Report

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Global IPv6 Development Report 2022

Measurement, analysis on socioeconomic impact and policy recommendations

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Table of Contents

Executive Summary

With the advent of new communication and information technologies, everything in the world is more closely connected, forming a huge network that bridges people and things. Future-shaping technologies such as AI, 5G, cloud, and IoT are like threads that connect us together.

A fundamental enabler lies at the core of all these technologies: the IP address. It gives devices a "key" that they need to connect to the network; without it, they can't talk to each other.

The previous protocol used for IP addressing was IPv4, which was designed in the early 1980s with a maximum total of only 4.3 billion addresses. The explosive growth of intelligent devices has exhausted the available IPv4 addresses, and IPv6 was introduced to solve this problem once and for all. With $3.8*10^{38}$ total addresses available, IPv6 would be able to assign every grain of sand on earth an IP address.

On the basis of providing massive address resources, IPv6 is also developing continuously. In addition to providing basic IP addresses, IPv6 provides higher-quality and smarter connections through the combination of emerging technologies, namely IPv6 Enhanced Innovation[1][2], offering more future possibilities and accelerainge the deployment of advanced business applications like 5G, cloud, and industrial IoT.

At this moment, we find it necessary to reflect on how the world has progressed in this transition and summarize the concrete socio-economic value IPv6 Enhanced Innovation have created. We construct an IPv6 Development Index and reference data from public databases to calculate and provide a country-level measurement of IPv6 development status. The framework is based on the well-acknowledged approaches previously adopted by the Latin American and Caribbean Internet Address Registry (LACNIC)[3], the Organization for Economic Cooperation and Development (OECD)[4], and Cisco[5]. In terms of data sources, we use data from Asia Pacific Internet Network Information Center (APNIC), Cisco and authoritative research institutions and organizations such as Routeviews, OVH and WOS as raw data input to ensure data reliability and objectivity.

Based on datasets referenced from above databases, we used the Index model to calculate Index result for 92 countries to measure their IPv6 development status, , and conducted a quantitative analysis of the economic impact of IPv6 Enhanced Innovation in various industries. On this basis, we divided 92 countries into three groups according to the level of IPv6 development and identified 3 countries as benchmark countries, and performed an in-depth analysis of their development. In addition, this year's report further analyzes the value, status, and reasons for IPv6 development in 15 countries around the world and puts forward tailored recommendations.

In policy recommendations, this report has been comprehensively upgraded compared with the 2021 study. Based on the common challenges and main differences between the development of IPv6 Enhanced Innovationin different groups of countries, we put forward detailed and executable recommendations for different country ranking groups of IPv6 Development Index.

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[1] ETSI White Paper No. 35 “IPv6 Best Practices Benefits Transition Challenges and the Way Forward”, 2020.08

[2] ETSI GR IPE 001 “IPv6 Enhanced Innovation: Gap Analysis”, 2021.08

[3] IPv6 Deployment for Social and Economic Development

[4] Internet Addressing: Measuring Deployment of IPv6, K.Perset, OECD digital economy paper No.172, Apr 2010

[5] Internet IPv6 Adoption: Methodology, Measurement and Tools

The results are strongly in favor of IPv6 Enhanced Innovation development though our analyses and estimates may be subject to limitations in sample scope and size: In 2025, it is estimated that the total industry value brought by IPv6 Enhanced Innovation will reach 7.3 trillion US dollars.

In conclusion, now is the perfect time for deployment of IPv6 Enhanced Innovation. Industry-wide adoption of IPv6 Enhanced Innovation has taken off. Major telecom operators, internet content providers, and equipment manufacturers have all participated in the rush into a new digital world.

1. IPv6: definition and value

In today's world, IP address is an important basic resource of the Internet, the basis for identification and data transmission between systems, and an important infrastructure for high-quality development of the global economy. However, with the wide application of the Internet, challenges and constraints of the global Internet Protocol version 4 (IPv4), such as the exhaustion of IP addresses and the difficulty in guaranteeing service quality, have become increasingly prominent due to the undervalued demand for both size and quality for IP addresses by the development of the Internet and the digital economy in the early stage of Internet design. In this context, it is gradually becoming a globally acknowledged consensus that we should **vigorously develop and deploy Internet Protocol Version 6 (IPv6) following the guidelines and best practices from IPv6 Enhanced Innovation. This will provide sufficient network addresses and broad innovation space for Internet and the digital economy.**

IPv6 Enhnaced Innovation guide to a proper deployment of IPv6 protocol as a basis to other functionalities defined in IETF, like SRv6. Innovative applications will provide much more convenient, open, intelligent, and secure internet and to facilitate an intelligent world where everything is intelligently connected.

1.1 Overview of IPv6

The IP address is the basis of the IP protocol (Internet Protocol) and is the unique identifier for network devices to access the Internet or a local network. Internet Protocol version 6 (IPv6) is the latest IP revision, developed as a successor to IPv4. While greatly enhancing the address pool, IPv6 and its updated technologies can connect and empower more other technologies to promote the overall development of society.

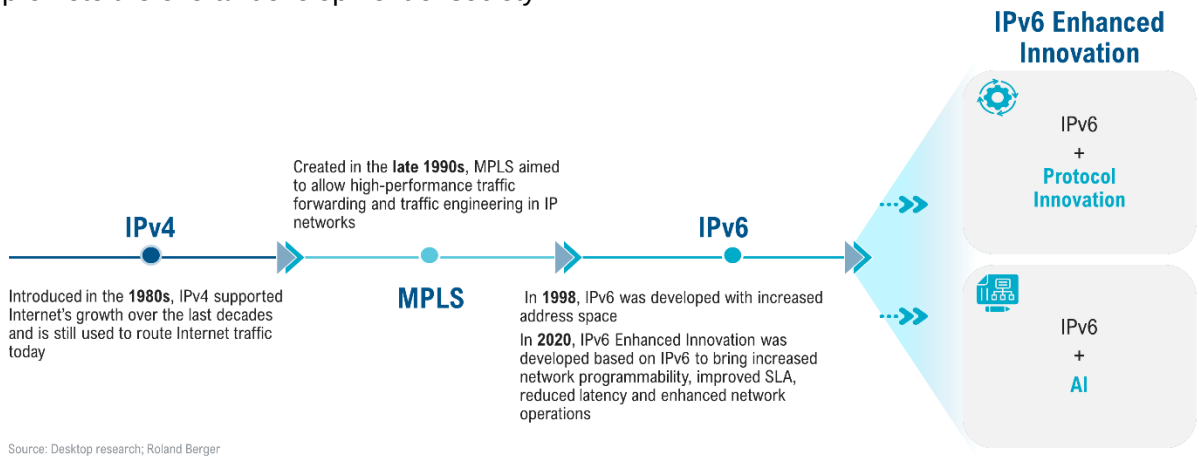
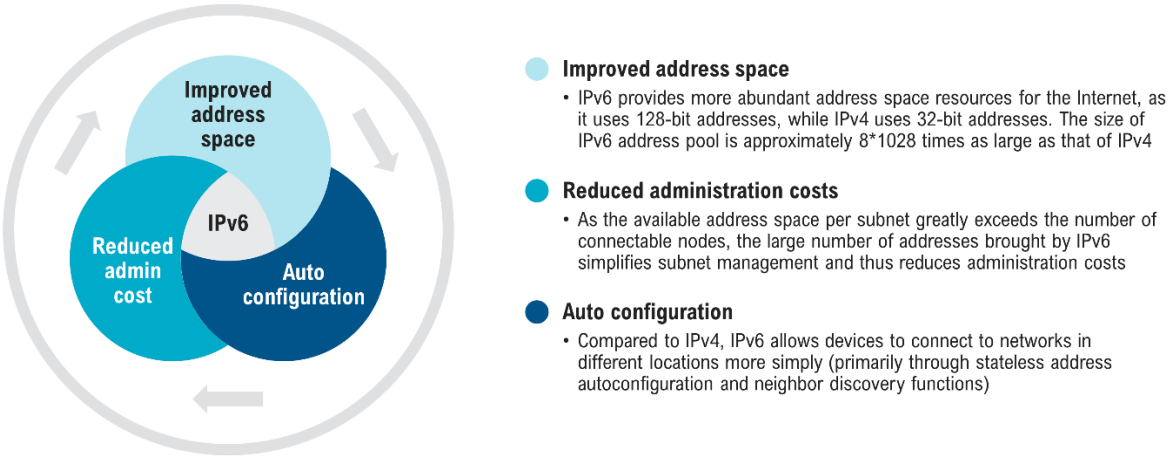


Figure 1. Development of IP technology

IPv6 technical advantages:

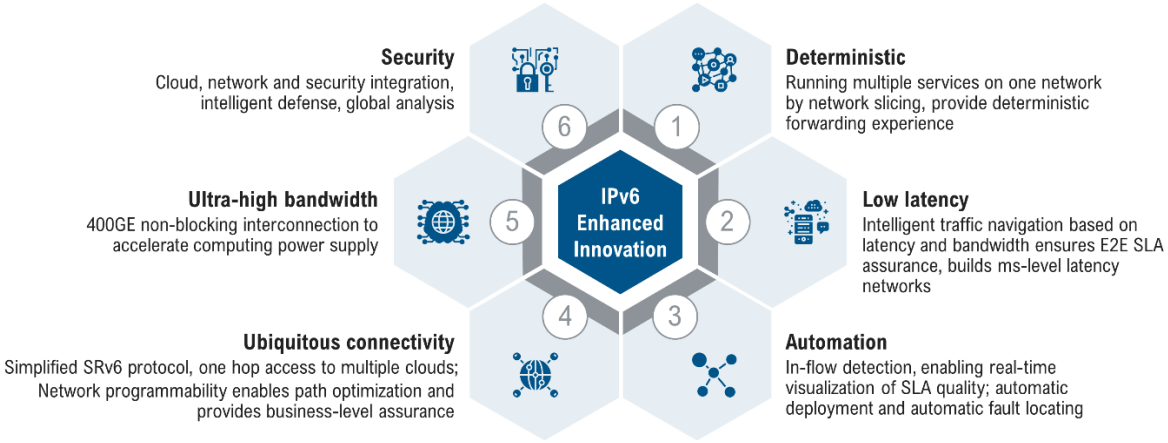


Source: Desktop research, expert interview; Roland Berger

Figure 2. IPv6 technical advantages

Advantages and technical features of IPv6 Enhanced Innovation

Based on IPv6 massive addresses, IPv6 Enhanced Innovation comprehensively improves IP network capabilities in six dimensions of ultra-broadband, wide connection, determinism, low latency, automation and security, and provides services for governments, operators, enterprises and enterprises in various industries and usage scenarios. The requirements of end users in various usage scenarios provide a high-quality foundation.



- *In October 2021, **ETSI partnered with 15 leading IP industry players** to publish its first report **ETSI GR IPE 001 "IPv6 Enhanced Innovation: Gap Analysis"***

Source: Desktop research; Roland Berger

Figure 3. IPv6 Enhanced Innovation advantages and technical features[6]

Key technologies in IPv6 Enhanced Innovation includes SRv6, IPv6 Enhanced Innovation Network Slicing, IFIT, BIERv6 and APN6, etc.

1.2 Necessity of transition to IPv6 Enhanced Innovation

To fully support the development of the digital economy, large-scale deployment of IPv6 is the basis and necessary foundation for realizing an intelligent world where everything is

[6]ETSI GR IPE 001 “IPv6 Enhanced Innovation: Gap Analysis”, 2021.08

connected. Actively deploying IPv6 Enhanced Innovation innovative applications is an important measure to achieve higher-quality development based on IPv6 to better facilitate the 5G and cloud era.

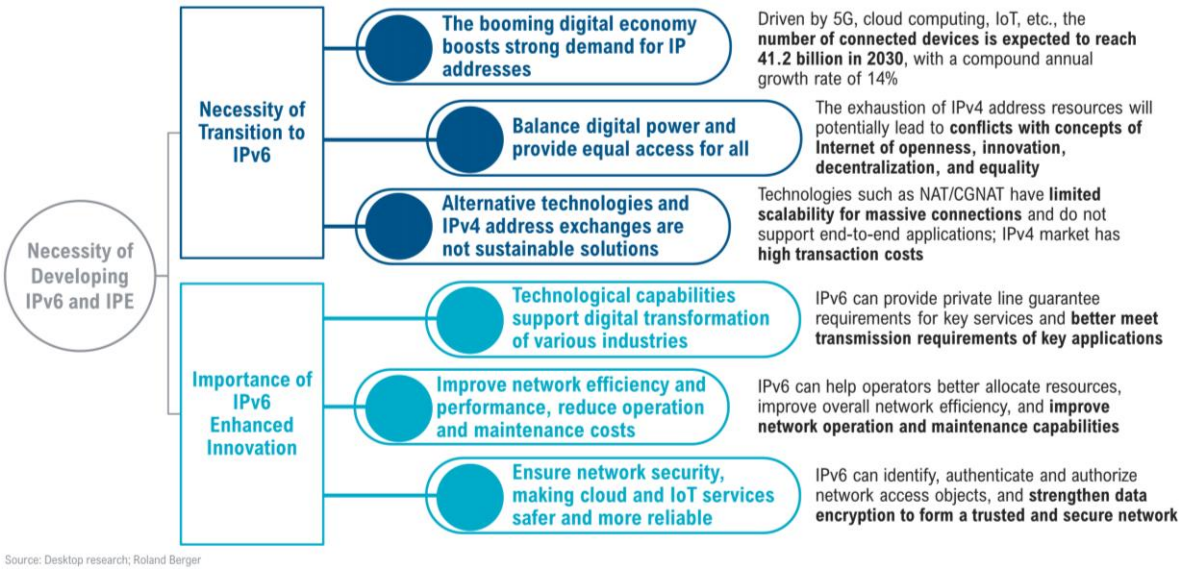


Figure 4. Necessity of Developing IPv6 Enhanced Innovation

1.3 Economic and social benefits of IPv6 Enhanced Innovation

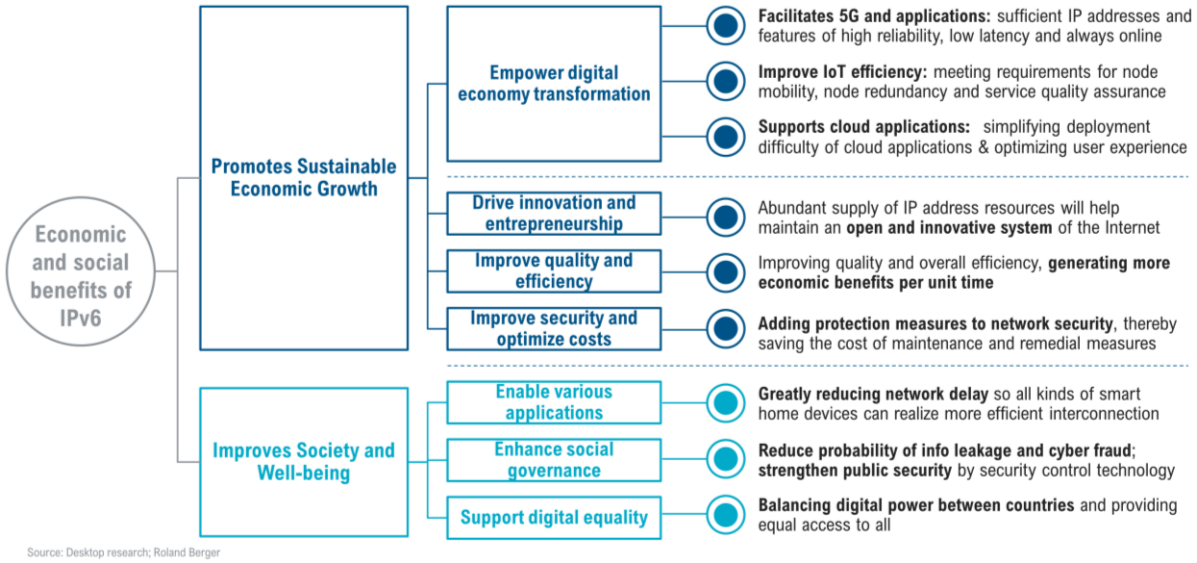


Figure 5. Social and economic benefits of IPv6 Enhanced Innovation

2. Industry Economic Value by IPv6

2.1 IPv6 economic impact 2025 estimate

2.1.1 IPv6 industry-sector economic impact model

Today the scope of IPv6 is not only IP addresses, but also includes IPv6 Enhanced Innovations including SRv6 and other technologies. IPv6 development will positively affect virtually every industry sector. Since industries have differing economic and regulatory structures that will affect the timing for IPv6 adoption, we chose 2025 as the analysis timeframe and focused on short-to-mid-term impact.

After analyzing the micro- and macro-economic impacts expected by IPv6, we projected forward to 2025, and looked at the economic contributions of IPv6 Enhanced Innovation through three lenses in 12 major industry sectors (See Appendix A for details). The first lens examined the value created by innovative technologies and their application scenarios, mainly focusing on 5G/IoT/cloud, empowered by IPv6 Enhanced Innovation. The second lens focused on the level of efficiency improvements enabled by IPv6 and IPv6 Enhanced Innovation. The third lens examined cost reduction by preventing data security issues with different issue type. The following provides an overview of the methodology for these three impacts.

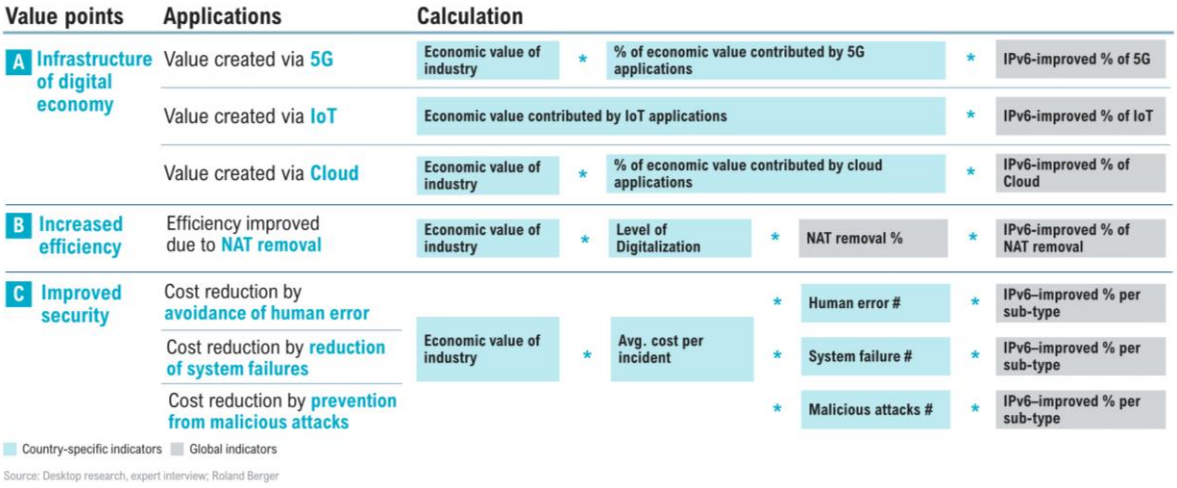


Figure 6. Methodology of IPv6 value creation by industry

2.1.2 IPv6 value creation by industry result analysis

Based on our model and expert input, we estimate that potential global value created across multiple industry sectors enabled by IPv6 could reach $7.3 trillion in 2025. This represents about 3.7% of all global real output in 2025.

IPv6 industry value creation:

The following figure presents the consolidated value enablement findings by industry, ranking from highest impact (information & communication, 5.1% of its total sales) to lowest impact (construction & real estate, 1.9% of its total sales).

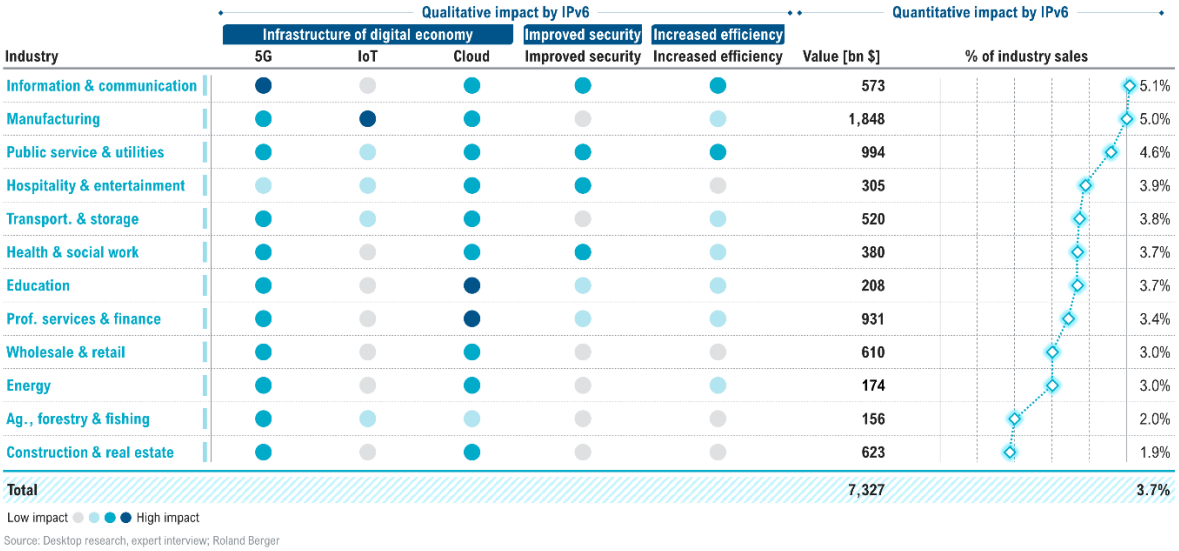


Figure 7. Global IPv6 value creation by industry

2.2 Major impacts and industry use cases of IPv6[7]

IPv6 as a fundamental enabler for other technologies have a wide range of impact on different industries. A detailed introduction of IPv6 Innovation enabled industry use-cases can be found in the full report.

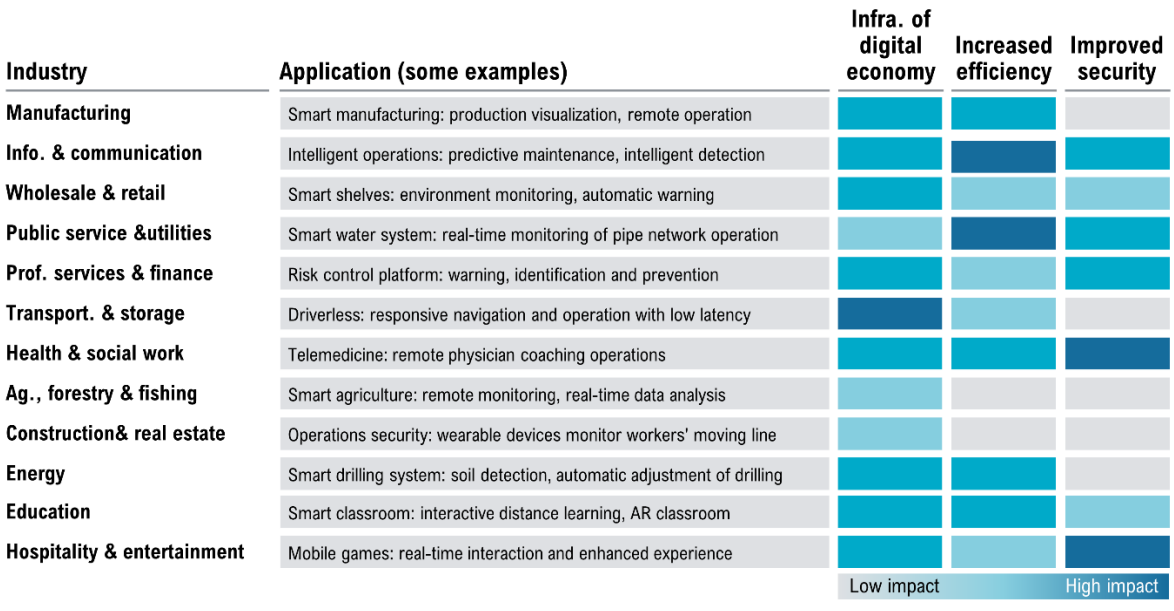


Figure 8. IPv6 enabled scenarios in each industry

[7] Based on desktop research from various press release and official websites

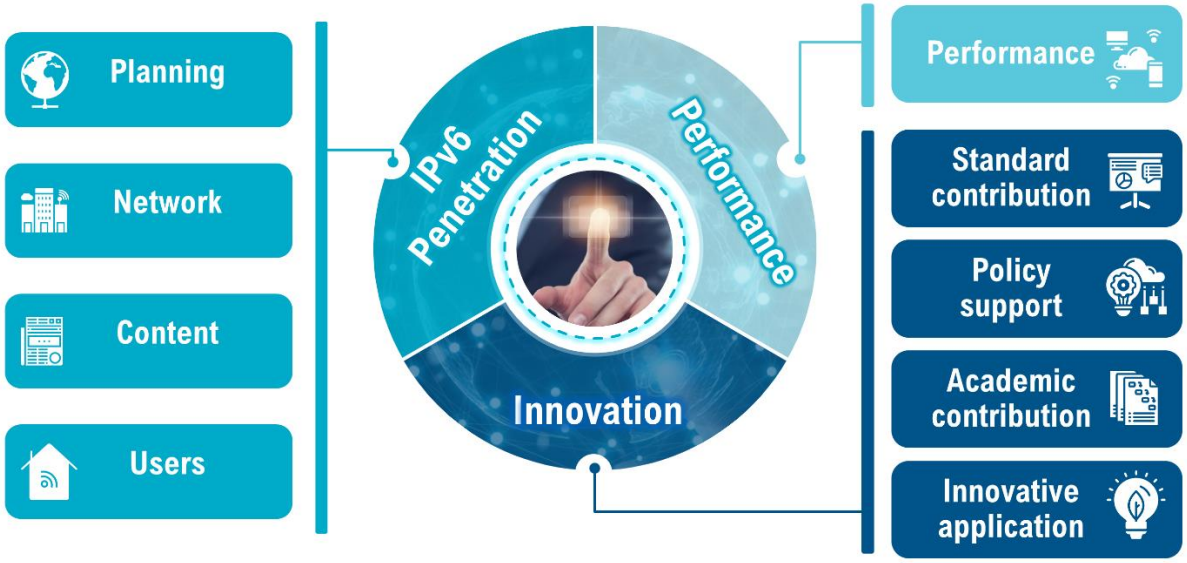
3. IPv6 Development Index and Country Analysis

3.1 IPv6 Development Index

Although IPv6 has great potential for economic value creation, each country has a different level of development. We construct an IPv6 Development Index that aims to provide a country-level measurement of IPv6 deployment status. The IPv6 Development Index is based on the well-acknowledged methodologies of the Latin American and Caribbean Internet Address Registry (LACNIC)[8], the Organization for Economic Cooperation and Development (OECD)[9], and Cisco[10].

3.1.1 Methodology

Based on references to the LACNIC, OECD and Cisco, we constructed the IPv6 Index by measuring the specificity of IPv6 in three major areas of deployment. **These three aspects are IPv6 pennetration (including IPv6 address planning, IPv6 deployment in networks, IPv6 deployment in content providers and user access to the network via IPv6), the performance of IPv6, and the level of innovation emphasizing on IPv6 Enhanced Innovation (including technical standards, policy, academics and pilot commercial projects of IPv6 Enhanced Innovation).**



Source: Desktop research; Roland Berger

Figure 9. Methodology of IPv6 Development Index

[8]IPv6 Deployment for Social and Economic Development
[9]Internet Addressing: Measuring Deployment of IPv6, K.Perset, OECD digital economy paper No.172, Apr 2010
[10]Internet IPv6 Adoption: Methodology, Measurement and Tools

Index Type	Level 1 dimension		Level 2 dimension			
Type	**Index**	**Indication**	**Index**	**Description**	**Source[11]**	**Weight**
IPv6 penetration	**Planning**	Ratio of allocated v6 prefixes to allocated v4 prefixes; Ratio of allocated IPv6 prefixes from which traffic has been seen to all allocated v6 prefixes	**Allocation of IPv6 prefixes**	Ratio of allocated v6 prefixes to allocated v4 prefixes	APNIC	8%
			Dev. of advertised IPv6 prefixes	Ratio of advertised v6 prefixes to allocated v6 prefixes	APNIC	8%
	Network	Measure the level of deployment of IPv6 in the network, incl. data centers of telecom operators and cloud service providers	**Adoption of IPv6 transit AS**	Ratio of dual-stack IPv6 Transit AS to all dual-stack Transit AS	Routeviews	17%
	Content	Measure the level of deployment of IPv6 in websites from content providers	**The website's support for IPv6**	Weighted ratio of IPv6 enabled to tested top 500 websites	OVH, Cisco, Google, Alexa	17%
	Users	Measure the accessibility to the internet through IPv6 for end-users	**End-user accessibility to IPv6**	Ratio of IPv6 capable users to number of internet users	APNIC	17%
Performance	**Performance**	Measure the quality of network and effects of IPv6 deployment during end-users' visits to the internet through IPv6	**Speed of IPv6 network connection**	Average RTT difference between IPv6 and IPv4 on dual stack end devices	APNIC	8%
			Reliability of IPv6 network connection	IPv6 failure rate on dual-stack end devices	APNIC	8%
Innovation	**Standard contribution**	Measure the contribution to international standards of IPv6 and IPv6 Enhanced innovation by each country	**Standard contribution**	# of companies, universities and other institutions in working groups of IEEE and IETF	IEEE, IETF	3%
	Policy support	Measure the # of organizations and supportive policies to promote IPv6 and IPv6 Enhanced innovation by each country	**Policy support**	# of org. established and policies published by the gov. to regulate the development of IPv6 and IPv6 Enhanced	Official websites	3%
	Academic contribution	Measure the academic contribution to IPv6 and IPv6 Enhanced innovation by each country	**Academic contribution**	# of academic papers on IPv6 and IPv6 Enhanced innovation technology published in top-level publications	WOS	3%
	Innovative application	Measure the level of deployment of IPv6 Enhanced innovation innovation projects to evaluate the capabilities of future innovation	**Innovative application**	# of operators and enterprises with IPv6 Enhanced Innovation pilots or commercial use cases	Desktop research	8%

[11] Data set in this report are as of August 2022; source includes APNIC IPv6 (https://stats.labs.apnic.net/ipv6/), APNIC v6pop (https://stats.labs.apnic.net/v6pop), APNIC v6perf (https://stats.labs.apnic.net/v6perf), APNIC roas (https://stats.labs.apnic.net/roas), etc. and desktop research

We use the weighting method to sum the sub-indicators involved in the three dimensions to calculate the final IPv6 development index of each country. The weight of each sub-indicator refers to the distribution of the indicator to balance different input variables. Finally, the IPv6 development index is calculated by normalizing different sub-indices, and the average value of each sub-indicator is calculated to determine the weight of the actual application.

The framework is based on approaches previously adopted by the OECD[12], LACNIC[13] and Cisco[14]. In terms of data sources, we use Asia Pacific Internet Network Information Center (APNIC), Cisco and other authoritative research institutions and organizations such as Routeviews, OVH and WOS as raw data input to ensure data reliability.

3.1.2 IPv6 Development Index result

The numerical range of the IPv6 development index is from 0 to 1, and a higher index value means a better development process of IPv6 and its innovative applications. We selected 92 countries around the world and calculated the IPv6 development index for each country in 2022 using data from the Asia-Pacific Internet Network Information Center (APNIC) and other relevant sources.

Based on the specific index values, we divide these countries into three categories: frontrunners, accelerators and starters. The Frontrunner countries are the top 25% of the IPv6 development index, the Starters are the bottom 25% of the countries, and the rest are the Accelerator countries. For the sake of comparability of indicators among different countries, we measure the deployment of IPv6 compared with IPv4 in the index.

[12]Internet Addressing: Measuring Deployment of IPv6, K.Perset, OECD digital economy paper No.172, Apr 2010
[13]IPv6 Deployment for Social and Economic Development
[14]Internet IPv6 Adoption: Methodology, Measurement and Tools

3.1.2.1 Global country ranking & groups

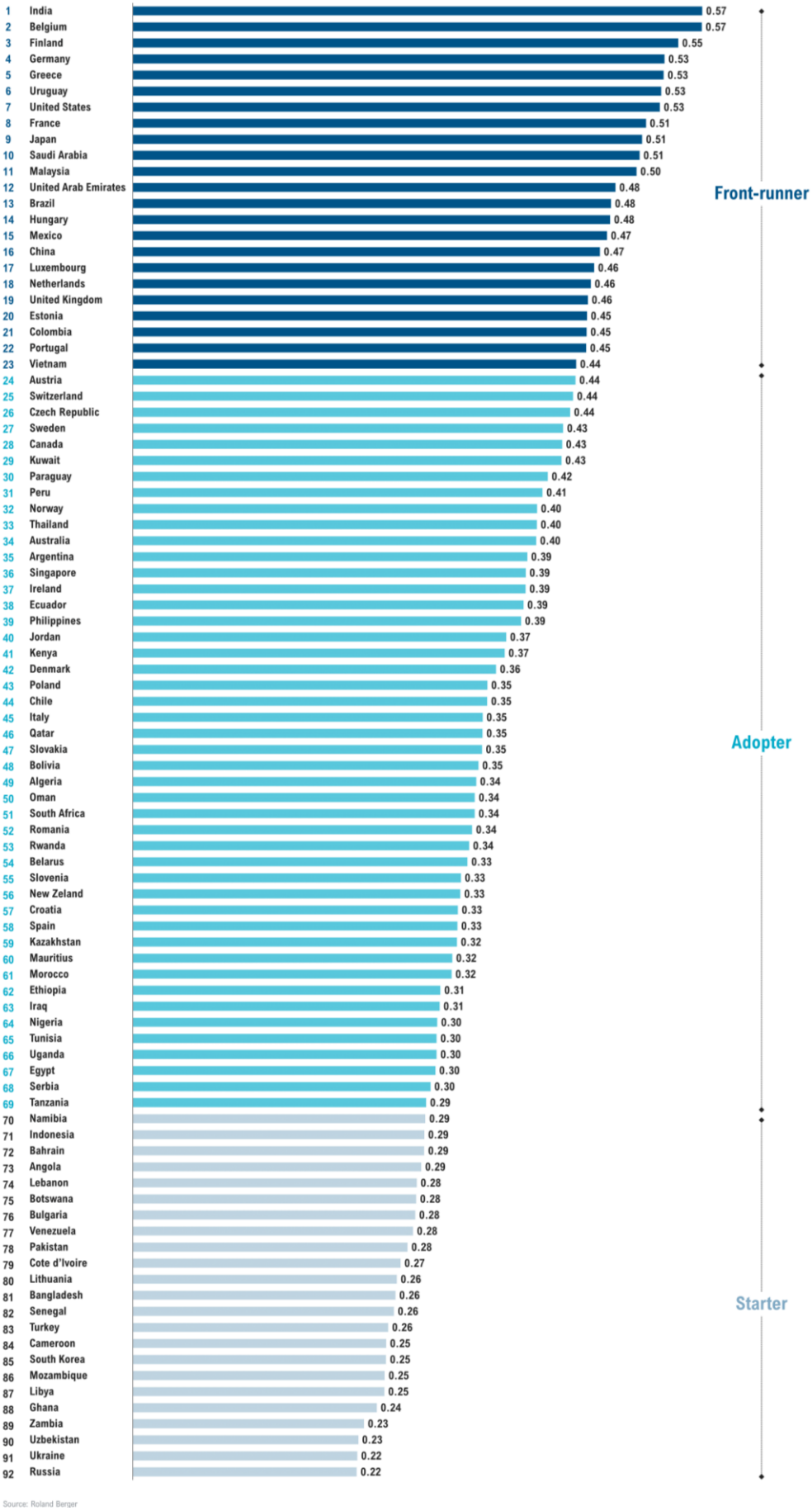


Figure 10. Country ranking of IPv6 Dvelopment Index

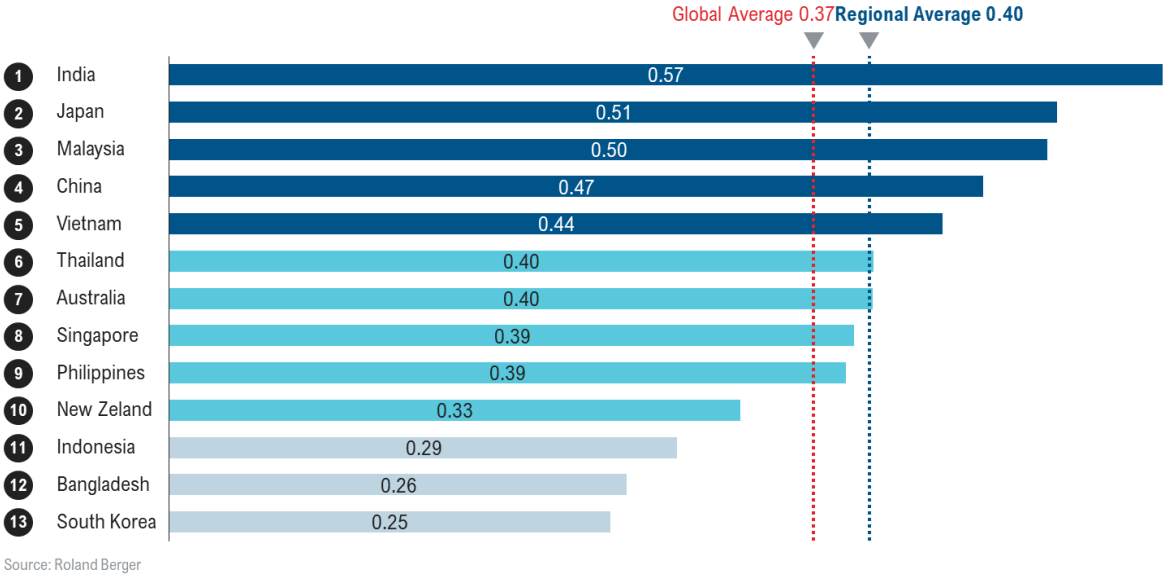
Front-runners		Adopters				Starters	
1	India	24	Austria	47	Slovakia	70	Namibia
2	Belgium	25	Switzerland	48	Bolivia	71	Indonesia
3	Finland	26	Czech Republic	49	Algeria	72	Bahrain
4	Germany	27	Sweden	50	Oman	73	Angola
5	Greece	28	Canada	51	South Africa	74	Lebanon
6	Uruguay	29	Kuwait	52	Romania	75	Botswana
7	United States	30	Paraguay	53	Rwanda	76	Bulgaria
8	France	31	Peru	54	Belarus	77	Venezuela
9	Japan	32	Norway	55	Slovenia	78	Pakistan
10	Saudi Arabia	33	Thailand	56	New Zeland	79	Cote d'Ivoire
11	Malaysia	34	Australia	57	Croatia	80	Lithuania
12	United Arab Emirates	35	Argentina	58	Spain	81	Bangladesh
13	Brazil	36	Singapore	59	Kazakhstan	82	Senegal
14	Hungary	37	Ireland	60	Mauritius	83	Turkey
15	Mexico	38	Ecuador	61	Morocco	84	Cameroon
16	China	39	Philippines	62	Ethiopia	85	South Korea
17	Luxembourg	40	Jordan	63	Iraq	86	Mozambique
18	Netherlands	41	Kenya	64	Nigeria	87	Libya
19	United Kingdom	42	Denmark	65	Tunisia	88	Ghana
20	Estonia	43	Poland	66	Uganda	89	Zambia
21	Colombia	44	Chile	67	Egypt	90	Uzbekistan
22	Portugal	45	Italy	68	Serbia	91	Ukraine
23	Vietnam	46	Qatar	69	Tanzania	92	Russia

Source: Roland Berger

Figure 11. Country Ranking of Global IPv6 Development Index

3.1.2.2 Regional country ranking

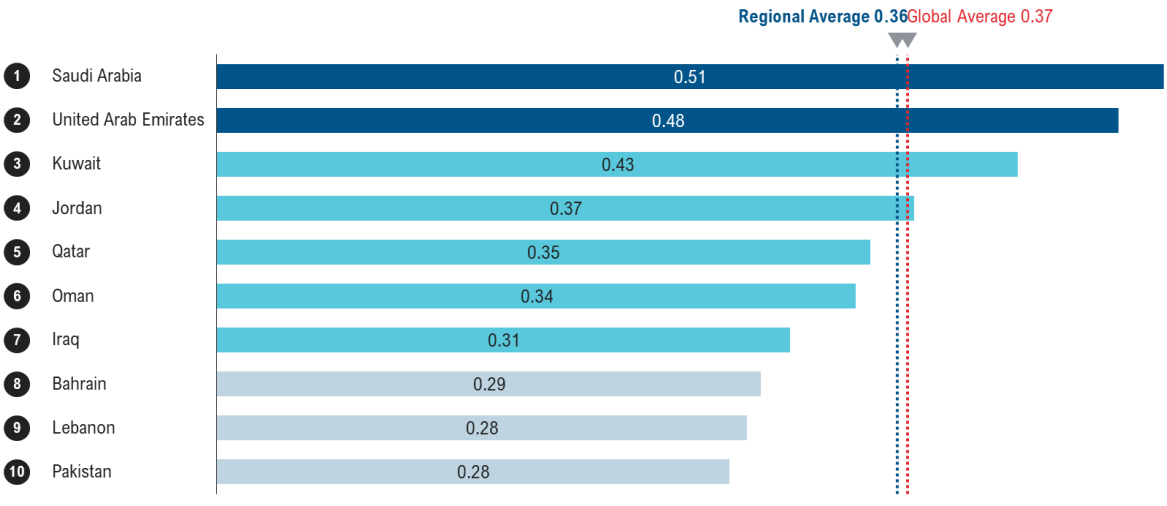
➢ **Asia Pacific**



Source: Roland Berger

Figure 12. Country ranking of global IPv6 Development Index – Asia Pacific

➢ **Middle East**



Source: Roland Berger

Figure 13. Country ranking of global IPv6 Development Index – Middle East

➢ Northern Africa

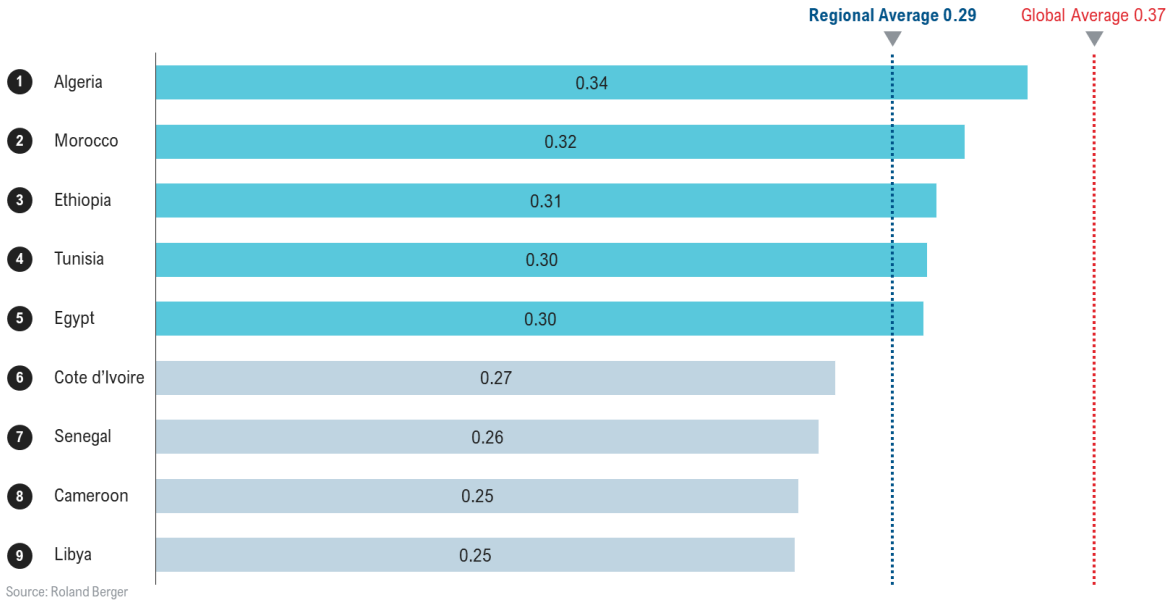


Figure 14. Country ranking of global IPv6 Development Index – Northern Africa

➢ Southern Africa

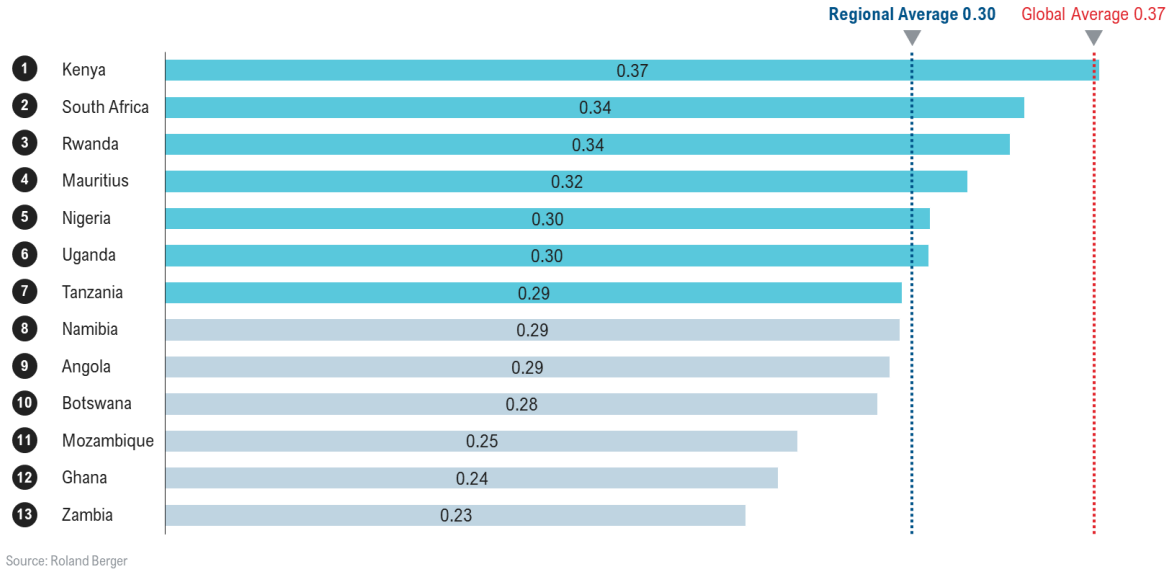


Figure 15. Country ranking of global IPv6 Development Index – Southern Africa

➢ Southern and Central America

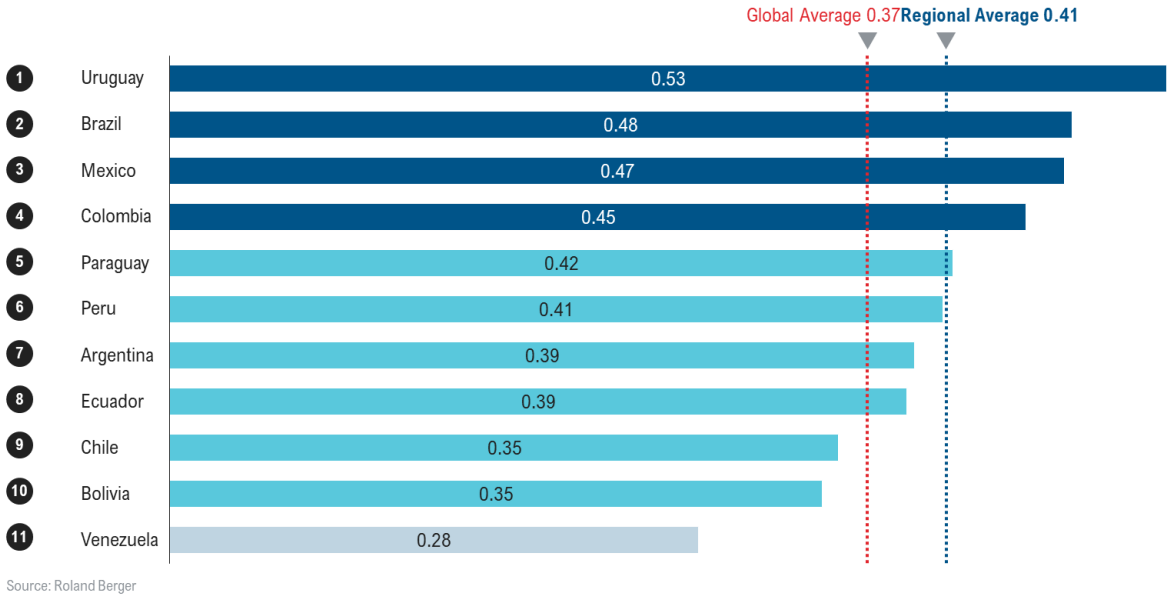


Figure 16. Country ranking of global IPv6 Development Index – Southern and Central America

➢ North America

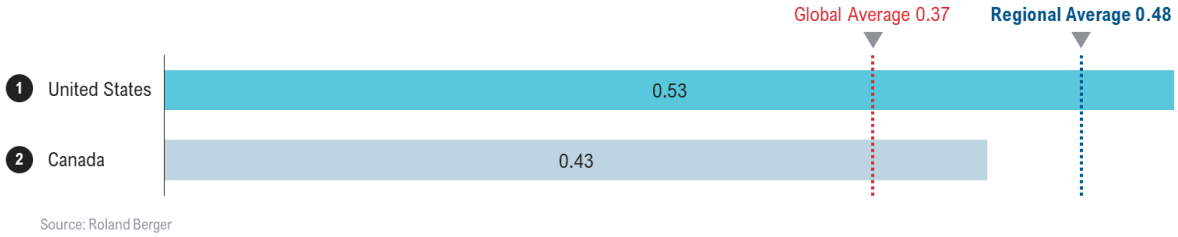


Figure 17. Country ranking of global IPv6 Development Index – North America

➢ Northern and eastern Europe

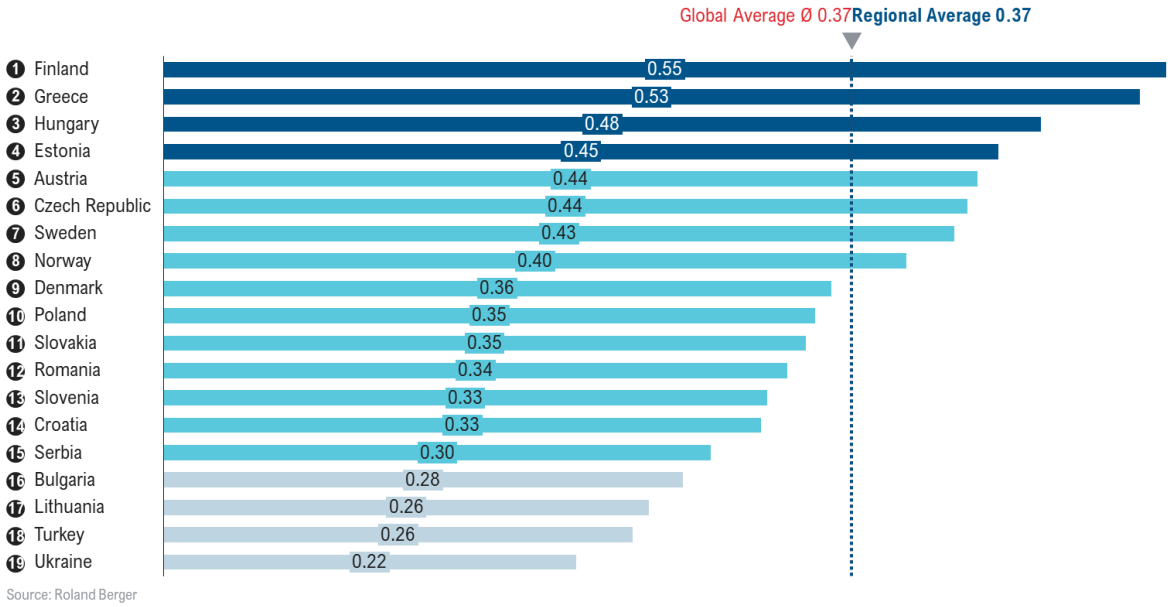


Figure 18. Country ranking of global IPv6 Development Index – Northern and eastern Europe

➢ Western Europe

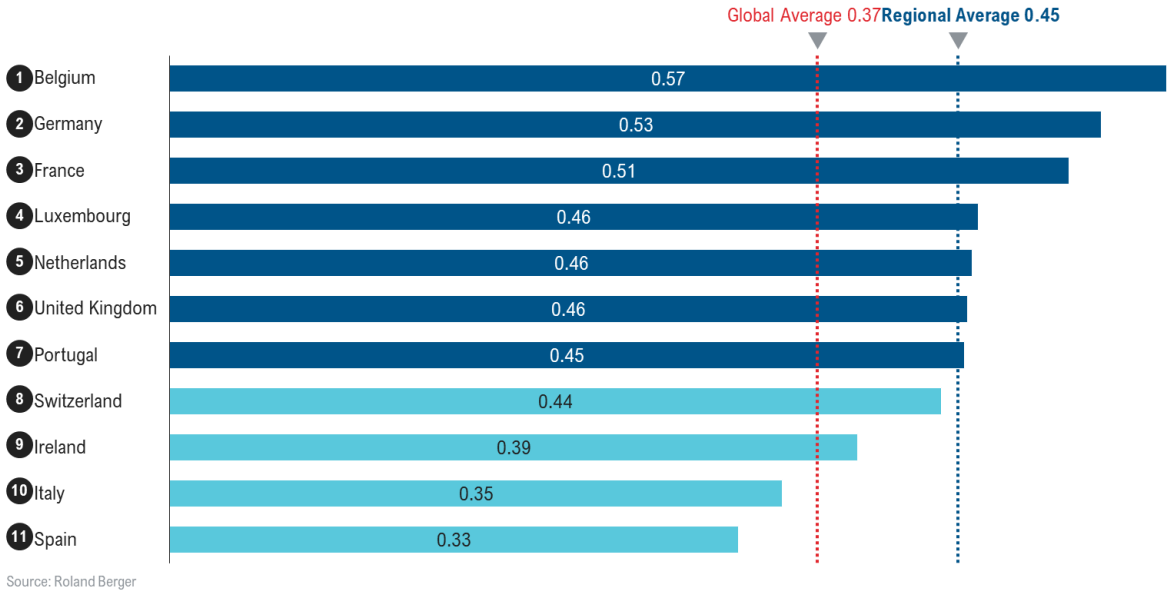


Figure 19. Country ranking of global IPv6 Development Index – Western Europe

➢ **Eurasia**

Figure 20. Country ranking of global IPv6 Development Index – Eurasia

3.1.2.3 Analysis of differences among groups

The average value of different development stages varies greatly, and the grouping method can better summarize and reflect the characteristics of the development stages of countries in each group and the elements that need to be completed. We categorize countries into three groups: **Front-runners, Adopters and Starters**. Among them, the leaders are countries that are relatively leading in the development of IPv6 and its innovative applications.

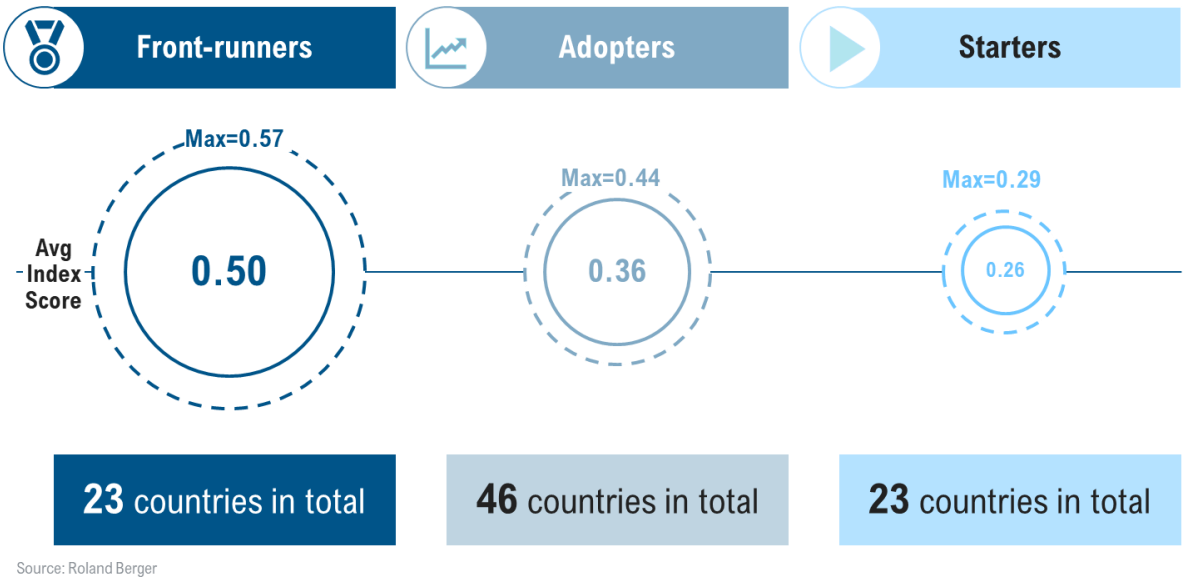


Figure 21. Average index score by groups

Driver analysis：

At the sub-indicator level of the IPv6 Development Index, the differences between countries mainly come from the four dimensions of network, users, performance and innovation. This illustrates the importance of improving users' ability to access the Internet through IPv6, deploying cutting-edge IPv6 innovative applications to improve IPv6 performance, and making sufficient cutting-edge preparations for the future.

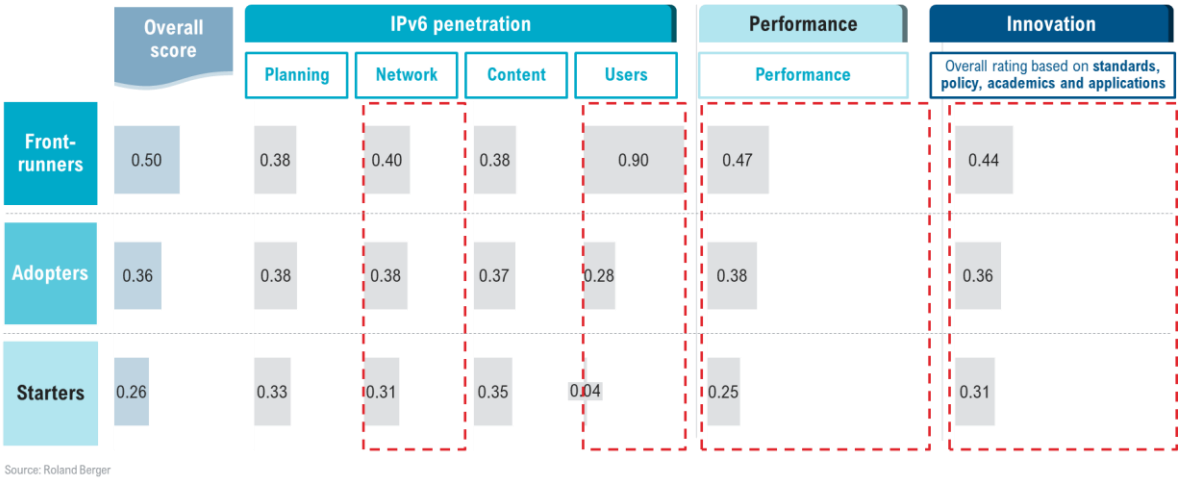


Figure 22. Average index score by groups

In the comparison of the various groups of the IPv6 Development Index, we found that performance and innovation are **the main factors that separate the differences among the three groups of front-runners, adopters, and starters:**

- **Performance:** There are certain differences among the three groups
  - **End-to-end equipment quality**: the quality of operator networks, content provider networks, and terminal equipment will directly affect the deployment of IPv6. The digitalization level of most starters and some accelerator countries is in the initial stage. Since operators have a relatively weak foundation in digital infrastructure equipment and applications, the deployment performance of IPv6 may be poor compared to the frontrunners.
  - **IPv4 deployment maturity**: Since the deployment of IPv4 line equipment in many countries is very mature, and IPv4-related optimization is complete, IPv6 equipment still needs time to be optimized. As a result, compared with IPv4, the performance advantages of IPv6 are difficult to fully reflect.

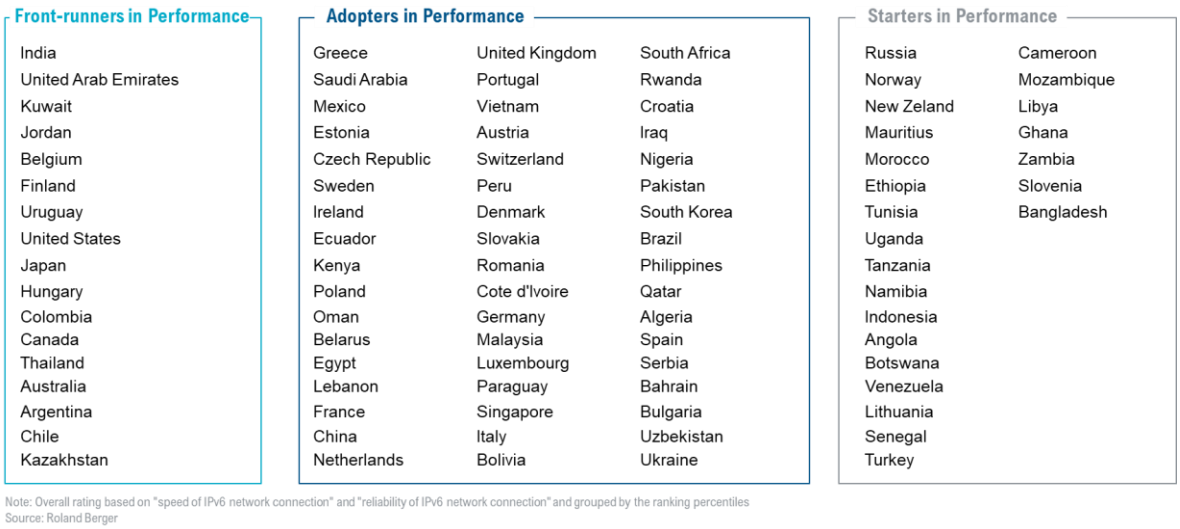


Figure 23. Country ranking of IPv6 Development Index – Performance

- **Innovation:** There are certain differences among the three groups
  - **The development process of IPv6 Enhanced innovation pilot projects:** the innovation initiatives of adopters and starters are more focused on carrying out commercial project pilot projects of IPv6IPv6 Enhanced innovative technologies in line with the trend. Most of the front-runners already have IPv6 Enhanced innovation commercial pilot projects such as SRv6, which has achieved an intergenerational leap in technology.
  - **IPv6 Enhanced technical capabilities:** Most of the leading countries are in the leading position in the accumulation of IPv6 Enhanced innovation and communication-related technologies and the degree of advanced disciplines, have strong capabilities to form technological breakthroughs and innovations, and deeply participate in the formulation of IPv6IPv6 Enhanced innovation-related industry standards.

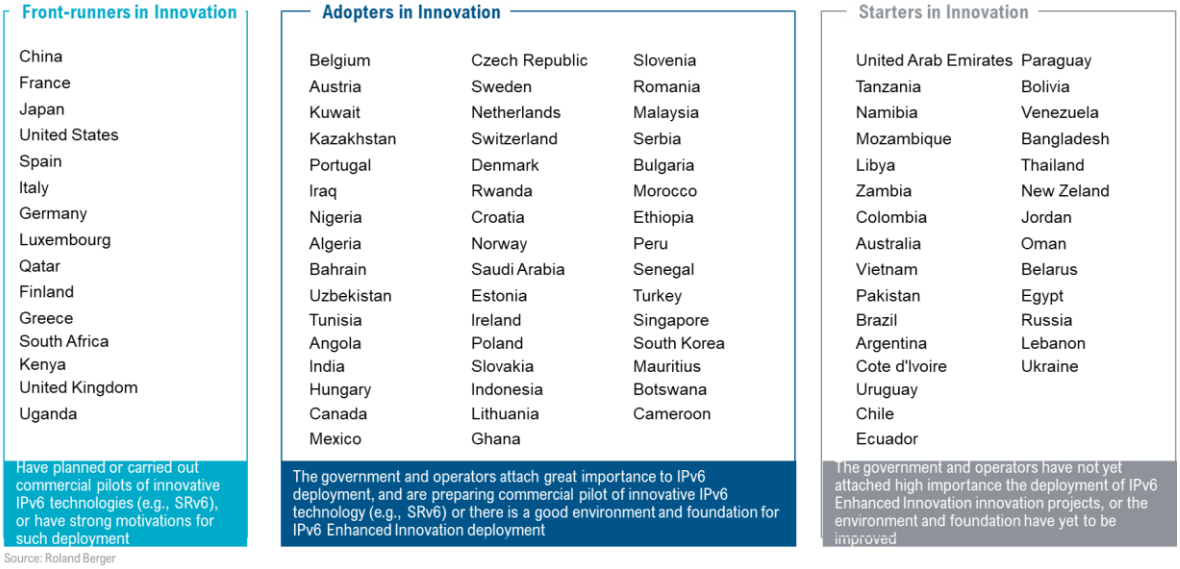


Figure 24. Ranking of deployment of IPv6 innovation

In IPv6 penetration rate, the network and users are also aspects with large differences in the performance of different groups, but the specific manifestations are different:

- **Network:** There is a big difference between starters with frontrunners & adopters
  - **Digitalization level:** The digitalization level and the development requirements of 5G and IoT will increase the motivation of operators to deploy IPv6. Front-runners and adopters generally have a high level of digitalization, and their terminals have a high demand for 5G and IoT development. The motivation of their domestic operators to deploy IPv6 will also increase significantly.
  - **Operator industry concentration:** Many countries among front-runners and adopters have a

high degree of operator industry concentration and a large average size of operators. Since the penetration of new technologies generally starts from leading enterprises and gradually develops to small and medium-sized enterprises, the resistance encountered during IPv6 transformation is relatively small, so the transformation speed is relatively fast.

1	Ethiopia	24	Austria	47	United Arab Emirates	70	Argentina
2	Qatar	25	Saudi Arabia	48	New Zeland	71	Spain
3	Oman	26	Finland	49	Czech Republic	72	Ireland
4	Morocco	27	Greece	50	Bahrain	73	Iraq
5	Mauritius	28	Jordan	51	Lithuania	74	Uganda
6	Uruguay	29	Luxembourg	52	Thailand	75	Cote d'Ivoire
7	Namibia	30	Ecuador	53	South Africa	76	South Korea
8	Kuwait	31	Denmark	54	Hungary	77	India
9	Angola	32	Senegal	55	Italy	78	Bulgaria
10	Switzerland	33	Estonia	56	Canada	79	Lebanon
11	Sweden	34	Venezuela	57	Turkey	80	Indonesia
12	Colombia	35	Philippines	58	Croatia	81	Bangladesh
13	Belarus	36	Singapore	59	Mexico	82	Romania
14	Netherlands	37	Belgium	60	Tunisia	83	Poland
15	China	38	Malaysia	61	Kazakhstan	84	Libya
16	Germany	39	United Kingdom	62	Kenya	85	Russia
17	Norway	40	Slovenia	63	Tanzania	86	Cameroon
18	Bolivia	41	Algeria	64	Serbia	87	Nigeria
19	Paraguay	42	Rwanda	65	Slovakia	88	Ukraine
20	Botswana	43	Peru	66	United States	89	Mozambique
21	Brazil	44	Vietnam	67	Egypt	90	Uzbekistan
22	Portugal	45	Chile	68	Australia	91	Ghana
23	Japan	46	France	69	Pakistan	92	Zambia

Source: Roland Berger

Figure 25. Country ranking of IPv6 Development Index – Network

- **Users:** There is a big difference between the frontrunners and the starters, mainly affected by the level of digitalization and equipment supply
  - **Digitization level:** Frontrunners have a high level of digitalization, and end users have high requirements for IPv6 and IoT applications.
  - **IPv6 deployment in the public sector:** IPv6 deployment within the government also widely exists in leading countries, which further affects the popularization of terminal IPv6.
  - **Ratio of terminal stock to increase**: some frontrunners belong to latecomer countries and have accelerated the development of digital construction in recent years; due to a large number of new users, new terminal increments can directly deploy IPv6 equipment, and deployment is more resistant than equipment replacement small.
  - **Concentration of operators**: Among the starters, the concentration of operators in many countries is relatively low, and the market competition is full. Since terminal routes are mainly provided by operators, it will take a long time for IPv6 to be recognized by the market, and the speed of implementation and deployment in terminals is relatively slow.

1	India	24	Canada	47	Oman	70	Venezuela
2	Belgium	25	Thailand	48	Indonesia	71	Turkey
3	Malaysia	26	Austria	49	Belarus	72	Lithuania
4	Saudi Arabia	27	Switzerland	50	South Korea	73	Uganda
5	Uruguay	28	Singapore	51	Slovakia	74	Botswana
6	Germany	29	New Zeland	52	Rwanda	75	Qatar
7	Greece	30	Paraguay	53	Denmark	76	Bahrain
8	Finland	31	Peru	54	Bulgaria	77	Tanzania
9	United States	32	Romania	55	Kazakhstan	78	Namibia
10	Mexico	33	Ecuador	56	Serbia	79	Senegal
11	Vietnam	34	Ireland	57	Croatia	80	Uzbekistan
12	Hungary	35	Norway	58	Italy	81	Morocco
13	France	36	Argentina	59	Kenya	82	Mauritius
14	China	37	Colombia	60	Russia	83	Angola
15	United Arab Emirates	38	Philippines	61	Spain	84	Algeria
16	Japan	39	Czech Republic	62	Egypt	85	Libya
17	Luxembourg	40	Kuwait	63	South Africa	86	Ghana
18	Portugal	41	Bolivia	64	Pakistan	87	Zambia
19	United Kingdom	42	Poland	65	Bangladesh	88	Tunisia
20	Brazil	43	Jordan	66	Cote d'Ivoire	89	Iraq
21	Estonia	44	Chile	67	Lebanon	90	Mozambique
22	Australia	45	Sweden	68	Ukraine	91	Ethiopia
23	Netherlands	46	Slovenia	69	Nigeria	92	Cameroon

Source: Roland Berger

Figure 26. Country ranking of IPv6 Development Index – Users

3.1.2.4 IPv6 Penetration analysis

In the IPv6 development index, the four indexes of planning, network, content and user represent the penetration of IPv6 in each link of end-to-end deployment.

1	Belgium	24	Switzerland	47	Belarus	70	Serbia
2	Uruguay	25	Austria	48	Denmark	71	Angola
3	India	26	Norway	49	Algeria	72	Lebanon
4	Brazil	27	Czech Republic	50	Morocco	73	Iraq
5	Malaysia	28	Peru	51	Qatar	74	Bulgaria
6	Germany	29	Singapore	52	Slovakia	75	Nigeria
7	Finland	30	Sweden	53	Ethiopia	76	Spain
8	Greece	31	Thailand	54	Kenya	77	Pakistan
9	Saudi Arabia	32	China	55	Tanzania	78	Bahrain
10	United Arab Emirates	33	Ecuador	56	Rwanda	79	Senegal
11	Vietnam	34	Canada	57	Romania	80	Mozambique
12	France	35	Philippines	58	Poland	81	Libya
13	United States	36	Australia	59	Namibia	82	Cameroon
14	Mexico	37	Argentina	60	Venezuela	83	Lithuania
15	Paraguay	38	New Zeland	61	South Africa	84	Turkey
16	Netherlands	39	Kuwait	62	Bangladesh	85	Kazakhstan
17	Luxembourg	40	Bolivia	63	Croatia	86	Cote d'Ivoire
18	Colombia	41	Ireland	64	Tunisia	87	Ukraine
19	Hungary	42	Slovenia	65	Botswana	88	Russia
20	Portugal	43	Jordan	66	Italy	89	Zambia
21	United Kingdom	44	Oman	67	Egypt	90	Ghana
22	Estonia	45	Mauritius	68	Uganda	91	South Korea
23	Japan	46	Chile	69	Indonesia	92	Uzbekistan

Source: Roland Berger

Figure 27. Country ranking of IPv6 Development Index – IPv6 penetration

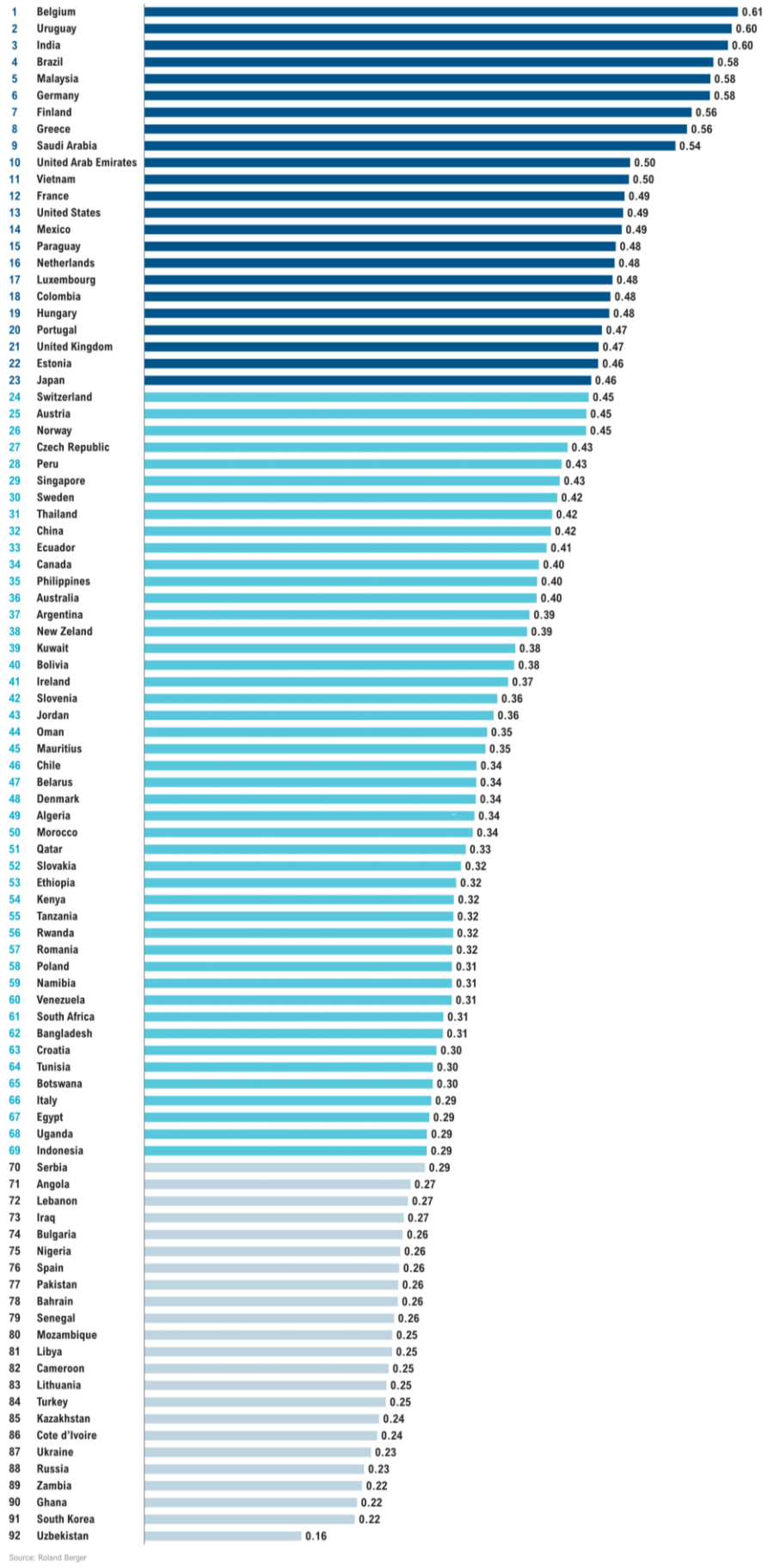


Figure 28. Country ranking of IPv6 penetration

3.2 Benchmarking country analysis

Among many countries, we selected the United States, China and Germany from the front-runners group for analysis as benchmark countries, in order to summarize their strengths and provide reference cases and leading deployment for other countries.

3.2.1 USA

The United States is a digitalization pioneer. It now has a highly developed digital industry, resulting in high demand for IP addresses. As a result, IPv6 was implemented early in the United States, and its adoption rate is higher than in most other nations. On the other hand, the United States possesses a huge number of IPv4 addresses, and its equipment and services are optimized to meet the needs of IPv4, whereas the setup of IPv6 native equipment and services has not yet been optimized. Therefore, it will take time for the relative penetration of IPv6 (in comparison to IPv4) to increase.

Implications

- The legislative priorities of early adopters with a healthy digital economy must be forward-looking, such as making the connection between IPv6 and other emerging technologies such as 5G and IoT. Pioneering the investigation of cutting-edge technologies and trial applications to transform the digital infrastructure is the means for leading nations to keep their competitive advantage.
- Undoubtedly, the growth of the digital economy is the driving force behind the development of IPv6. The necessity and economic significance of adopting IPv6IPv6 Enhanced Innovations rises as the demand for IP inside the digital infrastructure rises.
- Enforcing end-to-end IPv6-only networks for government services, healthcare, and education, etc., considerably increases the implementation of IPv6IPv6 Enhanced Innovations.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in the US would total $2.4 trillion by 2025, equivalent to 5.2 % of the gross value of these industries in 2025.

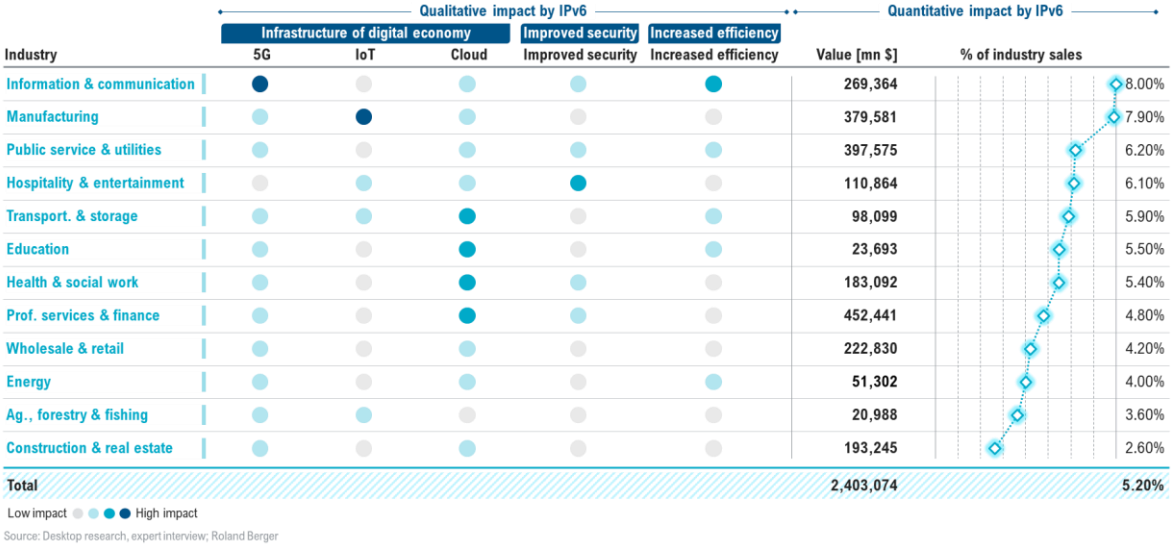


Figure 29. IPv6 industry value creation in United States

IPv6 development status

- USA is ranked 7 out of 91 countries with a score of 0.53 and falls into the category of front-runners. This means that USA is considered a leader in development of IPv6.

Figure 30. IPv6 development in United States

3.2.2 China

The Chinese government has achieved significant results in driving the IPv6 transition among operators, content service providers, and key device manufacturers through a set of multi-level and highly binding policies.

Implications

- National policies are observed to work the best when endorsed by a **high-level strategic blueprint**. The Digital China strategy outlined in the 14th Five-Year Plan is considered an example. To expedite the digital transition, it is recommended that governments embrace strategy that includes goals and support for the digital society, government, and economy.
- **Binding policies with clearly defined targets and standards** can effectively accelerate the penetration of IPv6 among operators, service providers, and users within a short time frame. Among all stakeholders, operators are most prone to policy influence and play the largest role in driving the deployment at the network and users' end.
- The active deployment of IPv6/IPv6 Enhanced Innovations by the leading operators can have a substantial effect on the overall deployment rate in the national networks. Moreover, it secures the provision of an IPv6 network environment for content providers.
- The active deployment of IPv6/IPv6 Enhanced Innovations by the leading operators can have a substantial effect on the overall deployment rate in the national networks. Moreover, it secures the provision of an IPv6 network environment for content providers.
- Governments should also work to advance breakthrough **digital infrastructure technologies**. Government support for IPv6 Enhanced Innovations technologies and businesses, as well as pilot projects, will considerably ease the growth of the digital sector and boost the national digital economy in the future.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in the China would total $578 billion by 2025, equivalent to 1.7 % of the gross value of these industries in 2025.

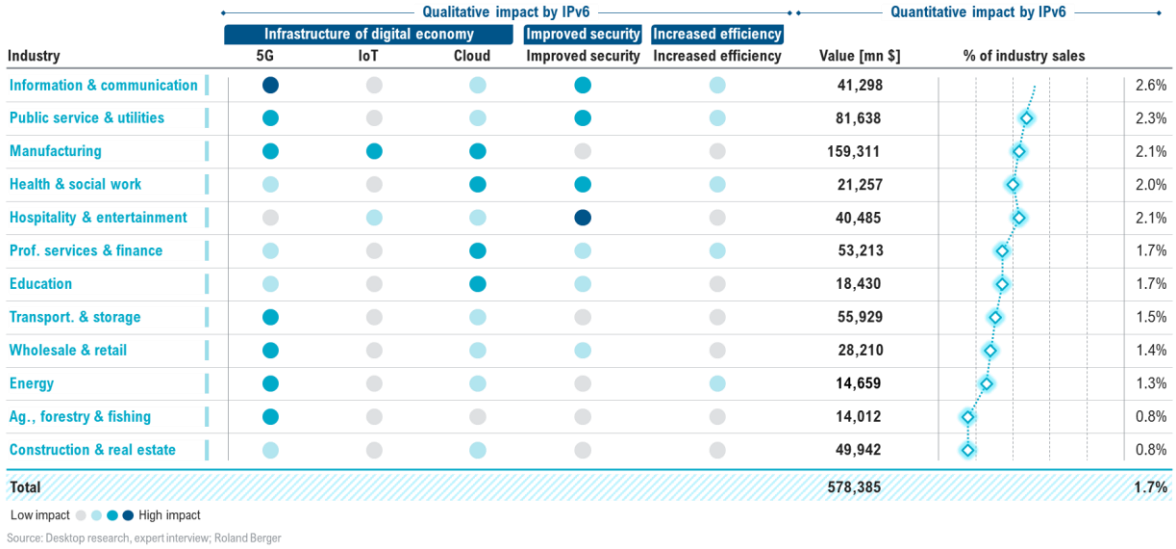


Figure 31. IPv6 industry value creation in China

IPv6 development status

- China is ranked 12 out of 92 countries with a score of 0.47 and falls into the category of front-runners. This means that China is considered a leader indevelopment of IPv6

Figure 32. IPv6 development status in China

3.2.3 Germany

Due to a relatively high degree of digitalization, the users' natural demand for IP addresses becomes a potent driver for IPv6 transition. In addition, as Germany began the deployment process early and the active public sector has contributed significantly to the promotion of IPv6, Germany is at the forefront of IPv6 implementation globally.

Implications

- The government should take the lead in deploying IPv6 and then encourage the private sector to make the appropriate change.
- As the digital economies grow, the modernization of digital infrastructures in major industries (e.g., manufacturing) is projected to generate enormous demand for IPv6 capabilities. Therefore, governments should integrate IPv6 into industrial settings (such as smart manufacturing) and support pilot projects for its implementations.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in Germany would total $288 billion by 2025, equivalent to 4.2 % of the gross value of these industries in 2025.

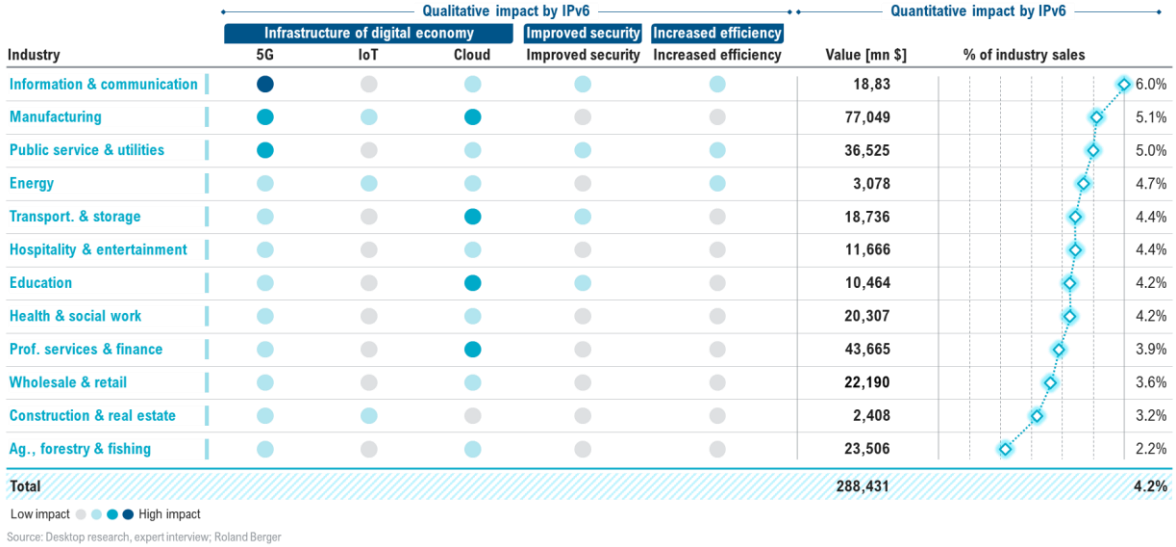


Figure 33. IPv6 industry value creation in Germany

IPv6 development status

- Germany is ranked 4 out of 92 countries with a score of 0.53 and falls into the category of front-runners. This means that Germany is considered a leader indevelopment of IPv6

Figure 34. IPv6 development status in Germany

3.3 Typical country analysis

3.3.1 Front-runners

3.3.1.1 France

France has a solid digital basis, as well as a strong academic reputation and influence in the telecommunication field. As the French public sector' started deployment of IPv6 since 2012, the private sector shows good IPv6 penetration; however, due to the fragmented market of operators and content services, there are a large number of small operators and small websites that have not yet transformed to IPv6, and it will take time to further the penetration.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in France could total $164 billion by 2025, equivalent to 3.6% of the gross value of these industries in 2025.

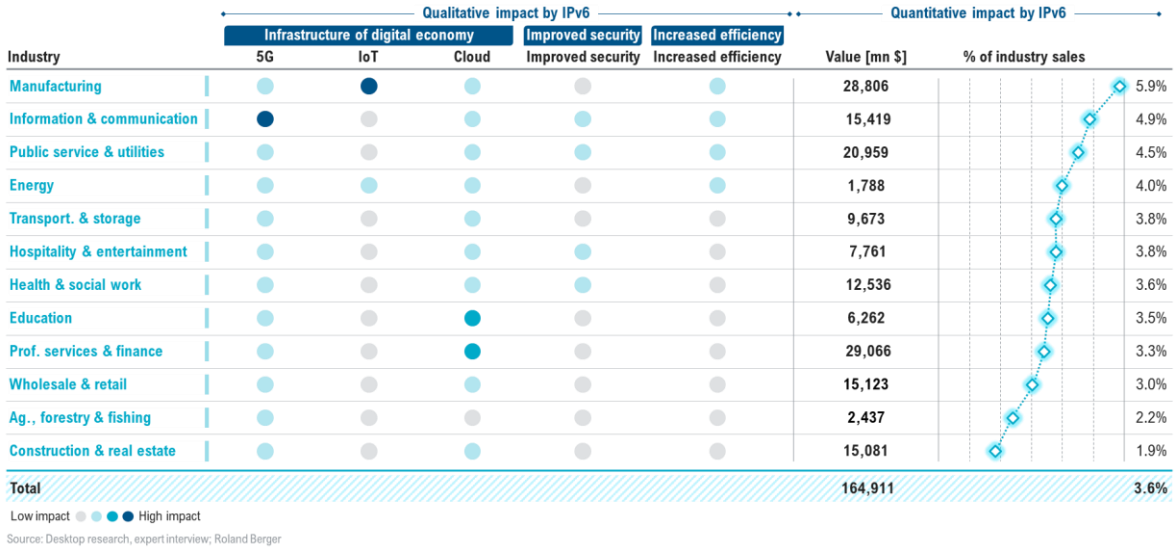


Figure 35. IPv6 industry value creation in France

IPv6 development status

- France is ranked 8 out of 92 countries with a score of 0.51 and falls into the category of front-runners. This means that France is considered a leader in the development of IPv6

Figure 36. IPv6 development status in France

Recommendations

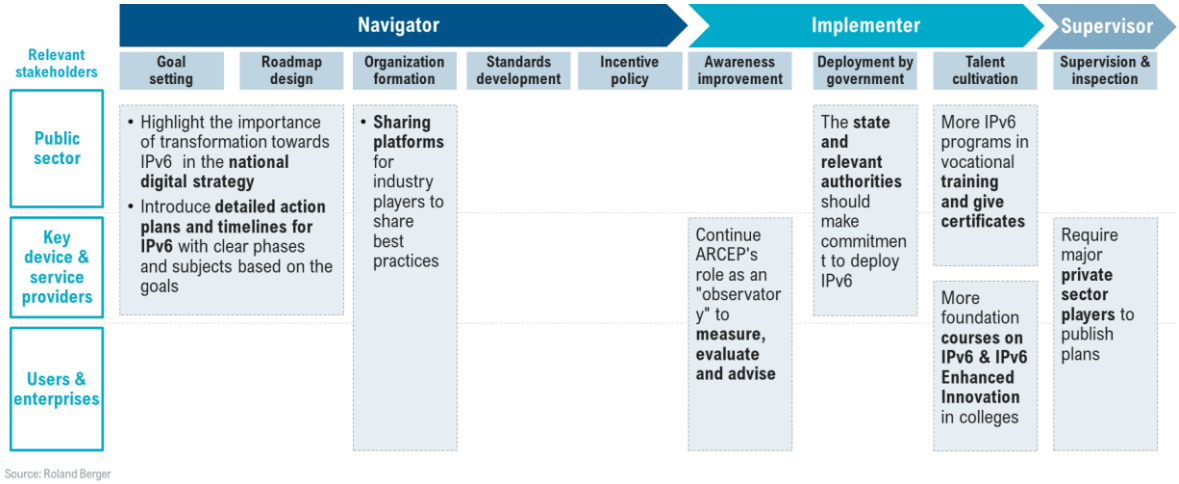


Figure 37. Policy recommendations for France

3.3.1.2 Saudi Arabia

Saudi Arabia has a high demand for IPv6 in the process of promoting the transformation of the digital economy. Around 2021, the government actively deployed IPv6 through the state-owned top operators, mandating quick IPv6 deployment and rapid penetration by the top operators.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in Saudi Arabia would total $123 billion by 2025, equivalent to 6.5 % of the gross value of these industries in 2025.

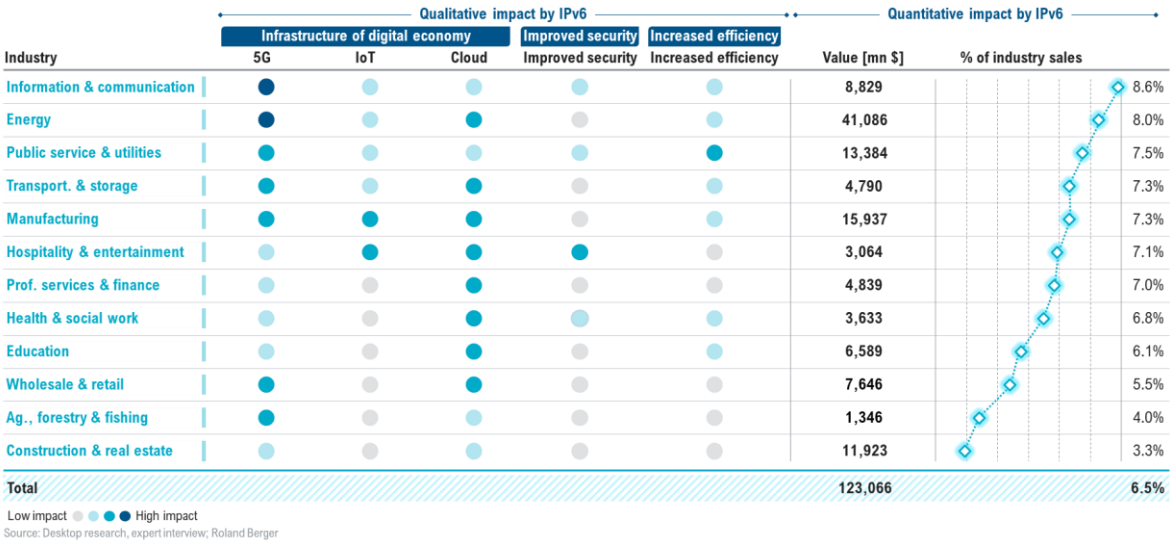


Figure 38. IPv6 industry value creation in Saudi Arabia

IPv6 development status

Saudi Arabia has a high demand for IPv6 in the process of promoting digital economic transformation. Around 2021, the government will drive SOE head operators to carry out rapid IPv6 deployment, quickly infiltrate and lay out commercial pilot applications of IPv6 Enhanced Innovation cutting-edge technologies

- Saudi Arabia is ranked 10 out of 92 countries with a score of 0.51 and falls into the category of front-runners. This means that Saudi Arabia is considered a leader in the global deployment of IPv6

Figure 39. IPv6 development status in Saudi Arabia

Recommendations

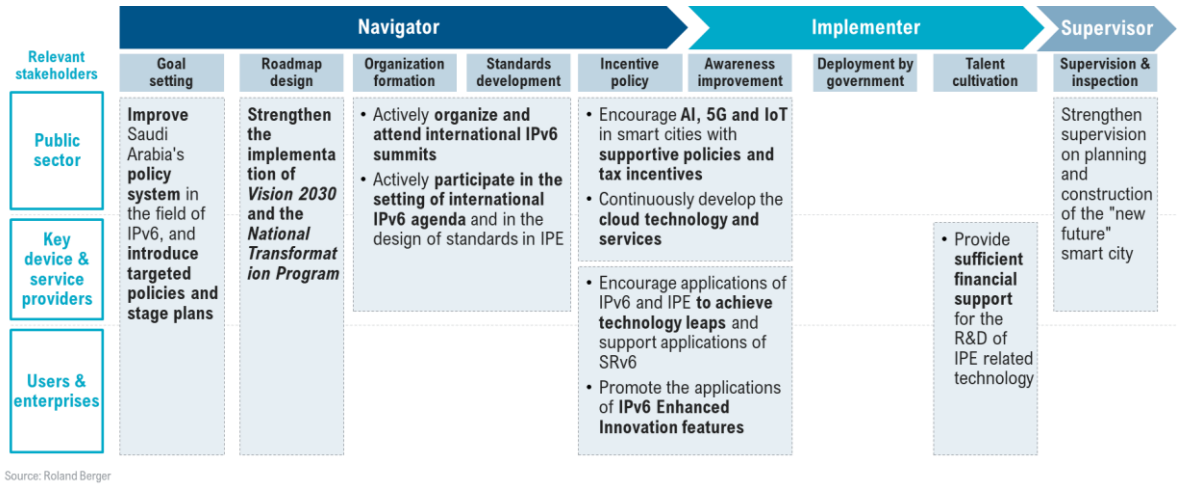


Figure 40. Policy recommendations for Saudi Arabia

3.3.1.3 Malaysia

Malaysia started the deployment process of IPv6 10 years ago and stepped up its policies in recent years. From 2020 onwards, IPv6 certification is made mandatory for all types of network equipment. However, due to a fragmented operator market, the deployment of IPv6 still needs time.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in Malaysia would total $108 billion by 2025, equivalent to 3.2 % of the gross value of these industries in 2025.

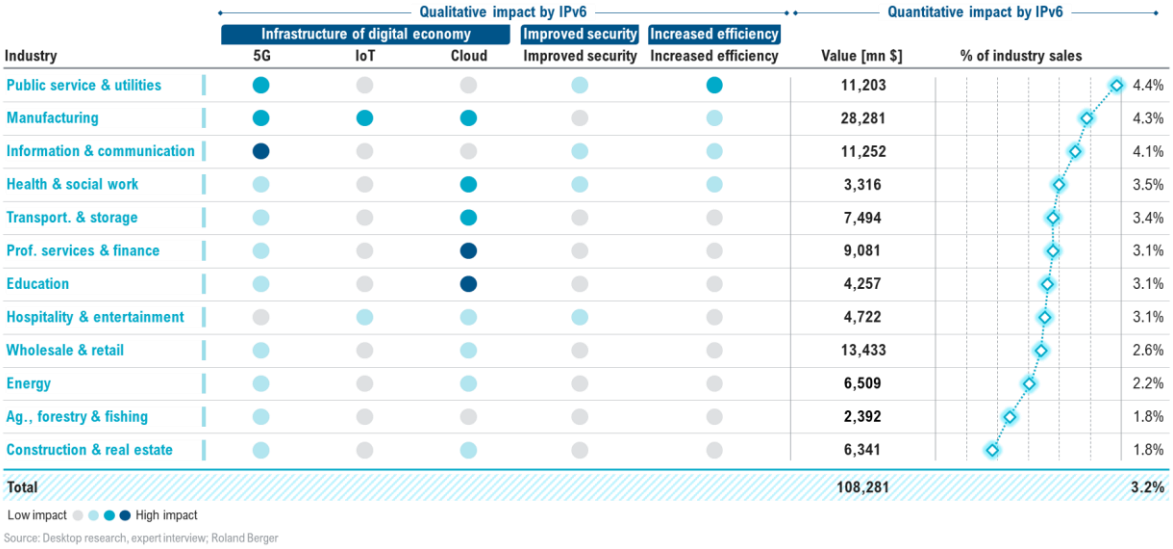


Figure 41. IPv6 industry value creation in Malaysia

IPv6 development status

- Malaysia is ranked 11 out of 92 countries with a score of 0.50 and falls into the category of front-runners. This means that Malaysia is considered a leader in the development of IPv6 globally.

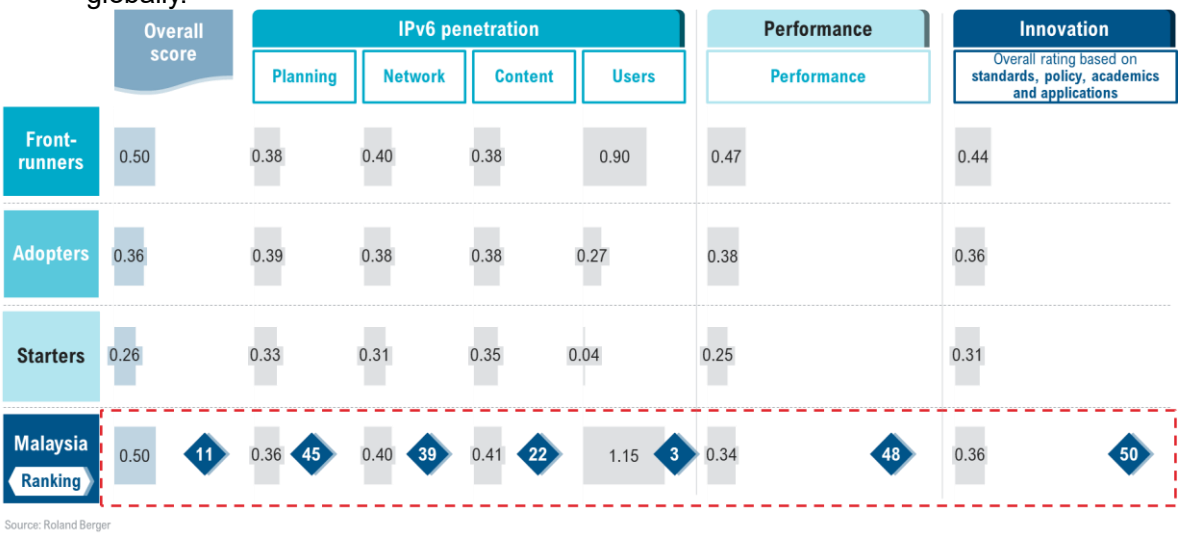


Figure 42. IPv6 development status in Malaysia

Recommendations

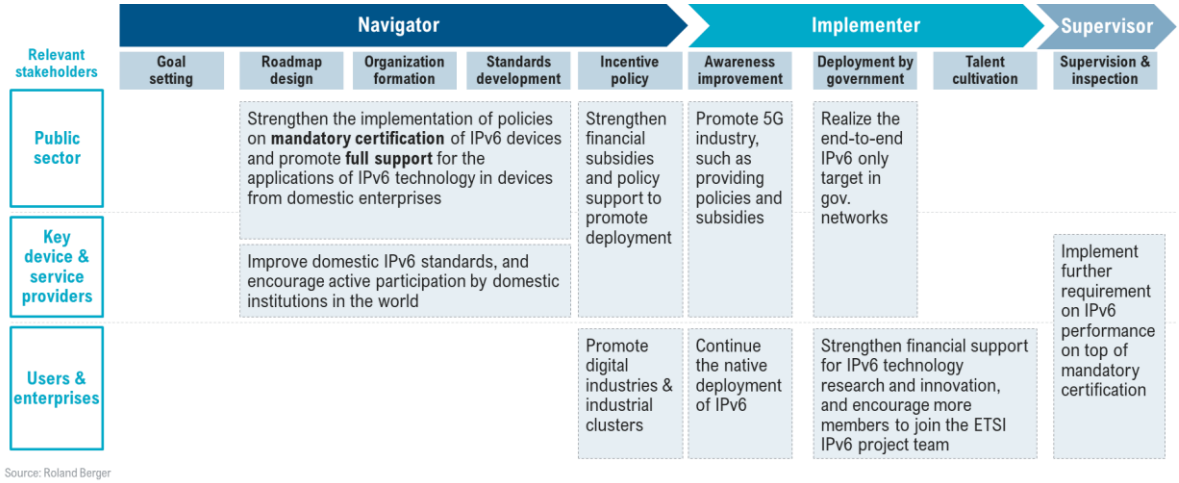


Figure 43. Policy recommendations for Malaysia

3.3.1.4 United Arab Emirates

Large international enterprises account for a large proportion of the UAE's network operators and content providers, enabling the government to lead SOE operators to rapidly deploy IPv6 when IPv4 addresses are relatively abundant.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in UAE would total $218 billion by 2025, equivalent to 6.7 % of the gross value of these industries in 2025.

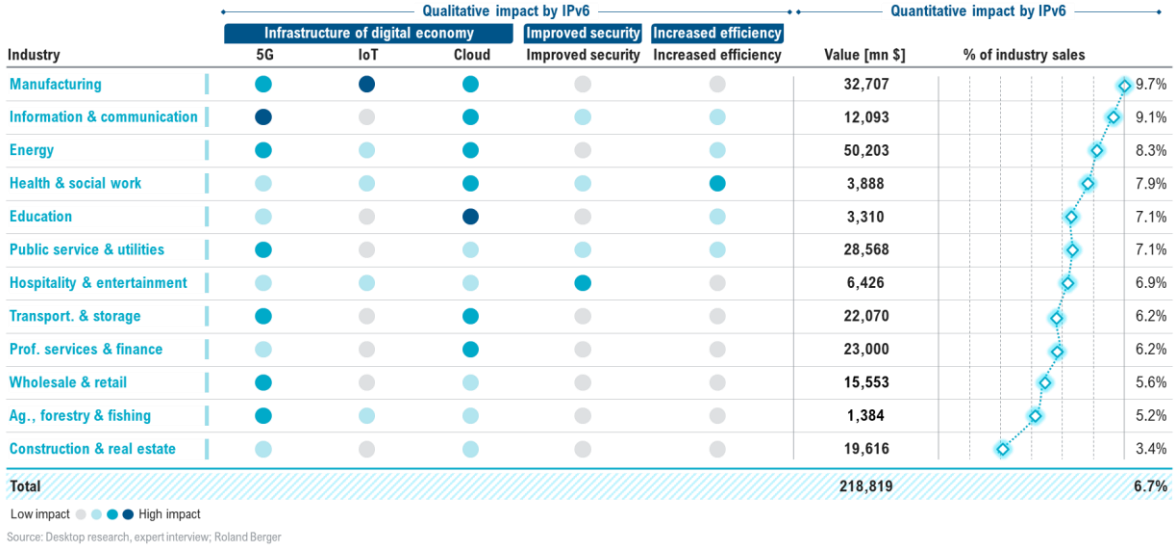


Figure 44. IPv6 industry value creation in United Arab Emirates

IPv6 development status

Figure 45. IPv6 development status in United Arab Emirates

Recommendations

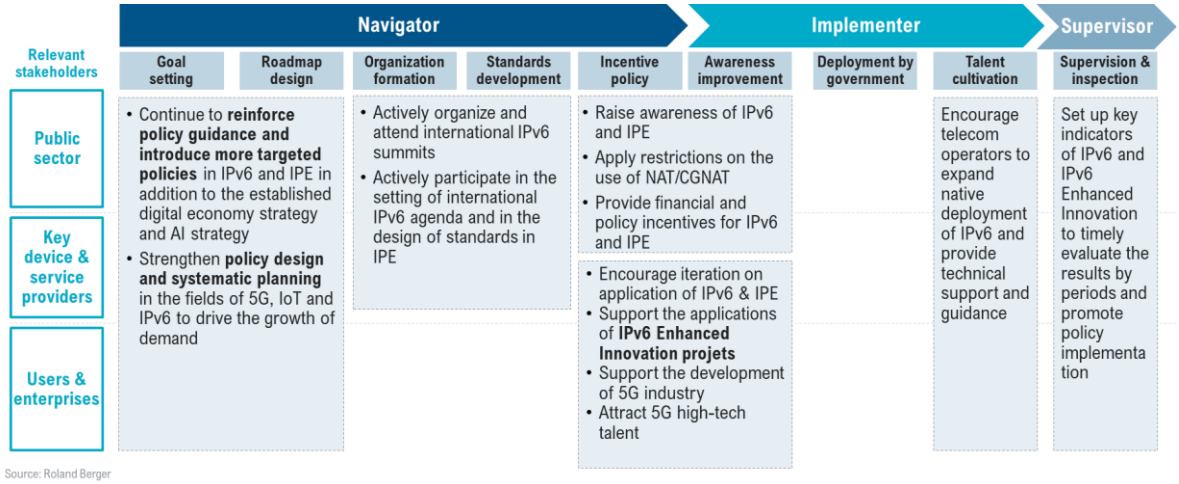


Figure 46. Policy recommendations for United Arab Emirates

3.3.1.5 Brazil

As one of the first-movers in South America, Brazil has a fairly substantial share of South American prefix resources. Nonetheless, development of 5G, AI, and other related industries that drive the growth of the user end demand began rather late, the level of government digitalization is also low.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in Brazil would total $163 billion by 2025, equivalent to 1.1 % of the gross value of these industries in 2025.

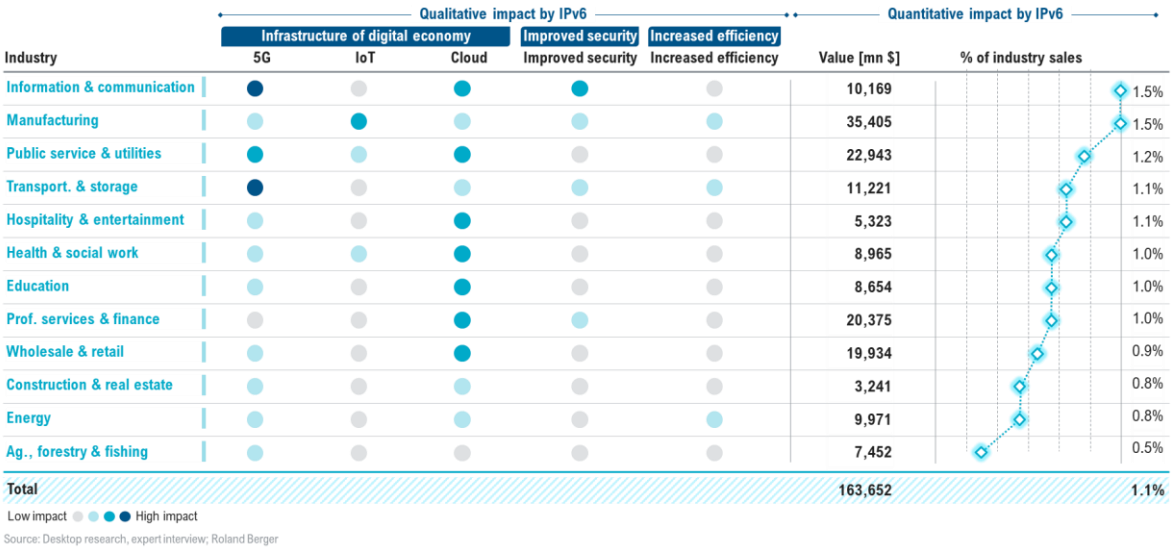


Figure 47. IPv6 industry value creation in Brazil

IPv6 development status

- Brazil is ranked 14 out of 92 countries with a score of 0.48 and falls into the category of front-runners. This means that Brazil is considered a leader in the development of IPv6 globally.

Figure 48. IPv6 development status in Brazil

Recommendations

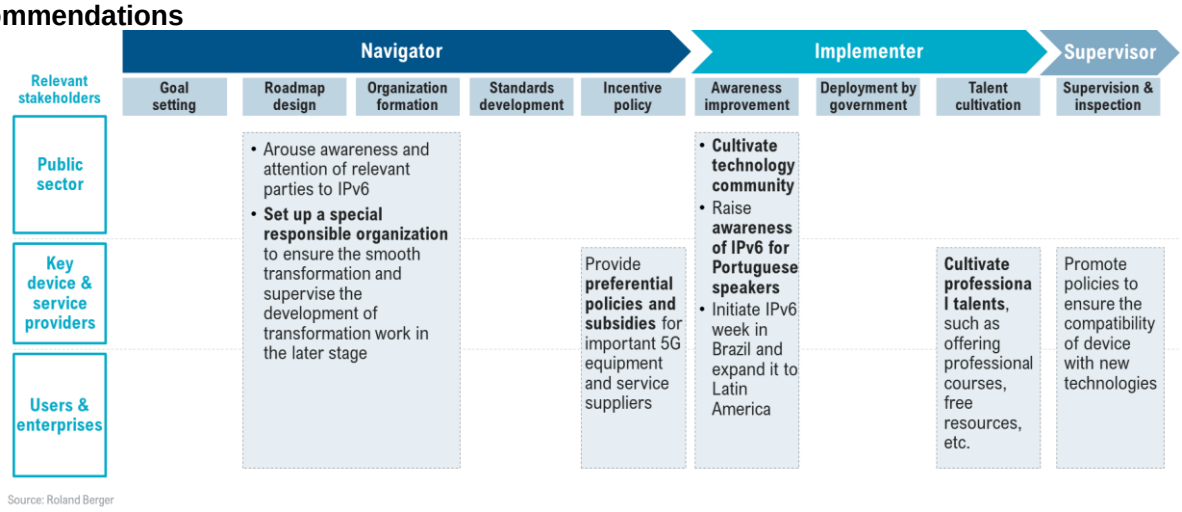


Figure 49. Policy recommendations for Brazil

3.3.1.6 Mexico

Mexico is experiencing a time of fast growth in its digital economy. There are numerous new IP requirements for which IPv6 can be installed immediately, making it easier to popularize IPv6 on the user end. Due to the huge number of small operators, however, IPv6 upgrade on the network side will take some time.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in Mexico would total $26 billion by 2025, equivalent to 1.1 % of the gross value of these industries in 2025.

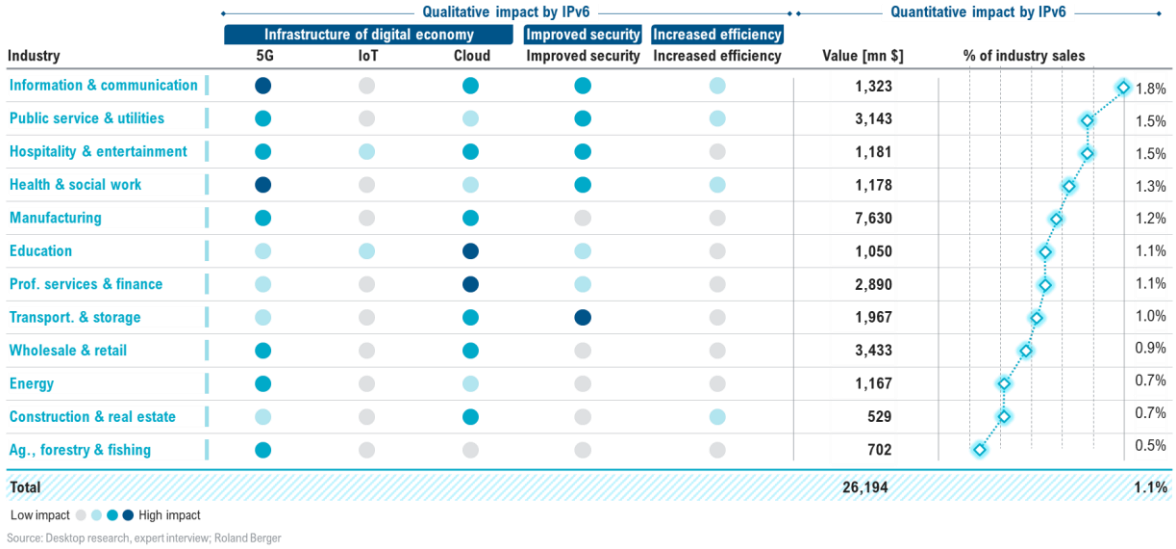


Figure 50. IPv6 industry value creation in Mexico

IPv6 development status

- Mexico is ranked 16 out of 92 countries with a score of 0.47 and falls into the category of front-runners. This means that Mexico is considered a leader in the development of IPv6 globally.

Figure 51. IPv6 development status in Mexico

Recommendations

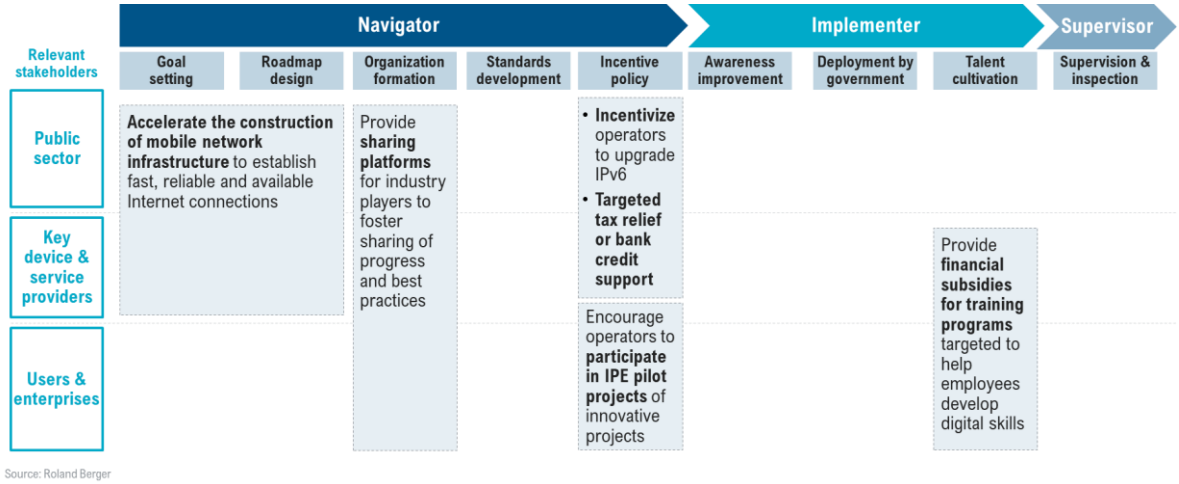


Figure 52. Policy recommendations for Mexico

3.3.2 Adopters

3.3.2.1 Thailand

Lack of IPv4 address incentivize both public and private sectors in Thailand to migrate to IPv6. Thailand's continuing top-down IPv6 strategic planning has enabled a seamless IPv6 transition, although frontier technology and forward-looking projects are still lacking.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in Thailand would total $31 billion by 2025, equivalent to 3.4 % of the gross value of these industries in 2025.

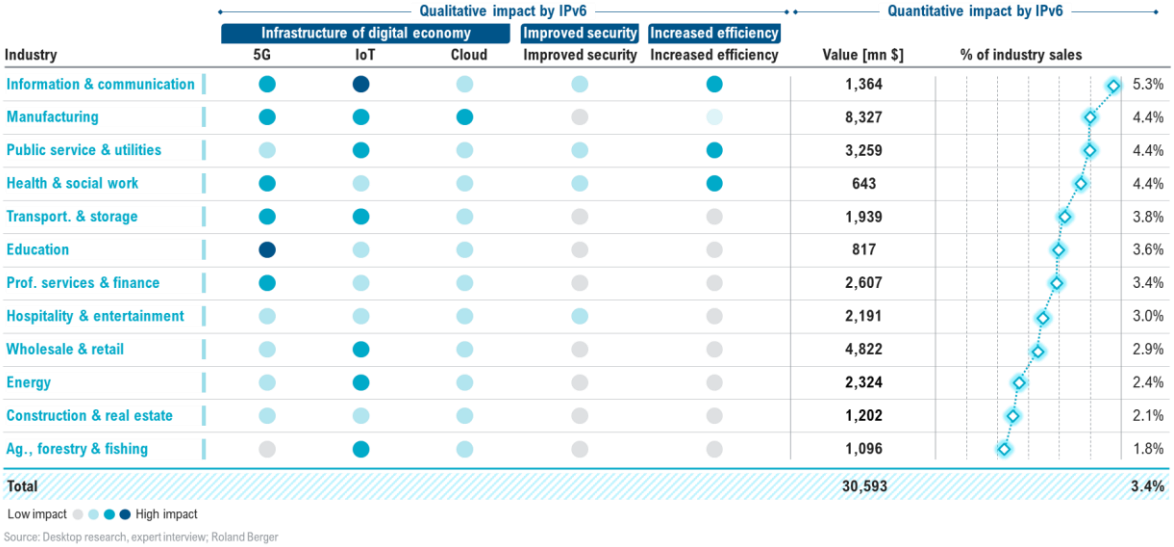


Figure 53. IPv6 industry value creation in Thailand

IPv6 development status

The Thailand 4.0 strategy proposed in 2016 focuses on consolidating existing industrial development capabilities (focusing on industries like automobiles and smart appliances), establishing new industries (focusing on industries like robotics and digitalization), and forming high-tech value chains (focusing on industries like networking, electromechanical integration, and innovation and culture), which are in line with the IPv6 value plateau of information technology. Therefore, IPv6 implementation can in large facilitate Thailand's strategic change.

- Thailand is ranked 36 out of 92 countries with a score of 0.40 and falls into the category of adopters. This means the level of IPv6 development in Thailand is in the medium level in the world.

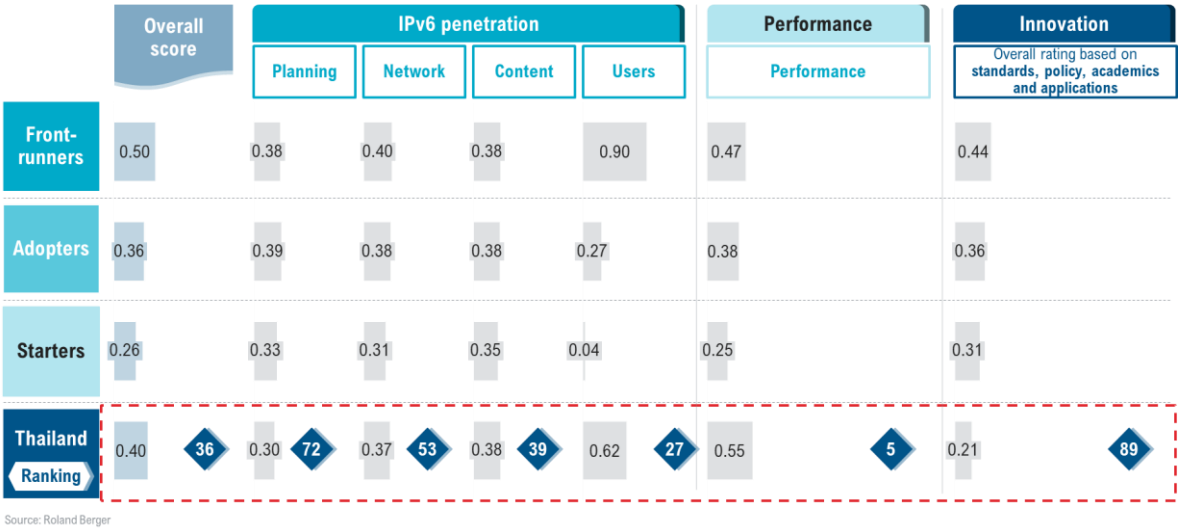


Figure 54. IPv6 development status in Thailand

Recommendations

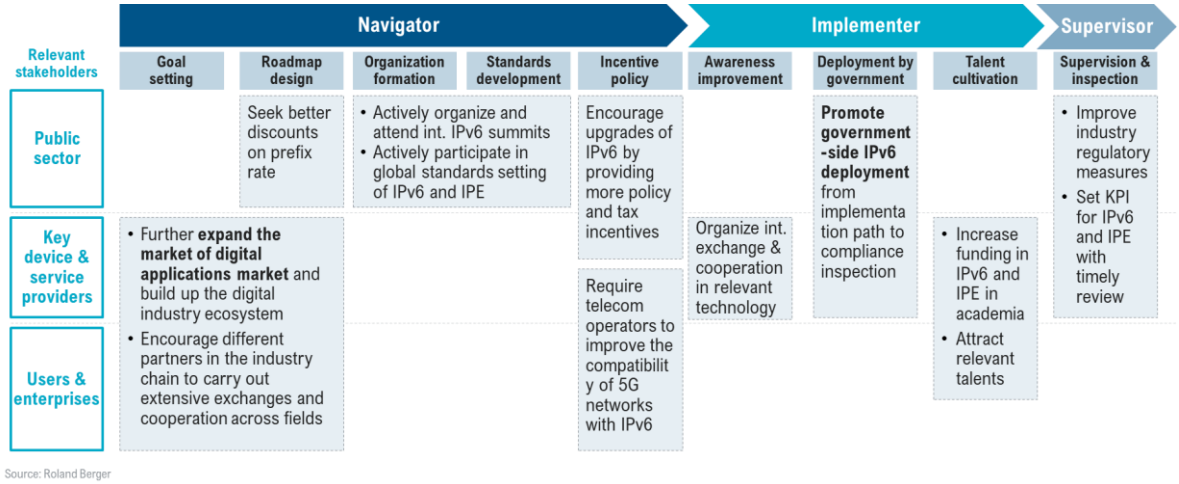


Figure 55. Policy recommendations for Thailand

3.3.2.2 Philippines

Not high levels of digitalization and demand for addresses are observed. Because of the insufficient infrastructure, however, a substantial number of new end devices can directly implement IPv6, reducing transition costs and facilitating user adoption.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in Philippines would total $25 billion by 2025, equivalent to 3.9 % of the gross value of these industries in 2025.

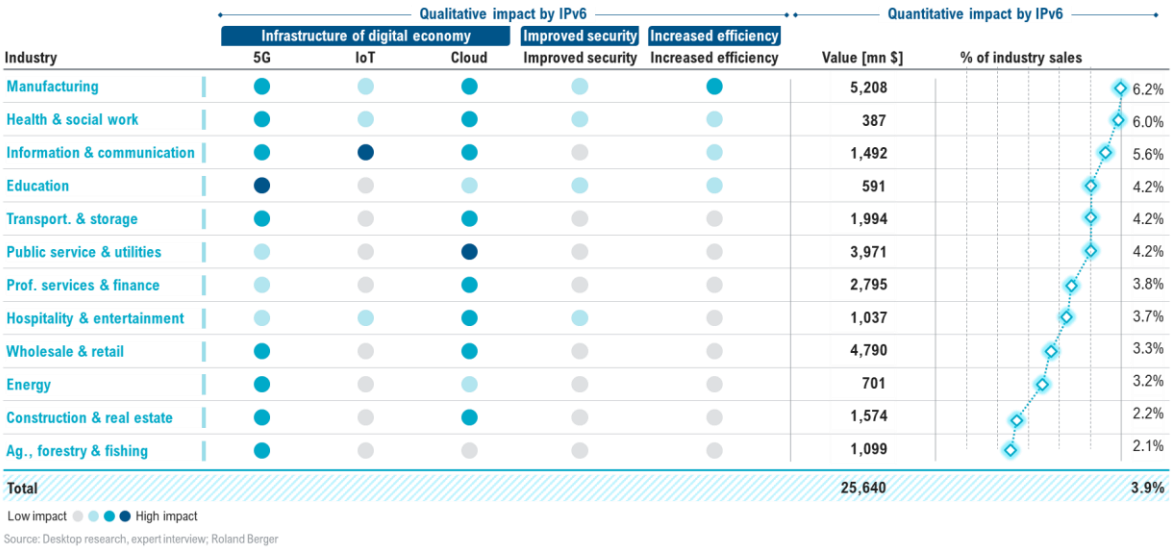


Figure 56. IPv6 industry value creation in Philippines

IPv6 development status

- Philippines ranks 43 out of 92 countries with a score of 0.37, grouped as an adopter. This means the level of IPv6 development in Philipines is in the medium level in the world.

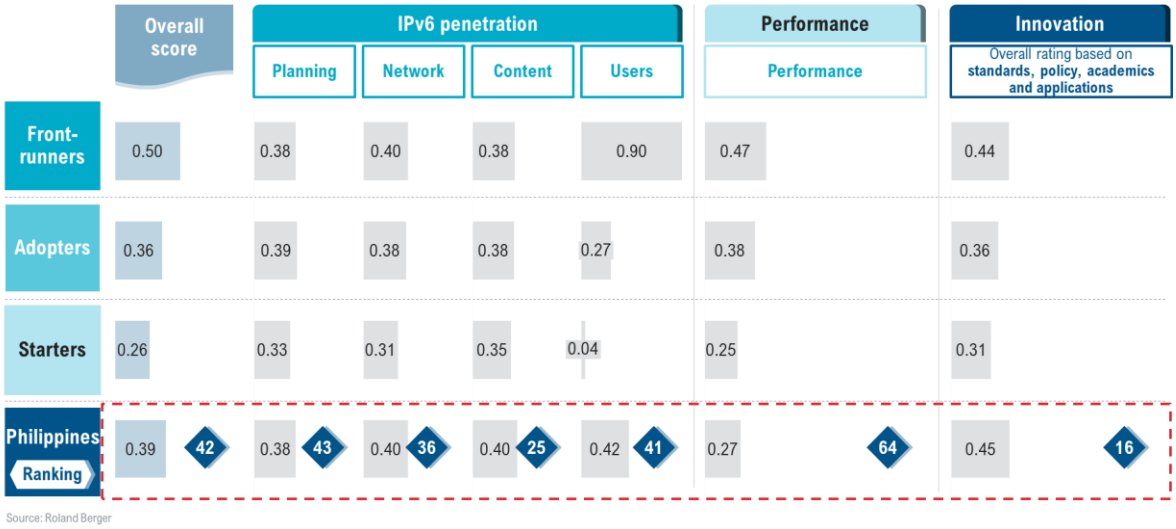


Figure 57. IPv6 development status in Philippines

Recommendations

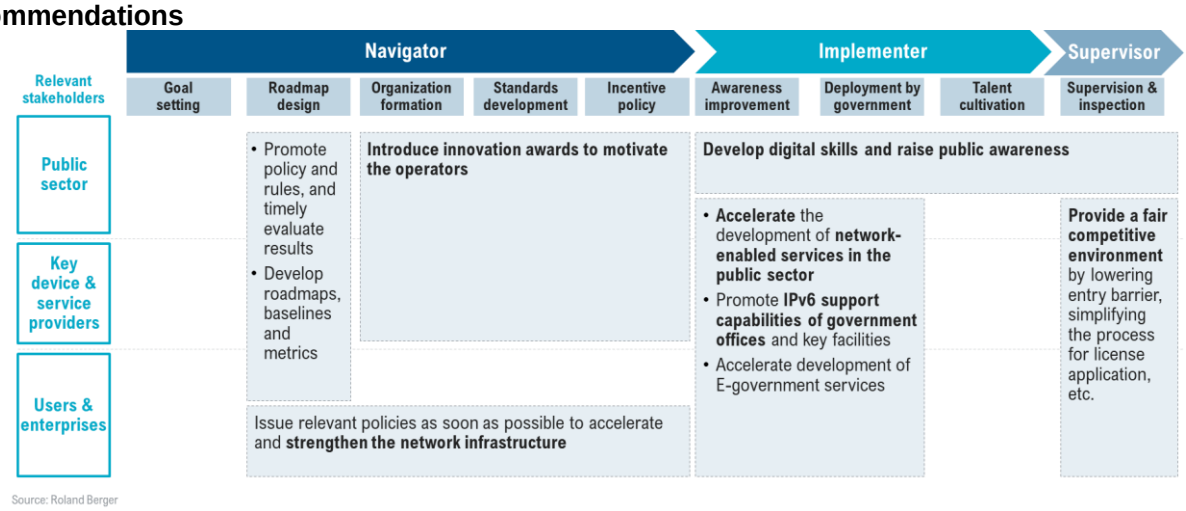


Figure 58 . Policy recommendations for Philippines

3.3.2.3 Italy

Italy has an edge in advanced technology research and academic contributions, but due to its high number of SMEs and poor digital economy penetration, there is less demand for IP addresses and a lack of impetus in IPv6 deployment by big operators.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in Italy would total $104 billion by 2025, equivalent to 3.3% of the gross value of these industries in 2025.

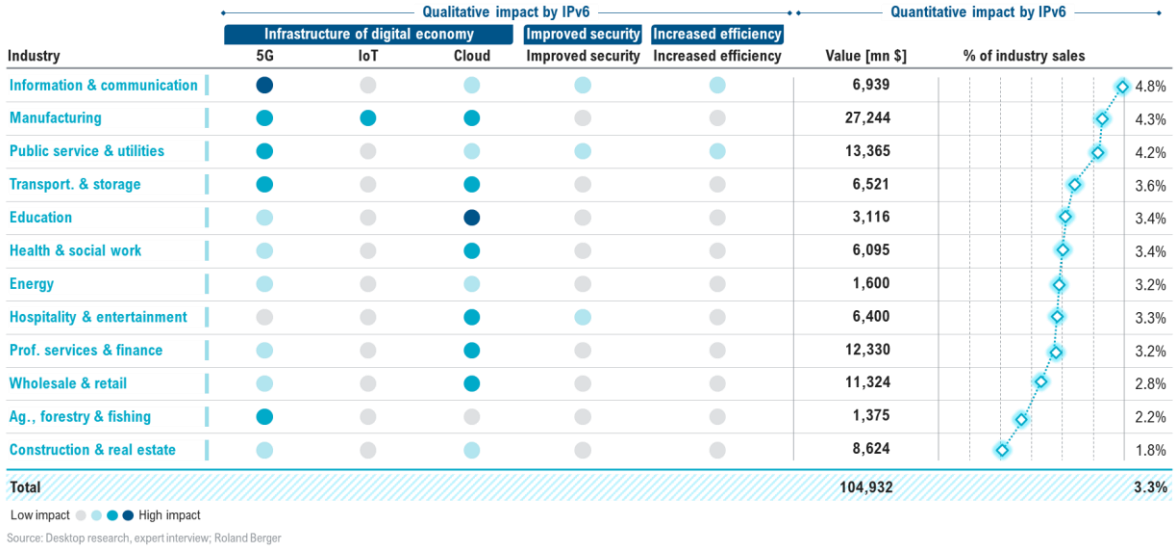


Figure 59. IPv6 industry value creation in Italy

IPv6 development status

- Italy ranks 48 out of 92 countries with a score of 0.35, grouped as an adopter. This means the level of IPv6 development in Italy is in the medium level in the world.

Figure 60. IPv6 development status in Italy

Recommendations

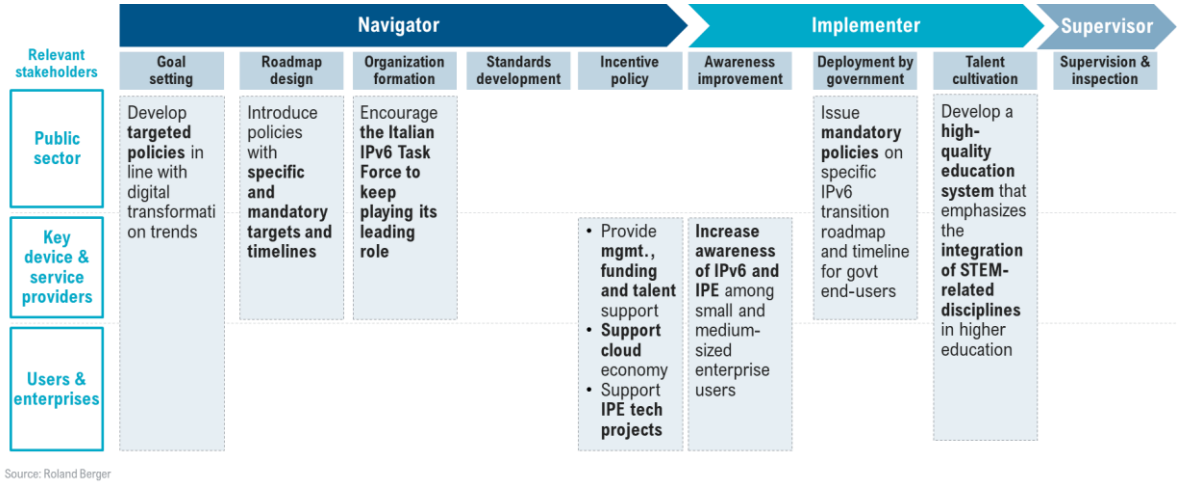


Figure 61. Policy recommendations for Italy

3.3.2.4 Algeria

The rapid growth of the ICT industry in Algeria in recent years, the strong government investment in critical ICT infrastructure and the constantly updated legal framework and regulations have all contributed in part to the deployment of IPv6.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in Algeria would total $5.2 billion by 2025, equivalent to 1.0% of the gross value of these industries in 2025.

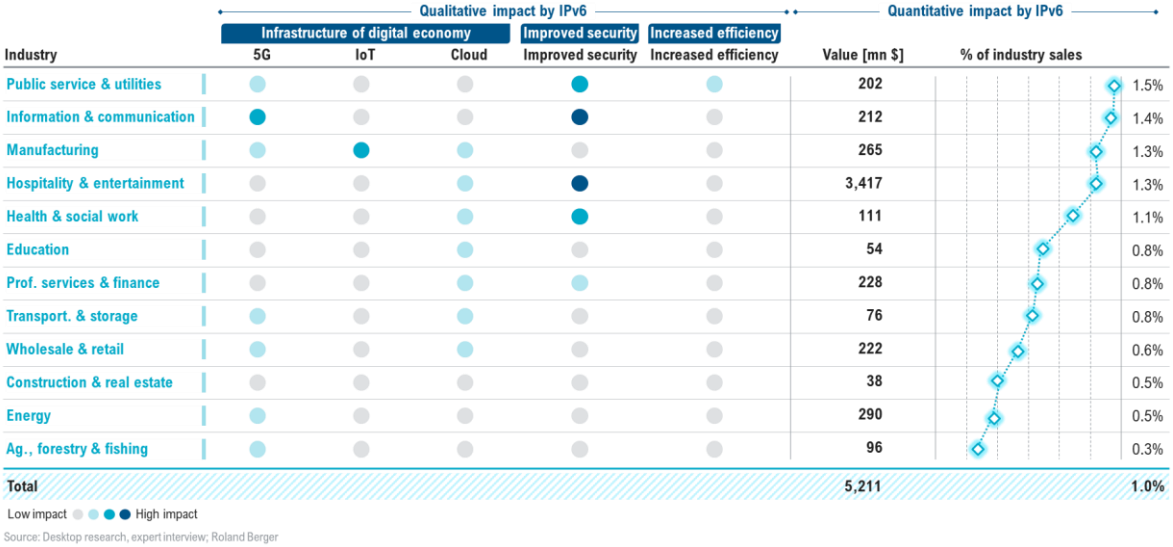


Figure 62. IPv6 industry value creation in Algeria

IPv6 development status

- Algeria ranks 52 out of 92 countries with a score of 0.34, grouped as an adopter. This means the level of IPv6 development in Algeria is in medium level in the world.

Figure 63. IPv6 development status in Algeria

Recommendations

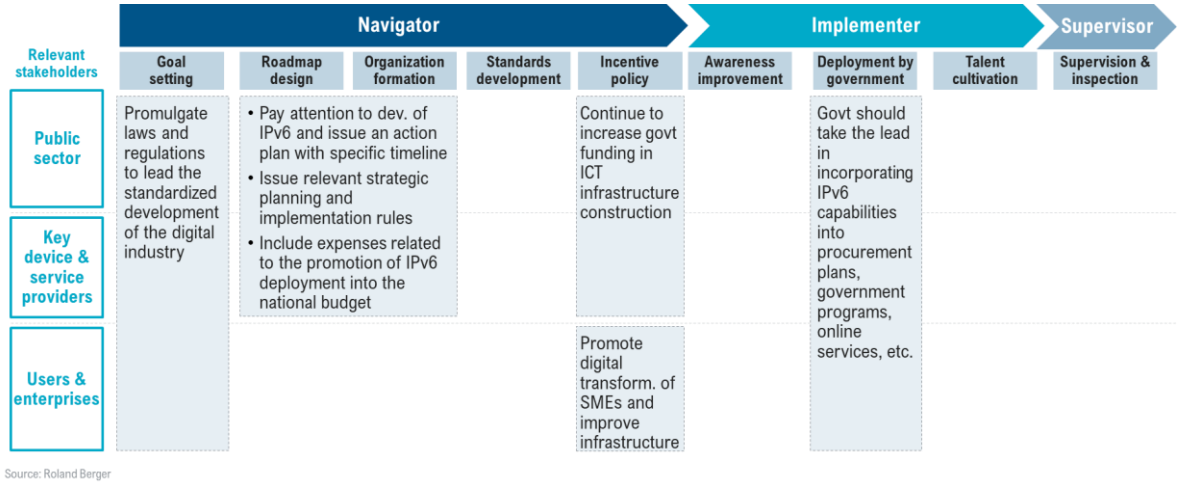


Figure 64. Policy recommendations for Algeria

3.3.2.5 South Africa

The general level of digitalization in South Africa is low, and in the lack of larger incentives, terminal demand for IPv6 is still modest, and operators are just beginning to switch to IPv6 due to the oversupply of IPv4 addresses in the country.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in South Africa would total $45 billion by 2025, equivalent to 5.1% of the gross value of these industries in 2025.

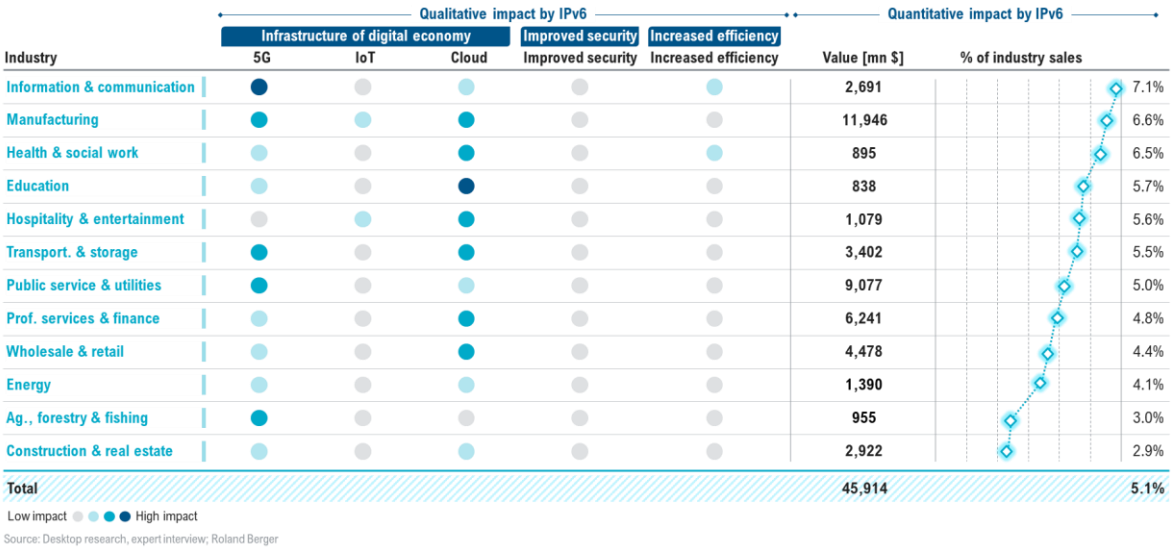


Figure 65. IPv6 industry value creation in South Africa

IPv6 development status

- South Africa ranks 54 out of 92 countries with a score of 0.34, grouped as an adopter. This means the level of IPv6 development in South Africa is in the medium level in the world.

Figure 66. IPv6 development status in South Africa

Recommendations

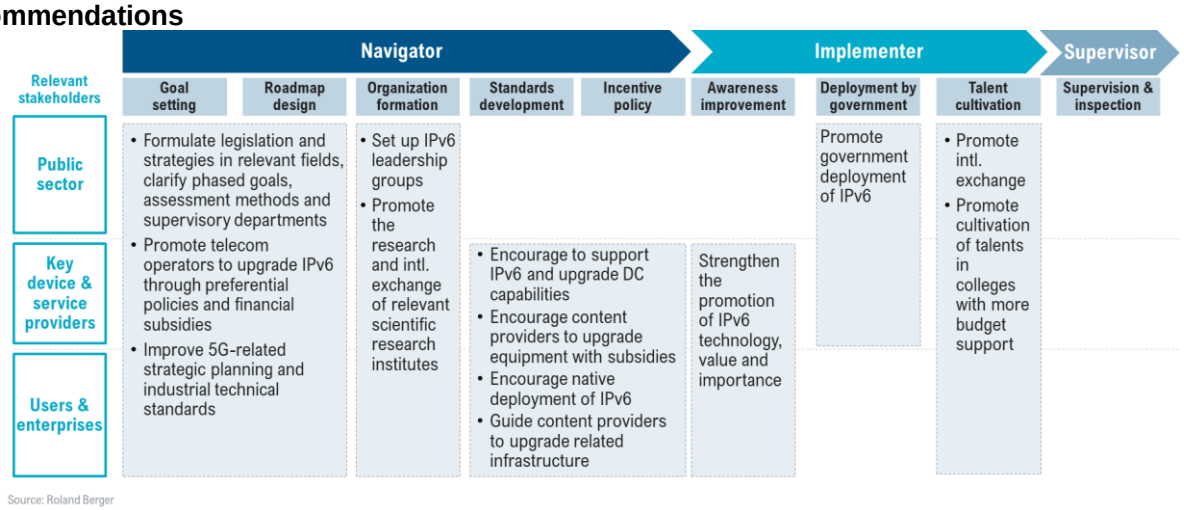


Figure 67. Policy recommendations for South Africa

3.3.2.6 Spain

Spain began the development of IPv6 technology early and has certain advantages in advanced technology development and academic contributions, but the major operators lack motivation in IPv6 deployment and there is no effective policy to promote the implementation; therefore, it has not yet surpassed the United States as the global leader in IPv6 deployment.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in Spain would total $75 billion by 2025, equivalent to 3.3% of the gross value of these industries in 2025.

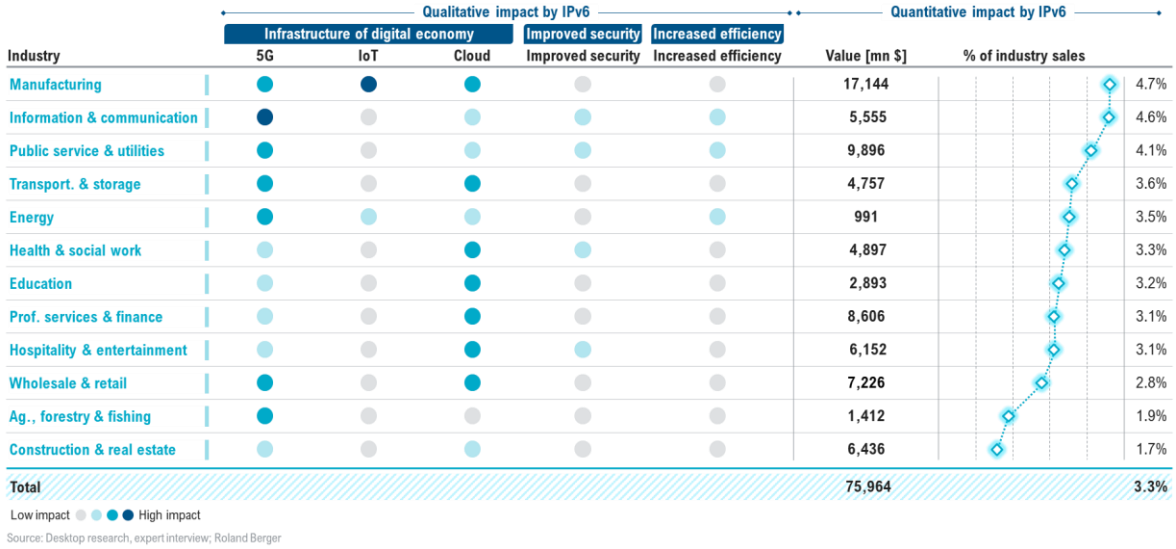


Figure 68. IPv6 industry value creation in Spain

IPv6 development status

- Spain ranks 61 out of 92 countries with a score of 0.33, grouped as an adopter. This means the level of IPv6 development in Spain is in medium level in the world.

Figure 69. IPv6 development status in Spain

Recommendations

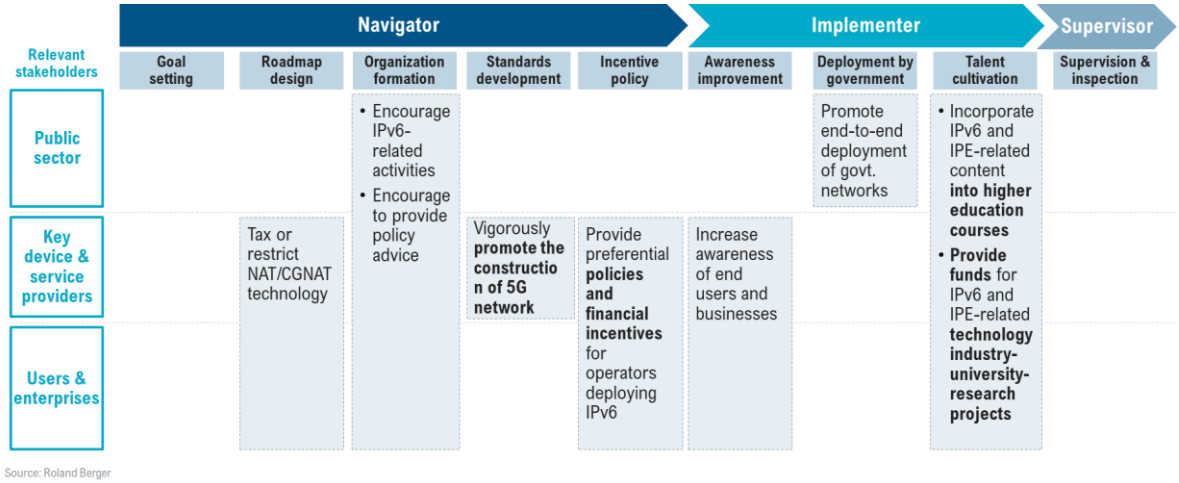


Figure 70. Policy recommendations for Spain

3.3.2.7 Nigeria

As the most populous country in Africa, Nigeria is valued by many multinational content providers of large sizes and leading expertise, resulting in satisfactory content support for IPv6. However, limited by its low level of digitization, in the absence of significant growth in the digital industry, IPv6 deployment in Nigeria remains at a medium level in the world.

IPv6 industry sector impact

We estimate that the potential value of IPv6 deployment across multiple industries in Nigeria could total US$52 billion by 2025, which is equivalent to 5.8% of the total real output value of these industries in 2025.

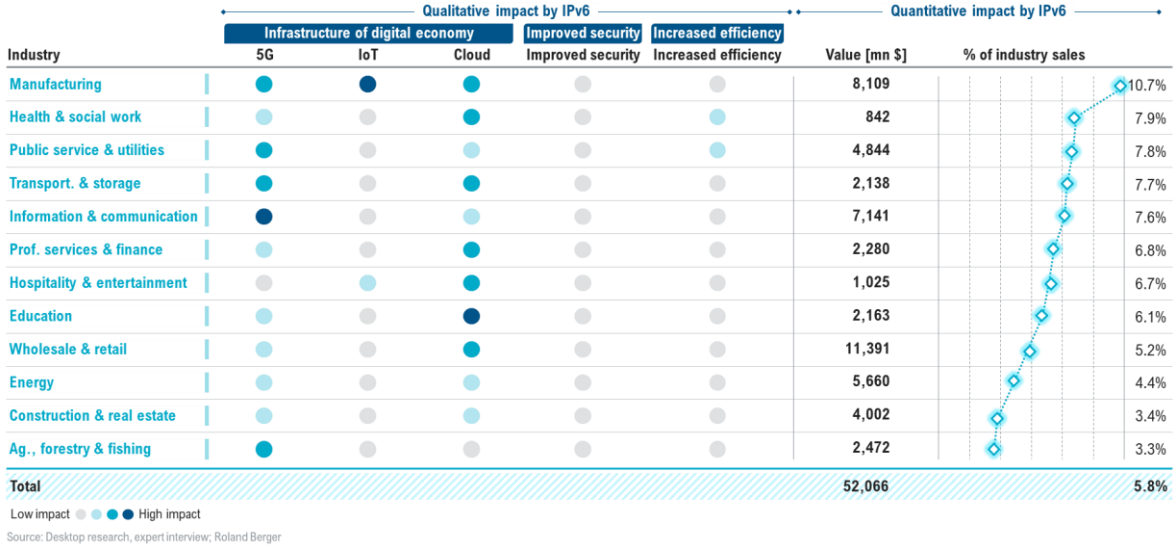


Figure 71. IPv6 industry value creation in Nigeria

IPv6 development status

- Nigeria ranks 67 out of 92 countries with a score of 0.30 and is grouped as adopter. This means Nigeria's IPv6 deployment level is in the middle of the world

Figure 72. IPv6 development status in Nigeria

Recommendations

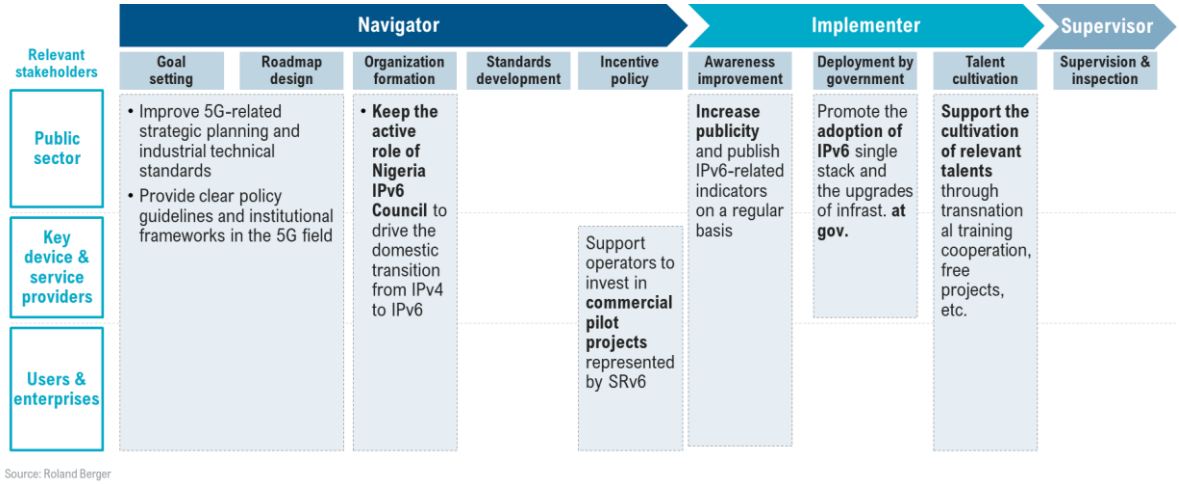


Figure 73. Policy recommendations for Nigeria

3.3.2.8 Egypt

The digitalization infrastructure in Egypt is very limited, but the digital economy has grown fast over the past few years. IPv6 and digitalization have evolved concurrently. Due to the absence of a mandated regulation, the digital economy's increased need for intellectual property must nevertheless be relayed to operators and end users.

IPv6 industry sector impact

We estimate that the potential value created by deploying IPv6 across multiple industries in Egypt would total $47 billion by 2025, equivalent to 5.0 % of the gross value of these industries in 2025.

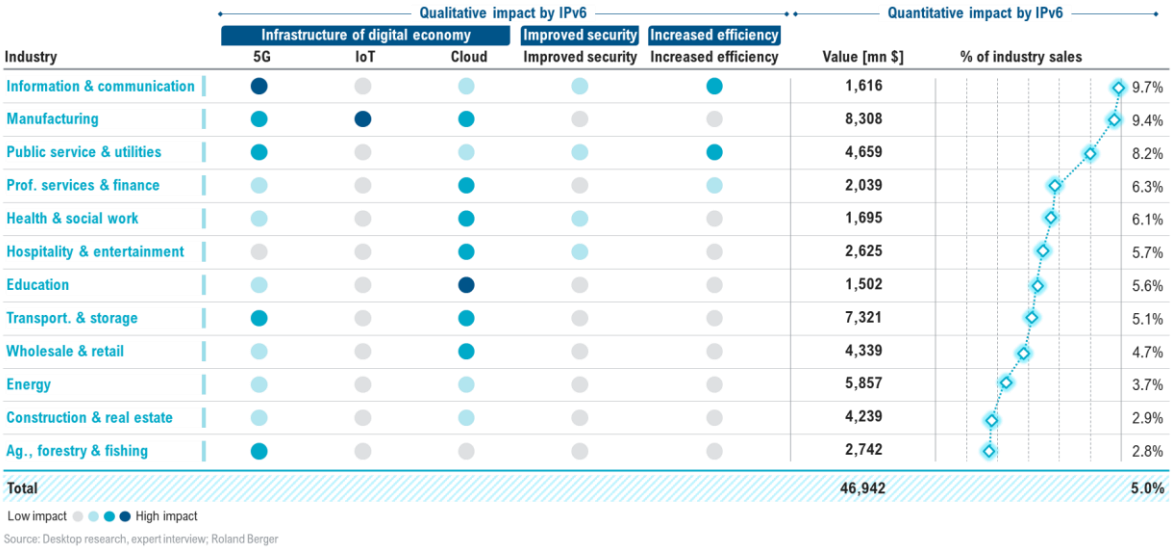


Figure 74. IPv6 industry value creation in Egypt

IPv6 development status

- Egypt ranks 70 out of 92 countries with a score of 0.30, grouped as an adopter. This means the level of IPv6 development in Egypt is in medium level in the world

Figure 75. IPv6 development status in Egypt

Recommendations

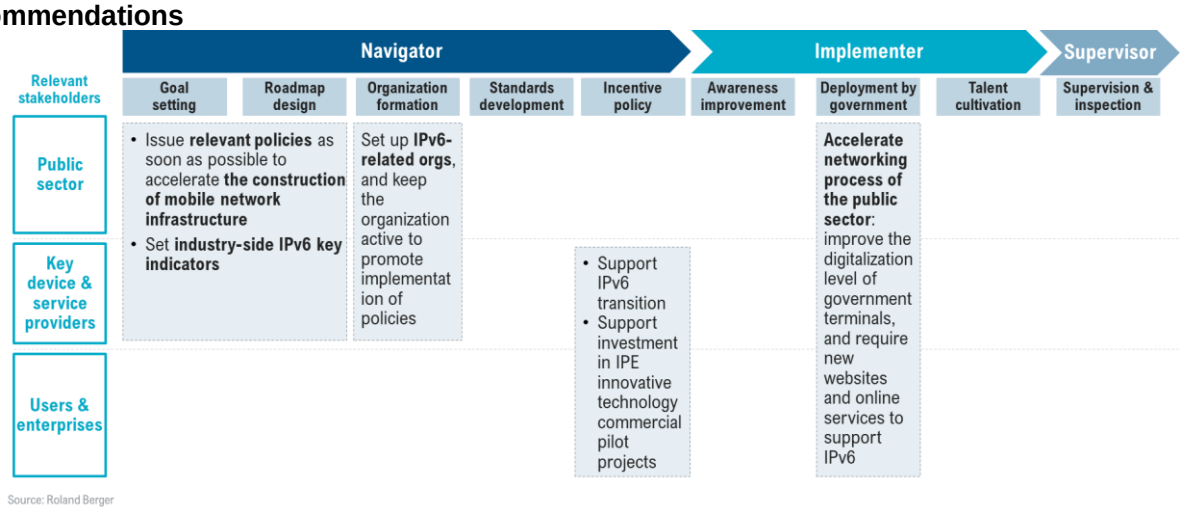


Figure 76. Policy recommendations for Egypt

3.3.3 Starters

3.3.3.1 Indonesia

Due to the low level of digitalization among terminals and therefore lack of demand, Indonesia faces weak incentives from leading ISPs and content providers to migrate to IPv6. However, it is among the world's leading countries in the deployment of cutting-edge IPv6 technologies.

IPv6 industry sector impact

We estimate that the potential value of IPv6 deployment across multiple industries in Indonesia could total US$78 billion by 2025, which is equivalent to 3.0% of the total real output value of these industries in 2025.

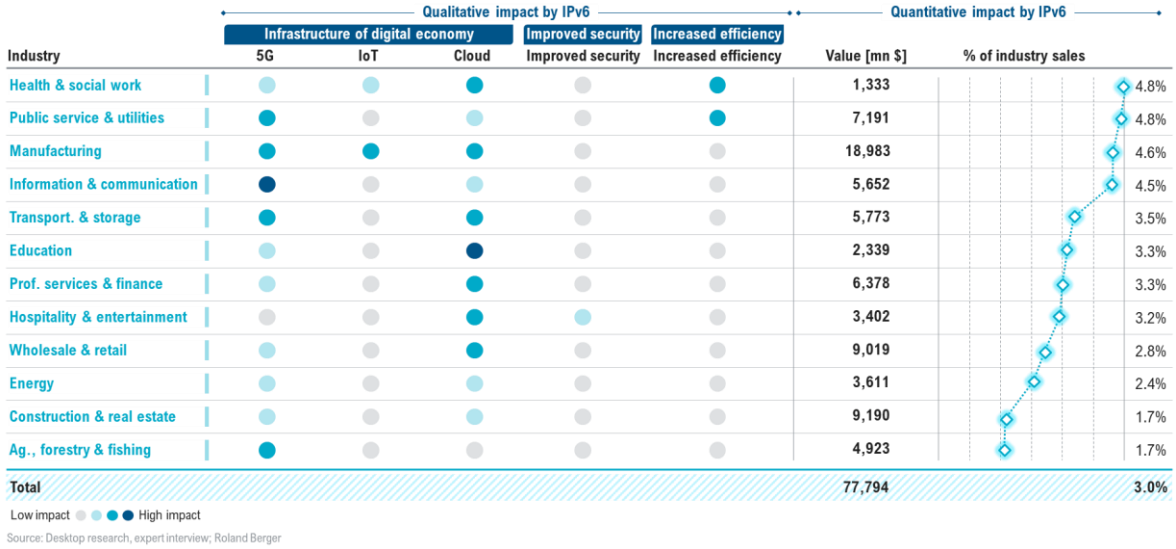


Figure 77. IPv6 industry value creation in Indonesia

IPv6 development status

- Indonesia ranks 74 in 92 countries, with a score of 0.29, and is grouped as an adopter. This means that IPv6 deployment status in Indonesia is in medium level.

Figure 78. IPv6 development status in Indonesia

Recommendations

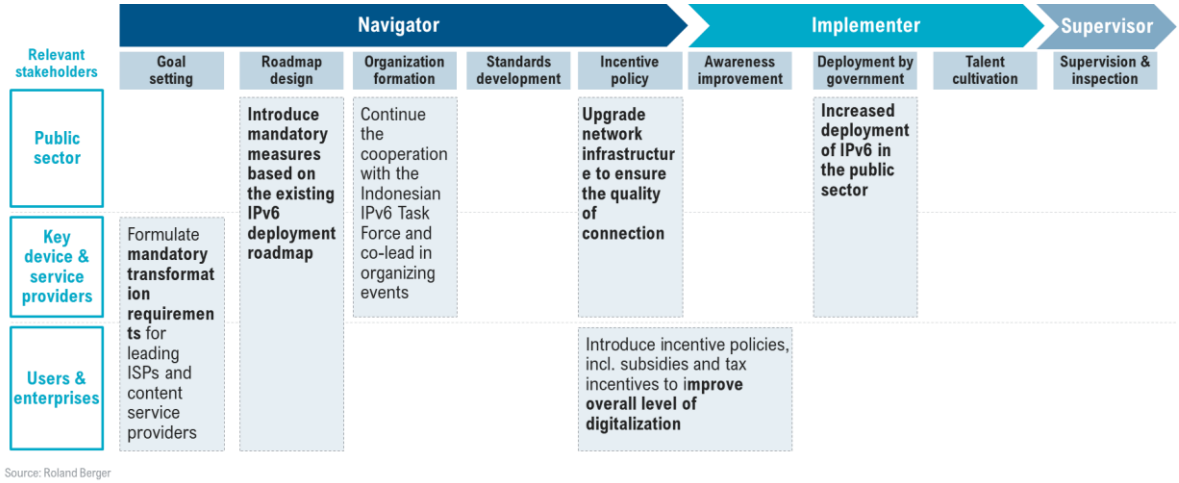


Figure 79. Policy recommendations for Indonesia

4. Policy Recommendation

4.1 Challenges faced in IPv6 Enhanced Innovation development

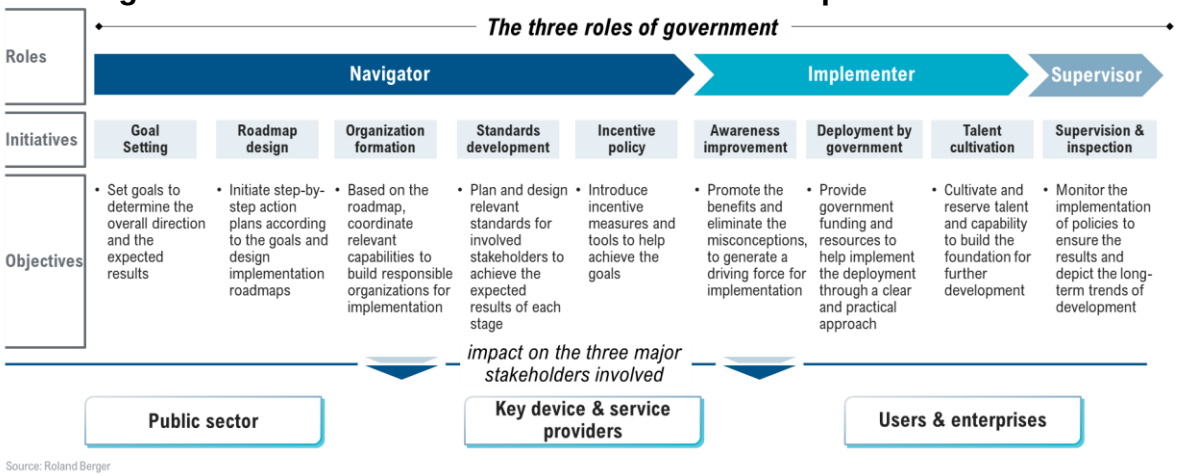


Figure 80. The three roles and nine initiatives of government

4.2 General recommendations by group

In general, for countries in different development stage, the government have varied emphasis:

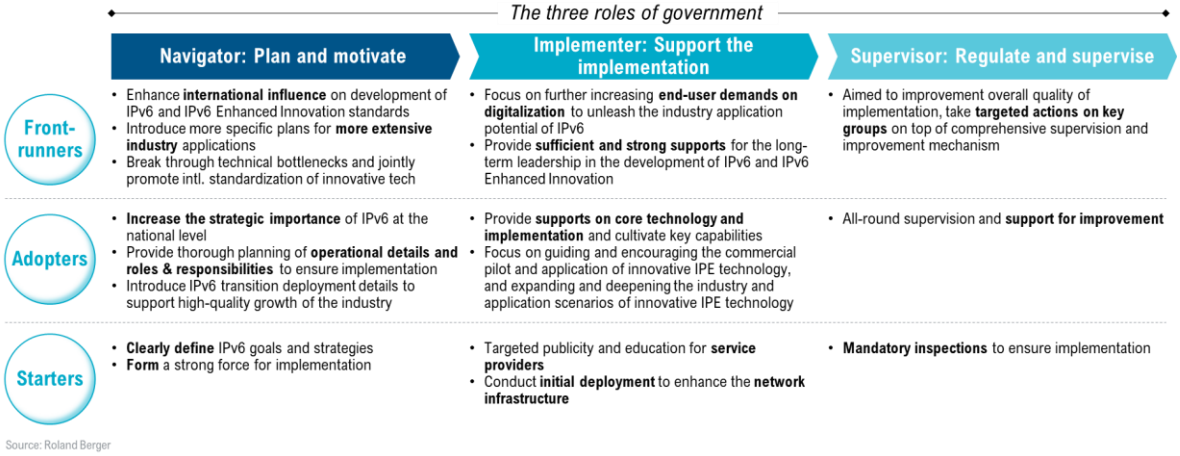


Figure 81. Policy focus for different segments

4.3 Detailed recommendations by group

4.3.1 Front-runners

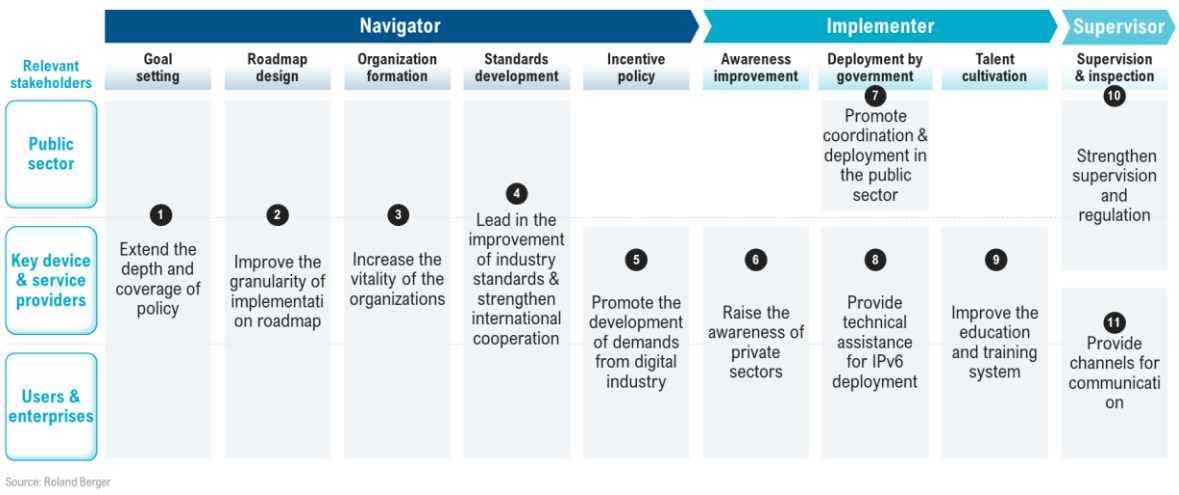


Figure 82. Policy recommendations for front-runners

4.3.2 Adopters

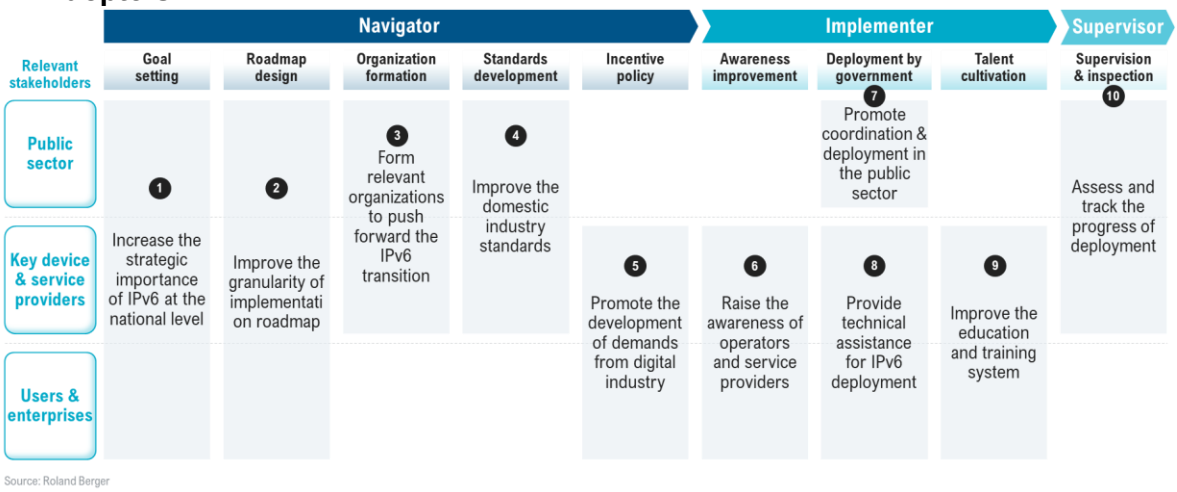


Figure 83. Policy recommendations for adopters

4.3.3 Starters

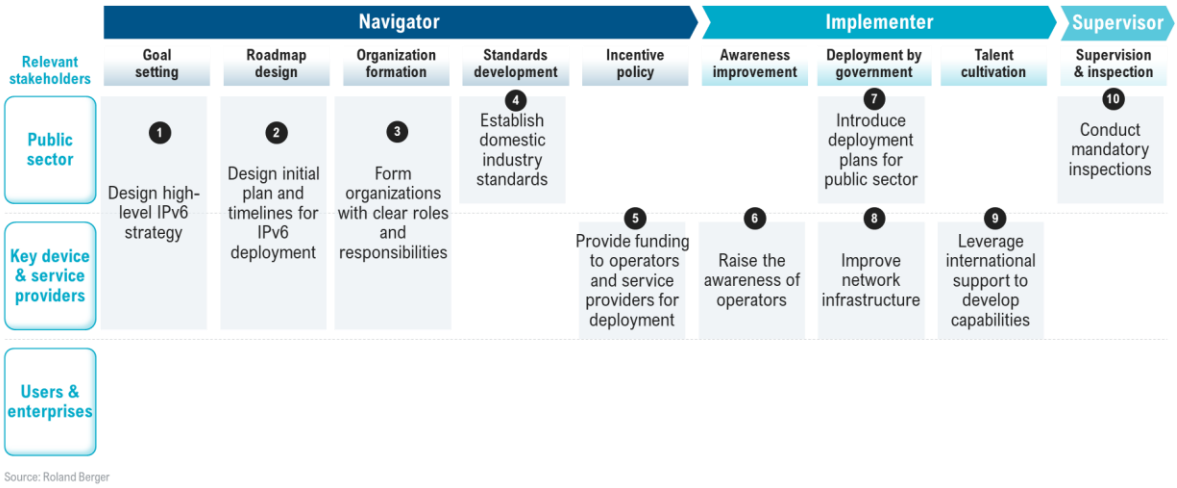


Figure 84. Policy recommendations for starters

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