AI and 5G connectivity for advanced telemedicine and diagnostics.	➢ High-level government leadership ensures decisive action and strategic direction. ➢ Inter-government collaboration promotes 5G adoption, exemplified by the Board of Investment (BOI) offering regulatory and tax incentives to attract private-sector investment in 5G-powered industries. ➢ Public-private partnerships accelerate 5G deployment and adoption, fostering innovation and economic growth. ➢ Industry-driven 5G rollout aligns with national economic priorities, ensuring targeted and impactful implementation.

6.3. Recommendation #3: Establish an Efficient, Future-Oriented Spectrum Policy and Strengthen Regulatory Support for 5G Deployment

An efficient and forward-looking spectrum policy, supported by robust regulatory frameworks, is essential for accelerating 5G deployment, optimizing spectrum utilization, and fostering innovation in next-generation connectivity. ASEAN countries must develop spectrum strategies that align with market demand, technological advancements, and national digital priorities, ensuring cost-effective and sustainable 5G expansion.

By adopting optimized spectrum allocation, regulatory incentives, and cross-sector collaboration, ASEAN nations can unlock the full potential of 5G, drive digital transformation, and enhance regional connectivity.

Regarding optimal spectrum allocation for 5G, GSMA (2022) outlines 10 strategic policy directions, providing a framework for governments, regulators, and the mobile industry to collaborate effectively in advancing 5G deployment. The 10 policy directions are elaborated in Table 6.3A below.

Table 6.3A: GSMA Recommendations for 5G Spectrum Allocation

Strategic Policy Direction	Key Actions
1. Prioritize Harmonized Spectrum Allocation for 5G Expansion	❖ Assign at least 100 MHz of contiguous midband spectrum per operator for initial 5G deployment. ❖ Increase lowband spectrum availability (including 600 MHz) to improve rural coverage and indoor penetration. ❖ Ensure 2 GHz of midband spectrum per market by 2030 to meet growing capacity demands. ❖ Allocate at least 800 MHz per operator in mmWave, with a roadmap to expand 5GHz per market as demand increases.
2. Balance Low, Mid, and High-Band Spectrum for Comprehensive 5G Coverage	❖ Lowband (<1 GHz): Essential for broad rural coverage, deep indoor penetration, and IoT growth. ❖ Midband (2.3–4.9 GHz): The foundation of 5G networks, providing optimal coverage and capacity for smart cities, education, and Industry 4.0. ❖ Highband (mmWave, 24–100 GHz): Enables ultra-high speed broadband and low latency applications in dense urban environments.
3. Support Global Spectrum Harmonization to Ensure 5G Scalability	❖ Engage in WRC23 and future ITU processes to secure harmonized spectrum bands (e.g., UHF, 3.3–4.2 GHz, 4.8 GHz, and 6 GHz). ❖ Align with international standards to enable affordable 5G equipment, roaming, and cross-border compatibility.
4. Ensure Exclusive Spectrum Licensing for Robust 5G Networks	❖ Exclusively licensed spectrum over wide geographic areas remains critical for ensuring network quality, security, and efficiency. ❖ Regulators should minimize spectrum fragmentation to optimize network performance and investment incentives.
5. Utilize Spectrum Sharing and Unlicensed Spectrum as a Complementary Strategy	❖ Shared and unlicensed spectrum can support specific use cases, such as WiFi offloading and private networks, while ensuring priority is given to public 5G networks.
6. Avoid Excessive Spectrum Set-Asides for Local or Vertical Use	❖ Setting aside spectrum for private or vertical industry use risks reducing public 5G efficiency. ❖ Instead, leasing and dynamic spectrum sharing should be explored to optimize spectrum utilization.
7. Maintain Affordable Spectrum Pricing to Promote 5G Growth	❖ Avoid inflated reserve prices, excessive annual fees, and auction limitations that could slow 5G rollout. ❖ Ensure fair and efficient spectrum auctions that encourage investment in high quality 5G services.
8. Address 5G Backhaul Needs to Support Network Performance	❖ Expand backhaul spectrum availability (e.g., Eband, 26 GHz, 32 GHz) to accommodate higher 5G data traffic. ❖ Ensure affordable backhaul licenses to facilitate nationwide 5G expansion.
9. Design Effective Licensing Terms and Award Mechanisms	❖ Regulators should engage with industry stakeholders to define licensing terms, spectrum renewal policies, and auction designs that maximize 5G benefits.
10. Establish a Long-Term Spectrum Policy to Encourage Investment	❖ Develop a national 5G spectrum roadmap with clear policies on long-term licenses, renewal processes, and future allocations. ❖ Provide regulatory certainty to encourage heavy investment in next generation 5G infrastructure.

For implementation, GSMA (2024c) suggests a spectrum allocation roadmap for 5G and 5G-A. As presented in Figure 6.3, the following three key messages stand out.

First, structured and inclusive spectrum planning is essential for 5G deployment. It requires collaboration among governments, industry stakeholders, and regulators to identify and clear the spectrum, ensuring efficient allocation. Additionally, it underscores the importance of conducting a cost-benefit analysis to balance competing demands and optimize the use of scarce spectrum resources for society.

Second, the design of an effective spectrum award process is critical to maximizing both economic and technological value. Allocation methods—such as auctions, call for proposals (CFPs), or direct awards—should be carefully selected based on national policy objectives, market dynamics, and technical requirements. The choice of mechanism must be anchored in a clear value proposition that balances efficiency, fairness, and long-term impact.

Spectrum pricing should be informed by sound valuation models, cost assessments, and projections of future demand, ensuring that it supports equitable access while maximizing socio-economic returns. Based on insights from our expert and stakeholder interviews, auctions are widely regarded as the most effective mechanism, provided that governments carefully account for the financial burden placed on CSPs and strategically reinvest auction proceeds to incentivize 5G-AI innovation and ecosystem development.

Third, regulatory clarity and implementation drive spectrum efficiency. Technology definitions, restrictions, and licensing obligations must be clearly outlined to enhance spectrum efficiency and market competitiveness. Additionally, the final award process should be transparent, with well-documented rules on licensing, band availability, and usage conditions to support mobile service expansion.

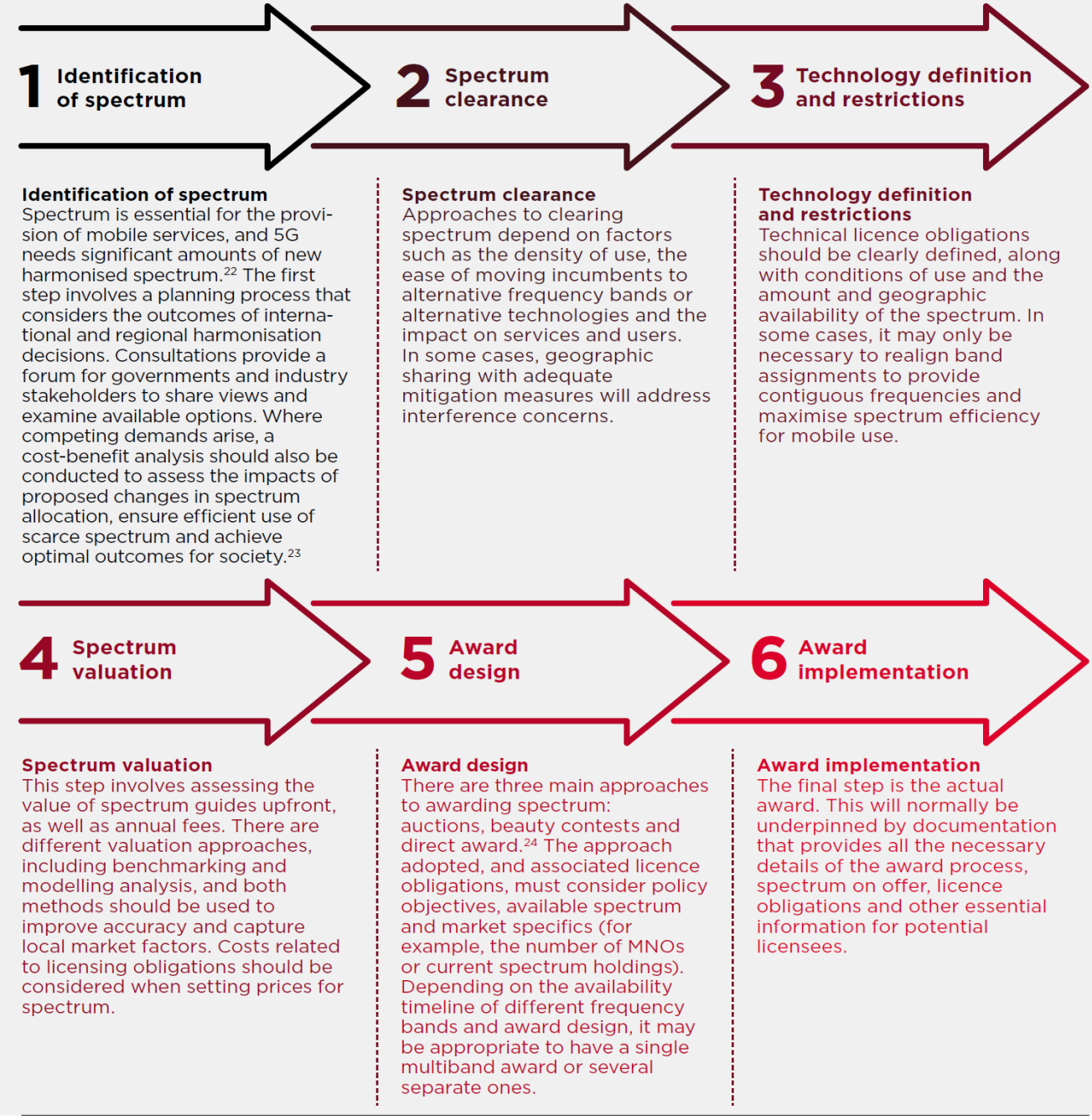
To establish an efficient, future-oriented spectrum policy and enhance regulatory support for 5G deployment, each ASEAN government can consider the following priorities:

1. Optimize Spectrum Allocation for 5G Growth
2. Strengthen Regulatory Support for 5G Infrastructure Deployment
3. Facilitate the Transition from 4G to 5G and Future 6G Networks

4. Enhance Spectrum Governance and Cross-Sector Collaboration

Key actions aligned with these priorities, along with best practice examples, are outlined in Table 6.3B.

Figure 6.3. Spectrum Roadmap and Steps for 5G and 5G-A



21. GSMA. (April 2022). *Roadmaps for awarding 5G spectrum in the APAC region*.
22. The key frequency bands to prioritise for 5G are outlined in section 1.3.
23. GSMA. (January 2022). *Maximising the socio-economic value of spectrum. A best practice guide for the cost-benefit analysis of 5G spectrum assignment*.
24. For the GSMA's position on auction best practice, see: GSMA. (September 2021). *Auction Best Practice: GSMA Public Policy Position*.

Source: GSMA (2024c)

Table 6.3B: Spectrum Policy and Regulatory Support for 5G Deployment – Key Priorities for Action

Priority	Key Actions	Examples of Best Practices
1. Optimize Spectrum Allocation for 5G Growth	- Prioritize mid-band (3.5GHz) and high-band (mmWave) spectrum for high-speed, low-latency 5G. - Implement dynamic spectrum sharing models to enhance efficiency. - Ensure fair and transparent spectrum auctions.	**Singapore** – IMDA adopted a technology-neutral spectrum framework, allowing flexible spectrum usage for different 5G applications. - IMDA auctioned the 3.5GHz mid-band spectrum while reserving 26 GHz and 28 GHz mmWave bands for high-speed, low-latency applications. **Thailand** NBTC allocated low-band, mid-band, and mmWave spectrum, ensuring comprehensive 5G coverage across urban and rural areas.
2. Strengthen Regulatory Support for 5G Infrastructure Deployment	- Streamline licensing procedures to reduce deployment delays. - Implement incentives (tax reductions, infrastructure sharing) to accelerate investment. - Ensure ASEAN-wide spectrum harmonization for cross-border 5G applications.	**Vietnam -** Vietnam has recently established a legal framework and incentives for telecom infrastructure sharing, enabling both passive (towers, base stations) and active (5G RAN) network collaboration among major operators to reduce redundant investments and optimize resource efficiency. **Malaysia** – Digital Nasional Berhad (DNB) oversees spectrum allocation and deployment through a single wholesale network model.
3. Facilitate the Transition from 4G to 5G and Future 6G Networks	- Reallocate underutilized 2G/3G spectrum to 5G. - Encourage private 5G networks for smart factories, healthcare, and logistics. - Develop long-term spectrum roadmaps for 5G-6G evolution.	**Thailand** – NBTC conducted transparent spectrum auctions across low, mid, and mmWave bands for urban and rural 5G coverage.
4. Strengthen Spectrum Governance & Cross-Sector Collaboration	- Establish national spectrum management authorities. - Promote public-private partnerships for 5G infrastructure investment. - Support R&D initiatives for AI-driven spectrum management.	**Singapore** – Dual-layer (Standalone & Non-Standalone) 5G network strategy optimizes adoption for enterprises and consumers.

6.4. Recommendation #4: Develop KPIs and AI-Enabled Monitoring to Track 5G-AI Readiness and Progress

To drive evidence-based decision-making and accelerate regional progress, each ASEAN country—and the region collectively—should establish a robust, AI-enabled framework of Key Performance Indicators (KPIs) to systematically assess both organizational-level 5G-AI readiness and national-level deployment and adoption.

These KPIs must be comprehensive, multidimensional, and aligned with global benchmarks, incorporating input from CSPs, technology providers, and policymakers. Importantly, AI-powered analytics should be embedded into the monitoring system to enhance accuracy, enable predictive insights, and automate trend detection—supporting real-time decision-making and continuous improvement.

At the enterprise level, three pillars are essential for successful 5G-AI integration:

- Network Infrastructure Readiness: Compatibility with 5G devices, cloud-native architectures, and edge AI capabilities.
- Spectrum & Connectivity Readiness: Availability of mid-/high-band spectrum, small cell infrastructure, and low-latency network capacity.
- Security & Compliance Readiness: Robust cybersecurity, AI governance, and data protection mechanisms.

Together, these components ensure enterprises can efficiently scale 5G-AI applications while strengthening ASEAN’s competitiveness in the global digital economy.

Table 6.4A: Key Pillars and Indicators for Enterprise 5G Readiness

Readiness Category	Key Indicators	Description
1. Network Infrastructure Readiness	5G Device & AI Hardware Compatibility	Availability of AI-enabled 5G-capable devices (e.g., sensors, edge gateways, industrial robots).
	Edge Computing & AI Inference Capability	Deployment of edge infrastructure that supports real-time AI processing and decision-making.
	Cloud-Native & AI-Optimized Architectures	Migration to cloud-native, virtualized environments designed for AI model training and deployment.
	SDN & Network Slicing for AI Workloads	Enablement of dynamic, isolated network slices tailored for AI use cases with varying latency and throughput needs.
2. Spectrum & Connectivity Readiness	Access to AI-Critical 5G Spectrum Bands	Allocation of mid-band and mmWave spectrum to support bandwidth-intensive AI applications.
	Small Cell & Private 5G-AI Network Deployment	Deployment of small cells and localized 5G networks to support AI-driven enterprise operations.
	High-Capacity Backhaul for AI Data Flows	Upgrade of transport and core networks to support real-time AI data flows and analytics.
3. Application & Use Case Readiness	Integration of AI-Driven 5G Applications	Implementation of AI-integrated 5G solutions such as predictive maintenance, digital twins, and computer vision.
	Vertical-Specific 5G-AI Use Cases	Customization of 5G-AI solutions in sectors like manufacturing, logistics, agriculture, and healthcare.
	URLLC for Mission-Critical AI Tasks	Use of ultra-reliable low-latency communication for time-sensitive AI applications (e.g., robotics, drones).
4. Security & Compliance Readiness	AI-Augmented 5G Cybersecurity Frameworks	Application of AI for threat detection, anomaly detection, and automated incident response.
	Regulatory Compliance for 5G-AI Integration	Alignment with AI ethics, data privacy, and spectrum regulations across markets.
	End-to-End AI-Driven Data Protection	Use of intelligent monitoring and encryption to secure 5G-AI data and device ecosystems.
5. Organizational & Workforce Readiness	AI and 5G Skills Development	Training staff in AI, 5G networks, edge computing, and cybersecurity.
	Integrated 5G-AI Strategy	Clear definition of business objectives, KPIs, and ROI frameworks for 5G-AI deployment.
	Ecosystem Partnerships	Collaboration with CSPs, AI vendors, cloud providers, and research institutions.
6. Cost & Investment Readiness	AI-Driven Cost-Benefit Analysis	Use of AI tools to simulate and optimize investment strategies for 5G-AI deployment.
	Scalability & 6G Preparedness	Ensuring that infrastructure is scalable, modular, and aligned with future technology evolution.

Indicators for Monitoring National 5G-AI Advancement

The progress of a nation in 5G-AI deployment should be evaluated across four strategic dimensions, each of which plays a critical role in driving next-generation digital transformation:

- Infrastructure & Deployment
- Adoption & Consumer Engagement
- Enterprise & Industry Transformation
- Policy & Regulatory Effectiveness

As outlined in Table 6.4B, these indicators go beyond basic network metrics to include AI-enhanced capabilities such as real-time performance monitoring, predictive maintenance, and intelligent traffic management. They also assess AI-enabled enterprise adoption, the proliferation of AI-powered IoT devices, and the use of machine learning for dynamic network optimization.

Furthermore, the framework incorporates the role of AI in governance, including automated regulatory compliance, spectrum analytics, and cybersecurity monitoring. Public-private partnerships are assessed not only for their scale and impact but also for their ability to foster AI-integrated innovation ecosystems that leverage 5G infrastructure.

Table 6.4B: Framework for Monitoring 5G Advancement at the National Level

Category	Indicator	Description
1. Infrastructure & Deployment	5G Network Coverage (%)	Percentage of the population or geographic area with active 5G infrastructure.
	AI-Analyzed Network Performance (Latency, Speed, Congestion)	Real-time network diagnostics powered by AI to monitor performance, predict bottlenecks, and optimize quality of service.
	Average 5G Download & Upload Speeds (Mbps)	Real-world data transfer speeds experienced by users.
2. Adoption & Consumer Engagement	5G Subscription Penetration Rate (%)	Proportion of mobile users subscribed to 5G services.
	5G Device Penetration (%)	Percentage of 5G-capable devices in use across the population.
	AI-Driven Usage Analytics	AI-generated insights on consumer behavior, data usage patterns, and content preferences to guide service innovation.
3. Enterprise & Industry Transformation	Enterprise 5G-AI Adoption Rate (%)	Percentage of businesses integrating 5G in conjunction with AI into operations.
	5G-Enabled IoT & AI Device Connections (Total & Growth Rate)	Number and growth rate of AI-powered IoT devices connected via 5G.
	AI Use in Industry 4.0 Powered by 5G (Case Studies/Projects)	Tracks national-scale use cases of AI and 5G in smart manufacturing, logistics, healthcare, etc.
4. Policy & Regulatory Effectiveness	Efficiency of Spectrum Allocation Processes	Speed, transparency, and fairness of national spectrum allocation procedures.
	AI-Assisted Regulatory Monitoring & Enforcement	Use of AI tools to monitor compliance, detect anomalies, and enhance regulatory responsiveness.
	Public-Private Partnerships in 5G-AI (Number & Impact)	Volume and effectiveness of collaborative efforts between government, CSPs, and industry in 5G-AI deployment.

6.5. Policy Recommendation #5: Empowering CSPs to Drive AI, Edge Computing, and Cloud for 5G Success

Communication Service Providers (CSPs) in ASEAN must adopt a bold and proactive strategy in leveraging AI-driven innovation, edge computing, and cloud services to enhance network performance, enable new 5G applications, and deliver specialized services. These technologies are critical enablers for maximizing 5G's potential and accelerating enterprise adoption, particularly in smart manufacturing, AI-powered customer experiences, and IoT-driven industries.

Globally, CSPs lead 5G deployment and adoption, and integrating AI, edge computing, and cloud is no longer optional—it is a strategic necessity for optimizing networks, scaling enterprise applications, and unlocking monetization opportunities. These advancements enhance network intelligence, improve efficiency, and reduce costs, while delivering ultra-low-latency, high-performance connectivity.

To accelerate this transition, ASEAN governments must establish an enabling regulatory framework and introduce targeted incentives to drive CSP investments in AI-native networks, cloud-driven services, and edge computing infrastructure. These measures will unlock 5G's full economic potential, positioning ASEAN as a leader in enterprise 5G adoption and digital transformation.

Table 6.5 highlights global and ASEAN best practices where CSPs have successfully integrated AI, edge computing, and cloud to fast-track 5G deployment and adoption. It also outlines policy implications for governments to support and scale CSP-led innovation in this strategic direction.

Table 6.5: Selected Best Practices of CSPs in Leveraging AI, Edge Computing, and Cloud for 5G Success

Category	Key Insights
AI-Driven Network Optimization and AI-Native Networks	*AI-Optimized 5G Networks:* SK Telecom (South Korea) partnered with Samsung to integrate AI-driven 5G optimization, improving network performance in high-traffic areas; transitioning to an AI-native network using deep learning.
	AI for Network Optimization T-Mobile (US) implemented real-time AI-based optimization for dynamic network adjustments, improving service quality.
Edge Computing for Ultra-Low Latency 5G Applications	*AI Data Centers (AIDC) and GPU-as-a-Service (GPUaaS)* SK Telecom (South Korea) invested in AI-powered data centers and edge computing for real-time processing in autonomous driving, smart cities, and industrial automation; partnered with Lambda and Penguin Solutions.
	5G Edge Slicing for Enterprises Nokia: Developed an edge slicing solution for customized 5G VPN services, enhancing security and latency for enterprises.
	Maxis (Malaysia) and Singtel (Singapore) have partnered to launch Malaysia's first integrated 5G orchestration platform, leveraging cloud computing, AI, and edge computing to accelerate enterprise 5G adoption. This initiative is designed to streamline network management, optimize 5G resources, and enable scalable, real-time applications for businesses across various industries, including manufacturing, logistics, healthcare, smart cities, and financial services. Launched an integrated 5G, cloud, and edge computing platform for enterprise 5G adoption, supporting smart manufacturing, healthcare, and logistics.
Cloud-Native Platforms to Enhance 5G Monetization	AI business unit grew by 32% year-over-year, offering AI-powered solutions like AI Contact Centers (AICC) and Vision AI.
	Cloud-Based 5G Deployments AWS collaborated with Fujitsu to automate cloud-native 5G network deployment, reducing operational costs.
	AI-Driven Cloud Gaming in Malaysia YTL Power partnered with NVIDIA: GeForce NOW to enable cloud gaming, showcasing 5G's potential in entertainment services.

6.6 Recommendation #6: Cultivating a Vibrant AI-Driven 5G Ecosystem

Each ASEAN country, along with the region as a whole, should develop a vibrant AI-driven 5G ecosystem by fostering strong collaboration among key stakeholders, including governments, communication service providers (CSPs), technology providers, vendors, universities, and international/regional organizations.

The primary objective is to build trust, strengthen stakeholder linkages, and optimize public-private partnerships (PPPs) to accelerate 5G deployment, drive innovation, and unlock new economic opportunities at both the national and regional levels.

Cultivating a National AI-Driven 5G Ecosystem can be achieved through the following four strategic directions:

1. Strengthening Multi-Stakeholder Collaboration
2. Deepening Trust as a Pillar of a Resilient 5G Ecosystem
3. Enhancing Public-Private Partnerships (PPPs) to Scale 5G Innovation
4. Fostering Regional Cooperation for a Unified ASEAN 5G Strategy

The key actions, along with global and ASEAN best practices aligned with these strategic priorities, are presented in Table 6.6.

Furthermore, it is crucial to underscore that the development of advanced, resilient digital infrastructure is a foundational prerequisite for realizing the full potential of an AI-driven 5G ecosystem. Without strong digital foundations—comprising high-speed connectivity, secure cloud infrastructure, intelligent edge computing, and scalable data platforms—the transformative power of 5G and AI cannot be effectively harnessed.

A robust digital infrastructure underpins network performance, AI deployment, cybersecurity, industry modernization, and digital inclusion. It enables low-latency, high-throughput communication necessary for mission-critical applications, while also supporting real-time data processing and analytics at the edge—both essential for next-generation use cases in manufacturing, healthcare, mobility, and more.

Therefore, ASEAN countries must prioritize coordinated and forward-looking infrastructure investments to not only unlock 5G-AI synergies but also to build a thriving, innovation-driven digital ecosystem. This will be key to enhancing national and regional competitiveness, enabling inclusive economic growth, and positioning ASEAN as a global leader in accelerated digital transformation.

Investing in advanced digital infrastructure is not merely a technical necessity—it is a strategic imperative. It plays a vital role in:

- Ensuring scalability and resilience of 5G networks for critical services
- Enabling AI deployment across diverse sectors through edge-cloud integration
- Reducing the digital divide by expanding coverage to underserved communities
- Attracting investment by providing a future-ready innovation environment
- Supporting regional interoperability for cross-border digital services and supply chains

In short, infrastructure is not just a support system—it is the enabler of ASEAN's digital future. Without it, the promise of AI and 5G will remain unrealized. With it, the region can lead the next wave of global digital innovation.

Table 6.6. Strategic Priorities for Cultivating 5G Ecosystem - Key Actions and Best Practices

Strategic Direction	Key Actions	Global/ASEAN Best Practices
1.Strengthening Multi-Stakeholder Collaboration	*Build an inclusive 5G ecosystem by strengthening linkages among key stakeholders, with each playing a proactive role in driving this effort:* ❖ Governments: Set policies, allocate spectrum, provide incentives. ❖ CSPs: Deploy and optimize 5G networks. ❖ Tech Providers & Vendors: Develop AI-driven 5G solutions. ❖ Universities & Research Institutions: Drive innovation and workforce development. ❖ International & Regional Organizations: Align standards, enable investment, and ensure interoperability.	South Korea: • Government-led coordination between policymakers, telecom operators, and industry players to align 5G deployment with AI, IoT, and smart city initiatives. • Public-private technology consortia to drive nationwide 5G adoption in key industries. UK: • Cross-sector collaboration involving universities, industry, and telecom providers to test 5G in manufacturing, logistics, and healthcare. Singapore: • 5G task force engaging government agencies, CSPs, and tech companies to develop AI-driven solutions for maritime, logistics, and financial services. • Collaborative 5G testbeds for urban mobility, smart ports, and digital banking.
2.Deepening Trust as a Pillar of a Resilient 5G Ecosystem	❖ Establish a Regional 5G Cybersecurity Framework: Standardized security protocols for data privacy, AI ethics, and cross-border interoperability. ❖ Ensure Transparency in PPPs: Clear policies on spectrum allocation, infrastructure sharing, and technology neutrality. ❖ Build Digital Trust with Consumers & Enterprises: Educate businesses on 5G's reliability, security, and economic benefits.	Finland: • Mandatory cybersecurity standards for all telecom operators. • Government oversight on critical infrastructure security and AI-driven threat monitoring.

Table 6.6. Strategic Priorities for Cultivating 5G Ecosystem - Key Actions and Best Practices (Cont.)

3.Enhancing Public-Private Partnerships (PPPs) to Scale 5G Innovation	❖ Establish National & Regional 5G Funds: Co-funding models for 5G infrastructure, AI-driven applications, and R&D. ❖ Facilitate Infrastructure Sharing Agreements: Encourage fiber-optic backhaul and network-sharing models to reduce deployment costs. ❖ Support 5G Adoption in Enterprises & SMEs: Provide subsidies & tax incentives to promote private 5G networks in manufacturing, logistics, and healthcare.	Germany: • Private 5G spectrum licensing for companies to develop smart factories and autonomous industrial solutions. • Government-co-funded R&D for AI-integrated 5G applications Malaysia: • Single wholesale network model to accelerate nationwide 5G rollout at reduced costs. • Telecom operators lease capacity instead of investing in separate infrastructure.
4.Fostering Regional Cooperation for a Unified ASEAN 5G Strategy	❖ Coordinate 5G Spectrum Policies: Align frequency bands, licensing models, and spectrum auctions to prevent market fragmentation. ❖ Develop ASEAN-Wide 5G Innovation Hubs: Enable cross-border R&D and testbeds for smart cities, industrial automation, and AI-driven applications. ❖ Create a Digital Economy Framework Agreement (DEFA): Standardize data governance, 5G security policies, and AI regulations across ASEAN.	Australia: • Bilateral and regional agreements on 5G technology transfer, cybersecurity, and digital economy frameworks. Thailand: • Harmonized spectrum allocation for low-latency cross-border telecom services. • Collaboration on 5G-enabled smart logistics and AI-driven regional connectivity. EU's Digital Single Market: • Ensures a seamless cross-border digital economy • Standardized spectrum policies and cross-border regulations to harmonize 5G deployment. • 5G roaming agreements to enable seamless digital services across EU nations.

6.7. Recommendation #7: Accelerating 5G Learning and Innovation for Growth and Success

ASEAN countries should take a proactive approach in fostering learning and innovation to accelerate the successful deployment of 5G use cases across industries. As 5G and AI evolve in synergy, nations that actively experiment, adapt, and innovate will gain a competitive edge in the global digital economy.

To implement this recommendation, ASEAN countries can focus on the following four strategic priorities:

1. Strengthening Knowledge Sharing and Capacity Building

- Establish regional AI-driven 5G innovation hubs to facilitate collaboration between governments, academia, and industry leaders.
- Invest in workforce development by expanding AI and 5G training programs for engineers, policymakers, and business leaders.
- Promote cross-border knowledge exchange to share best practices and lessons learned in 5G adoption.

2. Encouraging R&D and Industry-Led Innovation

- Provide incentives for startups and enterprises to experiment with AI-driven 5G applications.
- Foster sandbox environments and regulatory testbeds for piloting 5G use cases in sectors such as smart cities, healthcare, manufacturing, and logistics.
- Strengthen university-industry collaboration to drive the development of cutting-edge AI-powered 5G solutions.

3. Scaling Real-World 5G Use Cases

- Accelerate early adoption of AI-integrated 5G solutions in key economic sectors.
- Support public-private partnerships (PPPs) to scale successful pilot projects into nationwide deployments.
- Develop a clear commercialization roadmap to ensure a seamless transition of innovative 5G applications from testing to market adoption.

4. Enhancing Policy and Regulatory Support

- Establish agile, forward-looking policies that foster a dynamic, innovation-driven 5G ecosystem.
- Ensure harmonized spectrum allocation to enable faster and more efficient 5G rollouts.
- Streamline regulatory approval processes for deploying 5G infrastructure and AI-driven applications.

Building on these strategic priorities, the following illustrative cases highlight key lessons and practical applications. Table 6.7 presents selected lessons across three key aspects: the innovation front, key features with examples, and implications for ASEAN countries. Additionally, Box 6.1 showcases Singapore's practical experiences, providing a roadmap for regional adoption and adaptation.

Table 6.7. Advancing Innovation in 5G Use Case Deployment: International Best Practices

Innovation Front	Feature and Case Studies	Policy Implication for ASEAN
1. Private 5G Networks for Smart Factories	Dedicated spectrum for industrial 5G networks; BMW utilizes AI-driven automation and real-time quality control.	Allocate spectrum for private 5G networks; Encourage AI-driven automation and smart manufacturing practices.
2. Digital Twin Technology for Real-Time Monitoring	Real-time simulation of manufacturing processes; Siemens' Amberg Electronics Plant achieves 99.99% automation efficiency.	Establish regional digital twin testbeds for key industries; Integrate AI-driven monitoring in production facilities.
3. 5G-Enabled Collaborative Robotics (Cobots)	Cobots leverage AI, 5G, and IoT sensors for seamless human-machine collaboration; Volkswagen improved assembly efficiency by 30%.	Promote 5G-powered cobots in electronics, automotive, and semiconductor industries; Develop specialized vocational training programs for AI-driven automation.
4. Public-Private Workforce Upskilling	Fraunhofer Institutes train workers in 5G & AI automation; German government funds workforce reskilling.	Partner with global tech firms for 5G-AI workforce training; Provide incentives for digital skills training.
5. Private 5G Networks for Factories	Qualcomm launched 5G industrial testbeds; Qualcomm's 5G factory improved efficiency by 30%.	Set up 5G testbeds in industrial zones; Governments to allocate dedicated 5G spectrum for enterprises.
6. 5G-Powered AI & Edge Computing	Qualcomm's AI edge computing chips enable real-time factory analytics; used by John Deere for predictive maintenance.	Deploy AI-driven 5G edge computing in manufacturing; Support real-time AI analytics for predictive maintenance.
7. 5G-Powered Supply Chain & Logistics	Qualcomm & UPS use 5G IoT for smart warehouse automation; achieved 20% increase in logistics efficiency.	Integrate 5G in logistics hubs & ports; Promote AI-powered tracking & warehouse automation.
8. 5G Smart Cities & AI Initiatives	Qualcomm deployed AI-powered 5G smart traffic & surveillance in NYC; reduced congestion & enhanced efficiency.	Adopt 5G-powered AI for traffic & security management; Collaborate with Qualcomm for smart city pilots.
9. Public-Private Training for 5G Workforce	Qualcomm Thinkabit Lab provides hands-on AI & 5G training; 5G scholarships upskill engineers in IoT & AI.	Launch regional 5G training programs in partnership with Qualcomm to upskill engineers and startups. Initial pilots could involve key partners such as VSIP Group, the National University of Singapore (NUS), Viettel, and Singapore Polytechnic (SP).

Table 6.7. Advancing Innovation in 5G Use Case Deployment: International Best Practices (Cont.)

Innovation Front	Feature and Case Studies	Policy Implication for ASEAN
10. 5G Smart Factories	Ericsson's 5G smart factory in the U.S. increased production by 300%; Nokia automated Volkswagen factories.	Establish ASEAN's private 5G smart factories; Promote AI-driven robotic automation.
11. 5G Smart Ports & Logistics	Ericsson's 5G Smart Port in Rotterdam improved cargo processing by 20%; AI traffic control optimized fuel efficiency.	ASEAN ports should adopt 5G IoT for real-time tracking & automation; Partner with Ericsson for smart port testbeds.
12. 5G Smart Cities & Public Safety	Nokia's 5G-powered surveillance & smart grid in Dubai improved response times by 30%; AI-driven monitoring.	Governments should integrate 5G AI solutions for public safety; Build 5G-powered emergency response networks.

Box 6.7. Advancing Innovation in 5G Use Case Deployment: Singapore's Experience

Singapore, recognized for its proactive approach in developing policies and initiatives to promote 5G innovation and drive the deployment of 5G use cases across various industries, offers valuable insights for implementing this recommendation.
In terms of policies supporting innovative 5G deployment, the Infocomm Media Development Authority (IMDA) has played a pivotal role in fostering collaboration between CSPs and businesses, accelerating the adoption of 5G-powered solutions across key sectors.

Key Policy Initiatives:
5G Innovation Programme IMDA launched this initiative to accelerate 5G adoption in industries such as Robotics & IoT, AI & Data, and AR/VR. The program aims to commercialize and deploy 5G solutions, with funding support of up to 70% for approved projects.
Strategic Focus Areas: IMDA has identified four key clusters for 5G deployment:

- Maritime Operations: Enhancing port automation through real-time data analytics.
- Urban Mobility: Optimizing transportation with connected vehicles and smart traffic systems.
- Smart Estates: Developing intelligent infrastructure for better resource efficiency.
- Industry 4.0: Driving manufacturing innovation through automation and data exchange

Notable 5G Use Cases:

- Smart Factory: The Hyundai Motor Group Innovation Center Singapore (HMGICS) leverages 5G and advanced automation to revolutionize EV manufacturing. Partnering with Singtel, it employs a private 5G network for real-time data, digital twin simulations, and quality control. A cell-based production system replaces traditional conveyor belts, enhancing flexibility with AI and robotics. HMGICS also offers customizable EV options and VR factory tours, setting a new standard for smart manufacturing and Industry 4.0.
- Port Operations Automation: A 5G mmWave trial in collaboration with PSA, Singtel, and M1 demonstrated 50% latency reduction, enabling the scaling of Automated Guided Vehicles (AGVs) and Rubber Tire Gantry cranes (aRTG) at Tuas Mega Port.
- Autonomous Vehicles (AV): In 2024, FairPrice Group (FPG) received approval from the Land Transport Authority (LTA) to trial self-driving vehicles on public roads. Additionally, IMDA is exploring the possibility of permitting driverless trucks to operate at night (12:00 AM – 5:00 AM). This initiative aims to enhance logistics efficiency, address labor shortages, and reduce traffic accidents by leveraging off-peak hours for safer and more efficient transportation.
- Healthcare Transformation: Partnering with the National University Health System (NUHS), IMDA introduced 5G-enabled solutions for telemedicine and remote patient monitoring, reinforcing Singapore's role in smart healthcare innovation.
- With support from IMDA, Weston has deployed 5G-powered autonomous electric vessels to clean rivers and detect trash using real-time video analytics. Operated remotely via 5G connectivity, these unmanned surface vessels enhance operational efficiency, reduce reliance on manual labour, and cut carbon emissions by up to 80%.

6.8. Recommendation #8: Workforce Development for AI-Driven Digital Transformation with AI-Integrated 5G as a Priority

Each ASEAN country, along with the region as a whole, should implement forward-looking workforce development programs to accelerate AI-driven digital transformation, with a strong emphasis on AI-integrated 5G deployment and service development. These programs should offer comprehensive training covering technical, operational, and regulatory aspects of 5G while ensuring the seamless integration of AI-powered applications across industries.

The rapid deployment and adoption of 5G in AI-driven digital transformation demand a highly skilled workforce to manage its technical, regulatory, and operational complexities. This policy recommendation presents comprehensive strategies to develop a workforce that supports digital transformation across ASEAN, enhancing both national and regional competitiveness in the global digital economy

The AI-integrated 5G workforce development programs should achieve the following primary objectives:

- Develop a highly skilled workforce to support 5G deployment, AI integration, and cloud computing.
- Foster collaboration between academia, industry, and government to enhance workforce development.
- Ensure continuous upskilling and reskilling of professionals in telecommunications and related industries.
- Promote inclusivity by enabling SMEs and startups to access 5G talent.

Implementing this recommendation should focus on the following five key areas:

(i) Strengthening Education and Training Programs

- Integrate 5G, AI, and cloud computing into university curricula, covering network infrastructure, cybersecurity, and IoT applications.
- Develop specialized vocational training for technicians, engineers, and IT professionals in 5G deployment and maintenance.
- Partner with international institutions to create certification programs aligned with global 5G standards.

- Adopt best practices from global and ASEAN workforce development initiatives.

(ii) Enhancing Industry-Academia Collaboration

- Establish 5G innovation hubs in partnership with universities and research institutions for hands-on training and R&D.
- Provide industry-sponsored scholarships and internships for students specializing in 5G and related technologies.
- Encourage telecom companies to co-develop curricula to ensure industry-relevant skills.
- Strengthen AI-focused collaboration between academia and industry to advance automation, predictive analytics, and intelligent network management.

(iii) Upskilling and Reskilling Programs

- Implement national reskilling initiatives to transition telecommunications professionals into 5G technologies.
- Offer government-subsidized workshops and online courses on emerging 5G applications, including edge computing, network slicing, and private 5G networks.
- Develop mentorship and apprenticeship programs with experienced industry professionals.
- Focus on AI-driven competencies such as machine learning, data analytics, and AI-powered cybersecurity to enhance workforce adaptability.

(iv) Government Incentives and Support

- Provide tax incentives and grants for companies investing in 5G workforce development.
- Facilitate access to research funding for universities and private firms involved in 5G skill-building.
- Establish regulatory frameworks that encourage private sector investment in 5G talent development.
- Support AI-driven skill development initiatives aligned with global best practices.

(v) Encouraging SME and Startup Participation

- ❖ Provide affordable access to 5G training resources and consultancy services for SMEs and startups.
- ❖ Develop incubation programs to support entrepreneurs in 5G-enabled products and services.
- ❖ Establish public-private partnerships to ensure equitable access to 5G talent across businesses of all sizes.
- ❖ Leverage ASEAN and international collaboration to equip SMEs with AI-driven 5G applications and training opportunities.

Several leading economies have successfully implemented workforce development initiatives for 5G and AI adoption. Key international and ASEAN best practices are outlined in Table 6.8 below.

Table 6.8: AI-Integrated 5G Workforce Development Initiatives – Selected Global and ASEAN Best Practices

Country Area of Focus	Workforce Development Initiatives
South Korea AI & 5G Talent Programs	❖ Integrated 5G and AI education into vocational training centers and universities, fostering a strong talent pipeline. ❖ The Korean New Deal promotes digital upskilling through partnerships between the government, telecom companies, and academic institutions.
Germany Industry 4.0 Workforce Upskilling	❖ Government and industry collaboration for retraining workers transitioning from legacy industries to 5G-powered smart manufacturing. ❖ Fraunhofer Institutes focus on applied research and industrial training in 5G-enabled automation and AI integration.
United States Public-Private 5G Initiatives	❖ The National Telecommunications and Information Administration (NTIA) funds training programs for 5G engineers and cybersecurity experts. ❖ Tech companies like Verizon, AT&T, and Qualcomm collaborate with universities to offer certifications in 5G and AI applications. ❖ NICE Program provides a framework for cybersecurity, AI, and cloud computing training in collaboration with Google and Microsoft.
China 5G AI Education and Innovation Centers	❖ Established 5G AI Innovation Hubs integrating industry-driven curricula in technical universities. ❖ Telecom giants like Huawei and ZTE support nationwide AI and 5G workforce training programs.
Singapore TechSkills Accelerator (TeSA)	❖ Multiagency initiative offering modular courses on 5G, AI, and cybersecurity for professionals. ❖ Collaboration with Google, AWS, and IBM to develop certified training pathways.
Malaysia MyDIGITAL Initiative	❖ Focuses on upskilling local talent in 5G and AI through partnerships with telecom providers and global tech firms. ❖ 5G testbeds and AI hubs support hands-on industry training.
Thailand Digital Talent Development Alliance	❖ Aims to train 1 million digital workers by 2027 in AI, 5G, and cloud computing. ❖ Government incentives for corporate-led training programs in 5G-related skills.

6.9 Recommendation #9: Strengthening Cybersecurity

ASEAN countries, both individually and as a region, must proactively address the unique cybersecurity challenges posed by 5G networks, given their transformative capabilities and critical infrastructure role.

ASEAN countries, both individually and collectively, must proactively recognize and address the evolving cybersecurity challenges associated with 5G networks. The transformative nature of 5G—enabling ultra-fast connectivity, massive IoT integration, and AI-driven automation—also introduces new vulnerabilities, including increased attack surfaces, supply chain risks, and threats to critical infrastructure. As 5G becomes the backbone of digital economies, governments and industry stakeholders must implement robust security frameworks, enhance cross-border cooperation, and adopt global best practices to safeguard networks, data, and national security interests.

It is essential for ASEAN countries to prioritize cybersecurity and resilience in 5G networks to safeguard critical infrastructure and data. Building on global and regional best practices, Table 6.9 outlines five key strategies for strengthening 5G cybersecurity, highlighting relevant global and ASEAN best practices along with recommended action steps.

Table 6.9: Key Strategies for Enhancing 5G Network Cybersecurity

Strategy	Best Practice	Action Steps
1. Implement Zero-Trust Architecture (ZTA)	The U.S. Cybersecurity and Infrastructure Security Agency (CISA) emphasizes detecting malicious activities within 5G cloud infrastructures to prevent network compromises. cisa.gov	• Continuous Verification: Regularly authenticate and authorize all devices and users. • MicroSegmentation: Divide the network into smaller segments to contain breaches. • Advanced Threat Detection: Use AI-driven tools for real-time monitoring and response.
2. Strengthen Supply Chain Security	The European Union Agency for Cybersecurity (ENISA) provides guidelines on 5G cybersecurity standards, emphasizing secure supply chains. *(enisa.europa.eu)*	• Vendor Assessment: Conduct thorough security evaluations of suppliers and partners. • Compliance Requirements: Ensure adherence to international security standards. • Regular Audits: Perform periodic reviews to address emerging threats.
3. Secure IoT and Edge Devices	Singapore's Cyber Security Agency (CSA) has developed IoT cybersecurity guidelines for secure 5G deployments. *(asean.org)*	• Security by Design: Integrate security measures during IoT device development. • Regular Firmware Updates: Apply timely patches to fix vulnerabilities. • Network Monitoring: Continuously monitor devices to detect and mitigate threats.
4. Develop Comprehensive Cybersecurity Frameworks	The ASEAN Cybersecurity Cooperation Strategy (2021–2025) promotes regional policy harmonization and trust in cyberspace. *(asean.org)*	• Policy Harmonization: Align national cybersecurity policies with regional standards. • Capacity Building: Invest in training programs for cybersecurity professionals. • Information Sharing: Create platforms for exchanging threat intelligence among ASEAN nations.
5. Invest in Cybersecurity Innovation	Singapore has allocated SGD 8 million to establish a center for researching 5G vulnerabilities and developing security measures. *(opengovasia.com)*	• Research and Development: Fund projects to identify and mitigate 5G security threats. • Public-Private Partnerships: Collaborate with industry leaders to drive cybersecurity innovation. • Pilot Programs: Test new security technologies in controlled environments before deployment.

6.10 Recommendation #10: Strengthening ASEAN Cooperation and Coordination to Leverage 5G for AI-Driven Digital Transformation Across Countries and Sectors

ASEAN countries should fully recognize the critical importance and substantial benefits of regional collaboration and coordination, making it a priority in their efforts to leverage 5G for AI-driven digital transformation. A unified approach should be intentionally designed into their digital transformation strategies to enhance efficiency, effectiveness, and resilience, drive innovation, accelerate economic growth, and ensure sustainable success in the digital era.

ASEAN's ability to fully capitalize on 5G and AI integration depends on strong regional cooperation and policy alignment. A fragmented approach could lead to inefficiencies, cybersecurity risks, and uneven digital development across member states. By working together, ASEAN countries can maximize economic, technological, and strategic advantages, particularly in the five key areas, outlined in Table 6.10A.

To strengthen regional cooperation and coordination, ASEAN countries should collaborate closely to achieve the following shared key objectives:

i. **Enhance Policy and Regulatory Coordination:** Foster harmonized 5G policies across ASEAN to create a seamless digital ecosystem.

ii. **Strengthen Cross-Border Collaboration:** Facilitate joint projects and research initiatives on AI-powered 5G applications.

iii. **Promote Public-Private Partnerships:** Engage governments, industry leaders, and academia in developing AI and 5G-enabled solutions.

iv. **Ensure Inclusive Development:** Support SMEs and startups in adopting AI-driven 5G technologies to drive economic growth.

v. **Bolster Cybersecurity and Infrastructure Resilience:** Establish common frameworks to address emerging security challenges in AI-integrated 5G networks.

Table 6.10A. Key Advantages of ASEAN's Cooperation in Leveraging 5G for AI-Driven Digital Transformation

Key Advantage	Description & Benefits
Ensuring Seamless Digital Connectivity Across Borders	• Harmonized 5G regulations and standards enable cross-border digital trade, smart logistics, and supply chain integration. • Unified AI-driven digital services (e.g., fintech, e-government, smart cities) enhance interoperability across ASEAN markets. • Strengthening regional digital infrastructure prevents bottlenecks and inefficiencies in 5G deployment.
Economies of Scale and Cost Efficiency	• Joint investments in 5G infrastructure, spectrum sharing, and AI research reduce deployment costs for individual ASEAN countries. • Shared data centers, cloud platforms, and cybersecurity frameworks minimize redundancy and optimize resources.
Regional Synergy for Innovation and Competitiveness	• Cross-border collaboration accelerates AI-driven 5G applications in smart cities, manufacturing, and digital services. • ASEAN-wide standardization of regulations and policies ensures smooth interoperability and attracts global investors. • A unified digital ecosystem strengthens ASEAN's global position as a tech and innovation hub.
Enhanced Cybersecurity and Digital Resilience	• Coordinated efforts in cybersecurity frameworks, threat intelligence sharing, and data protection laws improve regional security. • Joint AI-driven cyber defense mechanisms protect critical infrastructure and digital economies. • Reduces reliance on foreign technologies, ensuring regional digital sovereignty.
Scalable Talent Development and Workforce Mobility	• ASEAN-wide AI & 5G training programs create a robust talent pipeline for future industries. • A shared labor mobility framework enables the free movement of skilled professionals across ASEAN markets. • Public-private partnerships enhance AI and 5G workforce readiness, benefiting all member states.

For implementing Recommendation #10, ASEAN countries should collaborate on the following joint initiatives outlined in Table 6.10B:

Table 6.10B: Joint Initiatives for Implementing Recommendation #10

Initiative	Key Actions
1. Establish an ASEAN 5G & AI Task Force	• Facilitate cooperation among policymakers, regulators, and industry players. • Develop joint strategies for spectrum management, network security, and digital innovation.
2. Develop Common Standards and Best Practices	• Align regulatory approaches for AI-integrated 5G networks to ensure interoperability and security. • Leverage global and ASEAN best practices to enhance 5G adoption.
3. Facilitate Workforce Development and Talent Exchange	• Implement regional training programs to equip professionals with AI and 5G expertise. • Encourage student and researcher exchanges between ASEAN institutions.
4. Enhance ASEAN-wide Infrastructure and Investment Strategies	• Promote joint investments in 5G deployment, especially in underserved areas. • Support SMEs and startups in leveraging AI-driven 5G applications.
5. Sign Bilateral and Multilateral Digital Economy Agreements	• Strengthen cross-border digital trade and data-sharing frameworks. • Foster regional agreements to harmonize digital regulations, cybersecurity measures, and AI governance.
6. Create a Regional 5G AI Innovation Hub	• Encourage knowledge-sharing and R&D partnerships across ASEAN nations. • Provide funding and incentives for cross-border innovation in AI-powered 5G solutions.

Section 7

Conclusion: Unlocking 5G-AI to Propel ASEAN's Digital Leadership

The deployment and adoption of 5G across ASEAN represents a once-in-a-generation opportunity to reshape the region's digital future. While ASEAN has made important strides, uneven adoption and persistent gaps in infrastructure, spectrum policy, institutional capacity, and workforce readiness continue to hold back its full potential.

As the global economy enters a new era defined by AI, cloud computing, and hyper-connectivity, 5G is the foundational enabler. It underpins smart cities, powers next-generation industries, transforms essential services, and makes real-time, AI-driven decision-making possible across every sector of society.

To secure a strategic competitive advantage, foster inclusive economic growth, and realize sustainable development, ASEAN must act with boldness and urgency. This report presents ten strategic policy recommendations, among which five are especially critical for immediate action:

7.1. Five Strategic Priorities for ASEAN's 5G-AI Future

1. Develop a Forward-Looking National 5G-AI Strategy

Each ASEAN country, and the region as a whole, should develop a forward-looking 5G AI-Driven Development Strategy with a clear roadmap for 2025–2030. This strategy must define a compelling value proposition, prioritize high-impact sectors (e.g., manufacturing, healthcare, agriculture, education), and outline actionable plans with measurable milestones.

To catalyse innovation, ASEAN should launch the 5G-AI Innovation Challenge to support startups and SMEs through mentorship, testbeds, and regional pilot opportunities.

5G is more than a connectivity upgrade—it is the backbone of AI-powered digital transformation. To unlock its full potential, stakeholders must prioritize:

1. Synergizing 5G and AI to accelerate innovation across sectors.
2. Driving enterprise 5G adoption to fuel productivity and growth.

3. Creating a virtuous cycle between infrastructure investment and high-value 5G services.

A strong strategy will position ASEAN as a global leader in next-generation digital innovation.

2. Establish a Dedicated National 5G-AI Lead Agency

Each ASEAN country should designate a dedicated national agency to lead 5G-AI strategy, coordinate implementation, and accelerate adoption across sectors. This agency will align national priorities, industry needs, and emerging technologies—laying the foundation for 6G readiness and digital competitiveness.

Key functions include:

1. Strategic Planning – Develop and update the national 5G-AI roadmap.
2. Spectrum & Infrastructure – Manage spectrum, support private 5G, and enable PPPs.
3. Industry Adoption – Scale enterprise and SME use in key sectors.
4. Regulatory Oversight – Establish legal, cybersecurity, and data frameworks.
5. Monitoring – Track progress through performance metrics.

Private 5G networks are critical to innovation, especially for SMEs. Governments must ensure affordable infrastructure, access to spectrum, and testbeds. ASEAN can draw on best practices from Singapore (IMDA), Malaysia (DNB), and Thailand (NBTC) to tailor effective governance models and avoid falling behind.

3. Implement a Future-Ready Spectrum Policy and Strengthen Regulatory Support

A forward-looking spectrum policy—backed by clear, adaptive regulation—is essential for accelerating 5G deployment, optimizing spectrum use, and unlocking next-generation innovation. ASEAN countries should align spectrum strategies with market demand, national priorities, and technological evolution to ensure sustainable, cost-effective 5G growth.

Three key imperatives stand out:

1. Plan inclusively – Coordinate spectrum planning across government, industry, and regulators; balance competing needs through cost-benefit analysis.
2. Design efficient awards – Select allocation methods (auctions, CFPs, or direct awards) based on national goals; ensure fair pricing and reinvest proceeds to support 5G-AI innovation.
3. Ensure regulatory clarity – Define licensing terms, technology use, and deployment rules to support efficient spectrum utilization and market competitiveness.

By optimizing allocation, streamlining regulation, and fostering cross-sector collaboration, ASEAN can maximize 5G's socio-economic impact and pave the way for 6G.

4. Develop Robust KPIs to Assess 5G-AI Readiness and Advancement

ASEAN countries should establish a comprehensive framework of Key Performance Indicators (KPIs) to assess and monitor 5G-AI readiness and adoption at both enterprise and national levels. These KPIs must reflect the convergence of 5G and AI, be aligned with international standards and be co-developed with communications service providers (CSPs), technology firms, and key stakeholders.

This measurement framework will not only accelerate enterprise adoption but also guide evidence-based policymaking and foster cross-country learning to strengthen ASEAN's digital competitiveness.

At the organizational level, three core pillars are vital for successful 5G-AI integration:

- Network Infrastructure Readiness: Compatibility with 5G devices, AI-enabling edge/cloud architectures, and real-time data processing.
- Spectrum & Connectivity Readiness: Access to high-capacity spectrum, scalable small-cell deployment, and low-latency infrastructure.
- Security & Compliance Readiness: Robust cybersecurity, ethical AI governance, and data protection frameworks.

These pillars form the backbone of a scalable, secure, and future-ready 5G-AI ecosystem.

5. Cultivate a Vibrant AI-Driven 5G Ecosystem

A thriving 5G-AI ecosystem cannot be driven by innovation alone—it demands deep, sustained collaboration across the entire digital value chain. Governments, communications service providers (CSPs), technology companies, universities, and regional institutions must work in close coordination to foster trust, co-creation, and strategic public-private partnerships (PPPs). These alliances are essential to accelerate deployment, scale transformative solutions, and unlock meaningful economic value across ASEAN.

At the core of this ecosystem lies a critical, non-negotiable foundation: the development of advanced digital infrastructure. It is the bedrock upon which all 5G-AI innovation depends, enabling stakeholders to connect, compute, and collaborate at scale. Without it, the full promise of 5G and AI cannot be realized.

ASEAN must therefore approach infrastructure investment with the same urgency and commitment as innovation itself—advancing both in parallel to build a resilient, inclusive, and globally competitive digital economy.

7.2. Envisioning ASEAN's 5G-AI Future: From Factories to Fields

To bring this strategy to life, ASEAN must also envision the human impact of 5G-AI transformation. Imagine:

- Smart manufacturing has become a way of life, with robots, digital twins, and predictive analytics transforming supply chains.
- Farmers using smartphones and IoT sensors to monitor soil moisture, forecast weather patterns, and automate irrigation—boosting yields, reducing waste, and increasing incomes.
- Autonomous vehicles, unmanned surface vessels, and drones navigate smart logistics corridors, clean waterways, and streamline cross-border supply chains.
- Surgeons performing critical procedures remotely, supported by zero-latency, AI-enhanced robotic systems.
- Smart cities thrive, enhancing livability, sustainability, and operational efficiency
- Students in remote areas access immersive virtual classrooms, learning side by side with peers in global hubs.

- People communicating across languages in real-time, breaking barriers with instant AI translation over 5G networks.

These are no longer distant dreams—they are the reality 5G and AI can enable.

7.3. The Path Forward: From Readiness to Leadership

Unlocking these possibilities will require more than just infrastructure—it demands visionary leadership, multi-stakeholder coordination, and agile policy execution. ASEAN must ensure high-level alignment between strategy, regulation, investment, and innovation.

If the region acts boldly now, it can not only close the digital divide—but lead the global conversation on inclusive, AI-driven transformation. The 5G-AI window is open. The time to act is now.

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Appendices

Appendix 1

mmWave Technology in ASEAN — A Strategic Enabler for Industrial IoT

As ASEAN countries accelerate their digital transformation—driven by rapid advancements in AI and the widespread rollout of 5G—millimeter wave (mmWave) technology is emerging as a critical enabler of next-generation Industrial IoT (IIoT). Operating in high-frequency bands (typically above 24 GHz), mmWave supports ultra-high-speed data transmission, ultra-low latency, and massive device density—capabilities essential to realizing the full potential of smart factories, precision agriculture, autonomous systems, and real-time industrial automation.

1. mmWave as a Differentiator for True Industrial IoT

Unlike sub-6 GHz 5G or legacy wireless systems, mmWave offers the performance required for real-time, high-bandwidth, mission-critical IIoT applications, such as:

- Machine vision and AI-based quality control
- Remote robotic operations with near-zero latency
- Digital twins and immersive XR for manufacturing
- Time-sensitive networking (TSN) for synchronized production
- Edge AI deployments requiring high-throughput connectivity

mmWave is more than a speed upgrade—it is a foundational technology that differentiates advanced IIoT ecosystems from basic connectivity solutions, enabling a step-change in industrial productivity and automation.

2. ASEAN's Strategic Approach to mmWave Deployment

ASEAN member states are adopting deployment strategies that align spectrum policy, industrial priorities, and infrastructure readiness:

(i) Spectrum Policy and Licensing Readiness

- Countries like Singapore, Malaysia, and Thailand are moving toward dedicated mmWave spectrum for industrial 5G use.

- Regulators are exploring private/local 5G licenses to support smart factories and innovation districts.

(ii) Pilots in High-Value Sectors

- Trials are underway in smart ports (e.g., Port of Singapore), logistics hubs, and electronics clusters in Malaysia and Vietnam.
- These serve as testbeds for AGVs, predictive maintenance, and real-time quality control.

(iii) Public–Private Ecosystem Development

- Governments are fostering partnerships between telcos, multinational firms, and startups to accelerate mmWave-based IIoT solutions.
- Incentives are being provided for 5G labs, industrial sandboxes, and edge-cloud pilots.

(iv) Targeted Infrastructure Investment

- Investments are focused on industrial parks, SEZs, and urban innovation corridors where mmWave's short-range, high-capacity advantages are maximized.
- Successful deployment depends on co-investment in fiber backhaul and dense small-cell networks.

3. ASEAN-Wide Collaboration Opportunities

To ensure equitable and scalable adoption, ASEAN should strengthen regional collaboration in:

- Harmonized cross-border standards for mmWave-enabled IIoT
- Joint investment frameworks for industrial innovation hubs
- Knowledge and technology transfer from mmWave frontrunners (e.g., Singapore, South Korea) to emerging ASEAN economies

In conclusion, mmWave presents a strategic opportunity to accelerate ASEAN's industrial transformation. In high-impact sectors such as manufacturing, logistics, and smart infrastructure, mmWave enables next-generation applications that boost productivity, innovation, and sustainability. While challenges remain—particularly in cost, coverage, and regulatory harmonization—targeted, high-value deployments of mmWave can position ASEAN as a competitive, connected, and future-ready industrial powerhouse.

Appendix 2

Appendix A. Executive Opinion Survey on 5G Development (December 2024-January 2025)

- *Instructions: This survey utilizes a 1-5 Likert scale. Please circle the number that best represents your view based on the context in your own country*
- *Confidentiality: To maintain respondent anonymity, only aggregate results from the survey sample will be reported.*

Question 1. Please indicate your expectations for the next five years (2025 to 2030) for each of the digital technology policy issues listed below, evaluated across two dimensions: (a) the pace of deepening/penetration and (b) the economic impact.

Issue	Very slow/ Quite insignificant	Slow/ Insignificant	Moderate	Rapid/ Significant	Very rapid/ Very significant
5G					
Q1.5G_a. Pace of deepening	1	2	3	4	5
Q1.5G_b. Economic impact	1	2	3	4	5
Generative AI					
Q1.AI_a. Pace of deepening	1	2	3	4	5
Q1.AI_b. Economic impact	1	2	3	4	5
Digital transformation (DX)					
Q1.DX_a. Pace of deepening	1	2	3	4	5
Q1.DX_b. Economic impact	1	2	3	4	5

Question 2. How important is each of the following six stakeholders in driving 5G development in your country?

Operator	Not Important	Somewhat Important	Rather Important	Very Important	Extremely Important
Q2.1. Universities	1	2	3	4	5
Q2.2. Government agencies	1	2	3	4	5
Q2.3. Telecom Industry	1	2	3	4	5
Q2.4. Vendors	1	2	3	4	5
Q2.5 Technology providers	1	2	3	4	5
Q2.6 International/ regional organizations	1	2	3	4	5

Appendix 2B. Cronbach's Alpha of the Executive Opinion Survey by Country

To evaluate the internal consistency and validity of the Executive Opinion Survey administered across eight ASEAN countries, we computed Cronbach's alpha for each country's dataset. Cronbach's alpha is a widely recognized measure of scale reliability and internal consistency, commonly used as an indicator of construct validity in social science and technology adoption research (Nunnally, 1978; DeVellis, 2016). According to conventional benchmarks (George & Mallery, 2003), a coefficient of 0.70 or higher is considered acceptable, indicating that the items reliably measure the same underlying construct.

Across all eight countries—Indonesia (IDN), Cambodia (KHM), Myanmar (MMR), Malaysia (MYS), Philippines (PHL), Singapore (SGP), Thailand (THA), and Vietnam (VNM)—Cronbach's alpha values exceeded this threshold, demonstrating a high level of internal consistency. As shown in Table 4.3 (Section 4), Indonesia reported an alpha of 0.7621, Cambodia 0.7750, Malaysia 0.7926, and the Philippines 0.7787, all indicating acceptable reliability. Higher values were observed in Singapore (0.8563), Vietnam (0.8727), Myanmar (0.9292), and Thailand (0.9365), reflecting very strong internal consistency.

These results compare favorably with prior research employing similar validation methods. For instance, Davis (1989) and Venkatesh et al. (2003) reported Cronbach's

alpha values above 0.70 when validating constructs within the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT). Similarly, studies on technology adoption in developing contexts, such as Hoque and Sorwar (2017) and Tarhini et al. (2015), reported reliability coefficients between 0.75 and 0.90. The World Bank's Enterprise Surveys also rely on Cronbach's alpha to assess internal consistency of perception-based indicators across countries and sectors (World Bank, 2016).

In summary, the consistently high Cronbach's alpha coefficients across all eight countries provide strong evidence of the internal reliability and construct validity of our survey instrument. These results support the appropriateness of the items used to capture expert perceptions on 5G deployment and ecosystem development, ensuring confidence in both cross-country comparisons and subsequent analyses.

Appendix 3

Structured Interview Questions for Targeted Stakeholders on 5G Deployment in ASEAN Countries (Interview Period: October–December 2024)

Our interview is focused on gaining insights into the following areas (13 main questions):

1. Do you believe that embracing 5G will significantly impact the economic growth and competitiveness of your country over the next 5 years (2025-2030)?
2. Assessment of the current dynamics of 5G deployment in the country
    a. The pace during the past three years: above or below the region's average; why?
    b. Expectation over the next three years: above or below the region's average; why?
3. Spectrum allocation for 5G
    a. What are the priorities for the following:
        i. Low band (e.g. clearing more low band for coverage)
        ii. Mid-band (e.g. releasing more mid-band for capacity)

iii. Hi-band (e.g. technology and device development and adoption)

b. Which frequency bands are expected to be assigned for 5G over the next three years?
c. In your view, what could be the optimal approach for spectrum allocation and the bidding process. (e.g. beauty contest, auction, other)

4. Elaborate the key drivers and barriers to 5G deployment, including why they exist and what policy measures can be implemented to enhance the drivers and address the obstacles.

5. Highlight the key policy initiatives launched by the government in your country to promote 5G adoption and innovation.
    a. Share your government's key incentives to promote innovation in 5G adoption and its use cases.
    b. Provide examples of how leveraging local expertise and complementary investments can enhance the returns on 5G adoption and innovation.

6. What do you think are the key components of an effective 5G eco-system?

7. Assess the vitality and development of the 5G ecosystem in your country.

8. Provide your perspective of the role of international and regional cooperation and coordination in accelerating 5G deployment in ASEAN countries.
9. How important are the following in driving 5G deployment in your country?
    a. Universities
    b. Government agencies
    c. Industry

d. Vendors
e. Technology provider

10. What are the most promising 5G use cases that you believe can be monetised in your country within the next 3-5 years?
11. What are the top priorities that you would recommend for accelerating 5G deployment in your country?
    a. Government policy?
    b. The business sector?
    c. Telcom operators?

12. What do you believe is the optimal number of operators for an efficient market? And why?

13. What single policy would encourage rollout and adoption of 5G?