Foresight for the ASEAN Plan of Action on Science, Technology and Innovation (APASTI) 2026–2035

Actions and priorities

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Abstract

This report provides supplementary foresight material to inform the development of the next ASEAN Plan of Action for Science, Technology and Innovation (APASTI 2026–2035) to be launched by ASEAN's Committee on Science, Technology and Innovation (COSTI) in 2025. Outcomes from workshops conducted in Jakarta and online with 80 representatives from all ASEAN Member States and across government, business and research sectors are provided along with desktop research and analysis on the science, technology and innovation capacity of ASEAN Member States. The report concludes by providing broad direction on prioritised action areas, or strategic thrusts, for the next APASTI. It also includes a recommendation based on the workshops, research and comments from representatives of Science Ministers given when the work was presented to the 86th Annual Meeting of COSTI in Singapore on 10 October 2024.

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Acronyms and abbreviations

AFA	ASEAN Foresight Alliance
AI	Artificial Intelligence
AMS	ASEAN Member State
APASTI	ASEAN Plan of Action on Science, Technology and Innovation
ASEAN	Association of Southeast Asian Nations
COSTI	Committee on Science, Technology and Innovation
IPCC	Intergovernmental Panel on Climate Change
ICT	Information and Communications Technology
GCI	Global Competitive Index
GenAI	Generative AI
GII	Global Innovation Index
LLM	Large Language Model (to power generative AI)
MCDA	Multi-Criteria Decision Analysis
MSME	Micro and Small to Medium Entreprises
R&D	Research and Development
SME	Small to Medium Enterprise
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
S&T	Science and Technology
TFP	Total Factor Productivity
VC	Venture Capital

1 Executive summary

Science, technology and innovation (STI) is central to modern economic growth and development. Innovation across many fields drives social and economic change and is a critical component of globally competitive industrial sectors and national economies.

As a region, ASEAN has moved up in global rankings for innovation over the previous decade. Much of this may be attributed to ASEAN fostering greater cooperation on science, technology and innovation, both between ASEAN Member States and with external development partners.

Since 1989 ASEAN's Committee on Science and Technology (COST – later COSTI to include innovation) has published a plan to support, build, coordinate and utilise scientific effort to achieve common goals and address regional challenges confronting ASEAN Member States.

The ASEAN Plan of Action on Science, Technology and Innovation (APASTI) is now in its fifth iteration. The current plan will expire in 2025, and the new APASTI (2026–2035) is in development. The APASTI 2026–2035 aims to position ASEAN as a global leader in STI, fostering prosperity, competitiveness, and inclusivity. It serves as a catalyst for technological advancements, economic growth, and an enhanced quality of life, with a focus on innovation, global collaboration, and sustainable development.

Foresight has been central to the development of the previous plans, and significant foresight has already been undertaken by the ASEAN Foresight Alliance to inform the development of the APASTI 2026–2035.

This report adds to the comprehensive foresight work already completed by the ASEAN Foresight Alliance (AFA), as well as material provided by the ASEAN Economic Committee and subcommittees of ASEAN.

This report:

- Undertakes further analysis on the science, technology and innovative capacity of ASEAN Member States in 2024.
- Identifies over 80 further specific actions for ASEAN to consider and groups those actions into six broader strategic thrusts for science, technology and innovation effort over the coming decade.
- Prioritises those areas of action through a multi-criteria decision-making process.
- Places the actions on a broad roadmap to inform priorities.

Analysis of science, technology and innovative capacity of ASEAN Member States in 2024

In 2024 ASEAN Member States as a regional bloc had a combined average ranking of 65.6 on the Global Innovation Index – up from 72.16 in 2016 (or up 7 positions in the rankings), showing steady but uneven progress over the last decade.

A cluster analysis describes four distinct groups of ASEAN Member States based on their innovative attributes.

There is significant diversity in ASEAN Member States' capacity to undertake and utilise scientific, technological and innovative activities. This ranges from Singapore, a high-income country that consistently ranks in the top ten of global innovation indices due to its strong investment in research and development (R&D), technology infrastructure, and education, to Cambodia, Laos, and Myanmar which currently have limited research infrastructure, lower STEM skills levels and reduced access to capital. Malaysia and Thailand have emerging innovation and technology hubs driven by growing tech ecosystems and government support for R&D, while Viet Nam and the Philippines outperform on STI indicators for their income brackets. Viet Nam is increasingly recognised for its tech startups and growing digital economy, and Indonesia has also seen rapid growth in research publications and in its e-commerce and fintech sectors.

The 'Readiness for Frontier Technology Index' suggests that ASEAN has significant potential to benefit from Industry 4.0 investment, with Singapore ranking 5th globally, followed by strong performances from Malaysia and Thailand.

ASEAN Member States have combined strengths growth in publications and science technology and innovation research activity, and the use of STI investment for productivity gains. They are weaker in research and digital infrastructure, access to finance for R&D, patenting rates, the use of STI to achieve gains in energy intensity, and in overall STI qualifications and skills.

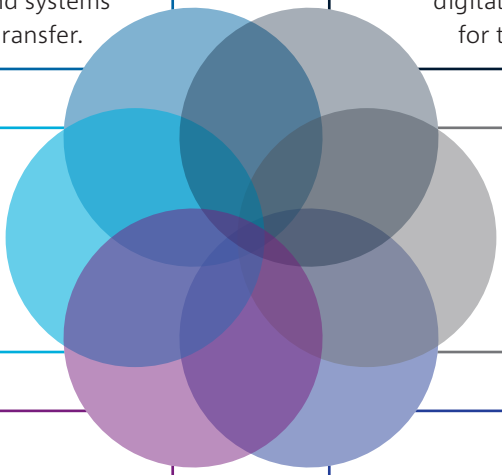
Looking forward, transformative technologies such as AI and high-performing computing, quantum technology and 6G communications are set to disrupt industries. They have both positive and negative foreseeable applications and need to be understood and regulated by policymakers to contribute to inclusive economic growth across ASEAN Member States.

One ASEAN

Coordination, collaboration, harmonisation of regulations and standards, interoperability of systems, IP and data-sharing, laws and systems to create frictionless tech and trade transfer.

R&D, info- and infra-structure

Platforms, information repositories and architecture, centres of excellence and digital and scientific infrastructure for R&D for transformative emerging technology.



Skills and talent

Access to education, skills mapping, collboration tools, skills development and mobility for advanced science capability.

Finance

For innovation including entrepreneurs, R&D, infrastructure and new business models for a digitally-mediated world.

Diversity

Inclusion, access and alternative perspectives for sustainability (including the regenerative economy).

Digital economy

Governance, civic empowerment, inclusion and adoption of new digital tools, principles and frameworks for responsible innovation particularly related to AI, quantum, bio-informatic data and privacy and security.

Workshop outputs

The workshops ranked the 10 forces of change, or megatrends, described by ASEAN Foresight Alliance in terms of their impact and uncertainty.

The top three trends in terms of impact over the coming decade were considered to be: 1. Environment and Planet, 2. Politics and Governance, and 3. Food and Water.

The top three in terms of uncertainty were considered to be: 1. Environment and Planet, 2. Politics and Governance and 3. Health Demographics.

Over 80 STI actions to address opportunities and challenges were identified under the forces of change. These were grouped into six strategic thrusts.

A multiple criteria decision analysis (MCDA) ranked improving skills and talent as the highest priority, while R&D info and infrastructure and finance were ranked in the next three places. Diversity and 'One ASEAN' actions were lower priorities.

The lower priority areas, despite containing a number of specific actions, may be seen as cutting across other areas of development.

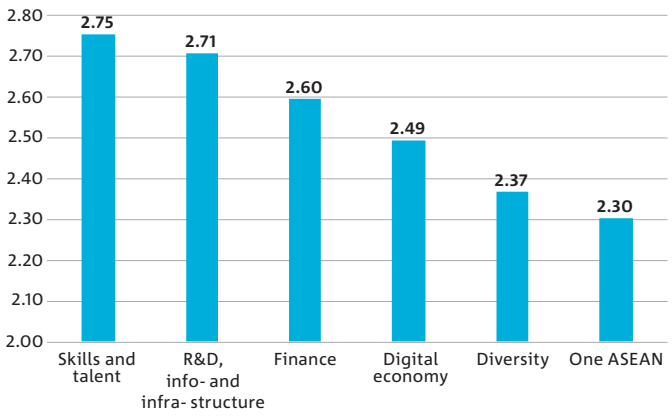
The prioritised actions match the identified areas of weakness for STI development in ASEAN Member States such as skills and talent and R&D infrastructure.

The actions were placed on a timeline that has been included as a broad roadmap to inform the APASTI 2026–2035 development and sequencing of activities.

The report concludes with recommendations for the development of the APASTI, specifically around the clarity and trackability of future APASTI strategic thrusts and identified actions.

With clear and achievable actions that address prioritised need and the ability to track progress on a more regular basis there is no doubt the next APASTI 2026–2035 can greatly assist ASEAN Member States in further building significant science, technology and innovation capability.

In doing so, the APASTI can also steer the application of STI capability to address the considerable challenges and opportunities of the next decade, and use it to build a prosperous, inclusive and sustainable future.



2 Introduction and goals of the APASTI

Science, technology, and innovation (STI) play a pivotal role in propelling economic growth and development – an integral aspect ingrained in the history of the Association of Southeast Asian Nations (ASEAN). Since its inception, ASEAN has consistently recognised the importance of STI, culminating in the adoption of the first regional Action Plan on Science and Technology (APAST) in 1985.

As the current ASEAN Plan of Action on Science, Technology, and Innovation (APASTI) 2016–2025 nears its conclusion, this project aims to inform the next plan covering the period of 2026–2035 (APASTI 2026–2035). This effort will culminate in the launch of APASTI 2026–2035 in June 2025 during the ASEAN Ministerial Meeting on STI in Jakarta, Indonesia, underscoring the commitment of ASEAN member states to shaping a visionary future for STI in the ASEAN region.

The APASTI 2026–2035 aims to position ASEAN as a global leader in STI, fostering prosperity, competitiveness, and inclusivity. It serves as a catalyst for technological advancements, economic growth, and an enhanced quality of life, with a focus on innovation, global collaboration, and sustainable development.

The success of APASTI 2026–2035 hinges on robust policies guiding decision-making, advancements in education for a skilled workforce, and a supportive environment for research and innovation. This project aims to obtain guidance for the APASTI 2026–2035 from an informed and representative range of views to inform a visionary future for STI in ASEAN, synonymous with sustainability, resilience, and inclusivity, ensuring ASEAN's leadership globally.

This project engagement will undertake foresight activities with key stakeholders and representatives of the science, technology and innovation communities of the ASEAN Member States. The resultant foresight materials will feed directly into the formation of the APASTI 2026–2035 and will be crucial in shaping ASEAN's STI landscape and providing strategic direction for impactful policies.

The foresight processes will engage ASEAN Member States and stakeholders and will seek to understand emerging trends, contributing to the development of APASTI 2026–2035.

The overarching aims and objectives of this work are to:

- **Engage ASEAN Member States and key stakeholders:** Incorporate diverse perspectives to shape the future of STI in ASEAN through APASTI 2026–2035.
- **Support ASEAN in navigating uncertainties:** Assist in navigating uncertainties and promoting sustainability, gender equality, disability inclusion, and social equity.
- **Develop foresight products:** Create foresight products to provide insights into the strategic direction of APASTI 2026–2035. These products will enhance the equitable resilience and adaptability of the ASEAN region in a rapidly evolving technological future.

3 Background

3.1 The APASTI and its role in science, technology and innovation direction in the ASEAN region

The APASTI 2026–2035 will be the sixth plan ASEAN has produced to direct, coordinate and support science, technology and innovation effort across the ASEAN Member States and the region as a whole. The first plan was produced in 1989 (Figure 1).

The vision of the 2016–2025 APASTI is '*a science, technology and innovation-enabled ASEAN which is innovative, competitive, vibrant, sustainable and economically integrated.*'

To achieve this vision the APASTI contains goals and strategic thrusts, or areas of actions to focus the development of STI capability and systems.

The actions and priorities listed under the strategic thrusts drive STI development, cooperation and partnerships across the region through the creation of coordinating committees, and through matching actions with development partners and funding agencies.

The APASTI also leverages STI capability across the region to address the shared challenges and opportunities of ASEAN Member States.

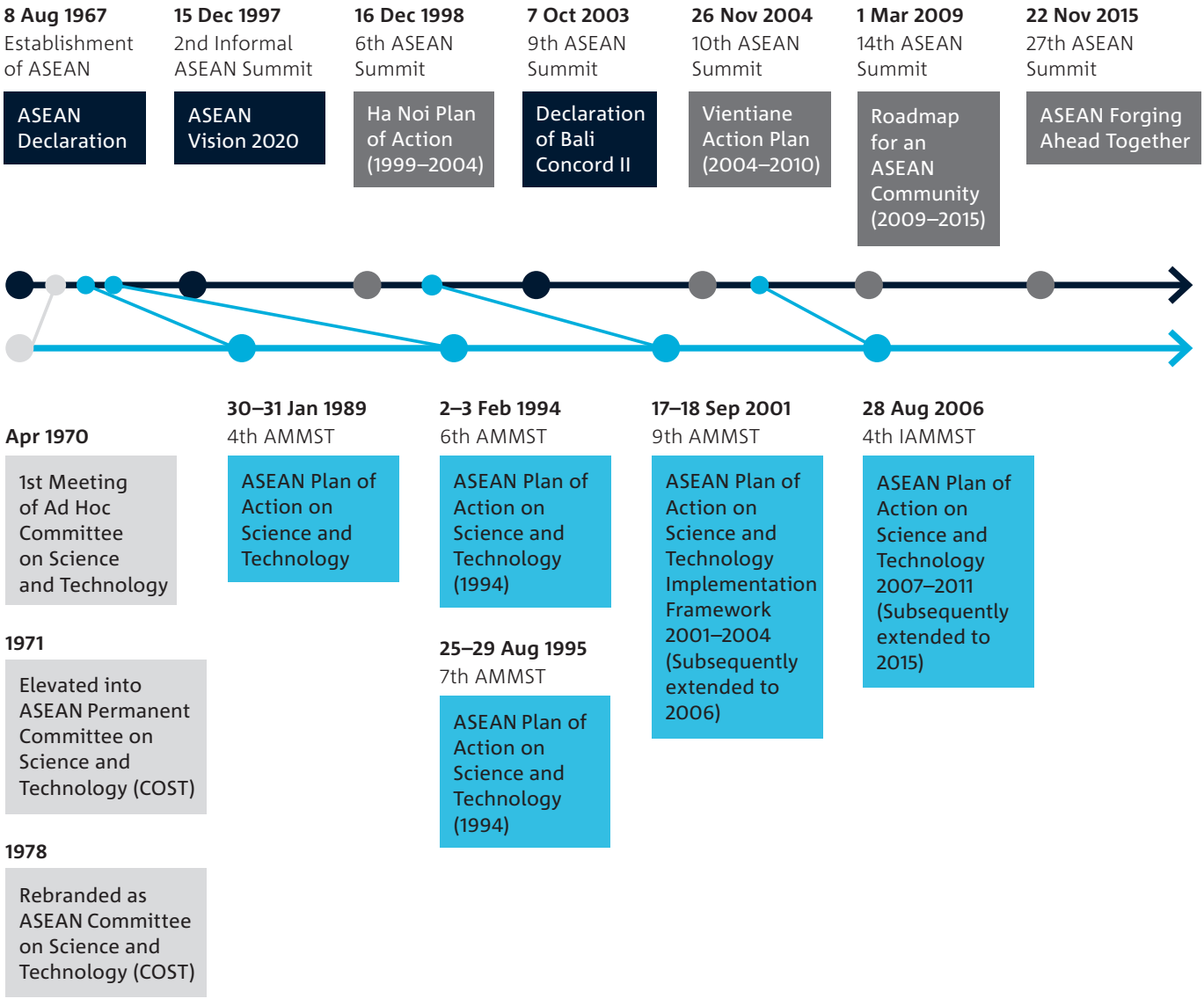


Figure 1. Timeline of action plans for science, technology and innovation since the first meeting of the ASEAN Committee on Science and Technology in 1970

Source: ASEAN APASTI 2016–2025

Review of the current APASTI (2016–2025)

In 2023, Cambridge Industrial Innovation Policy, IfM Engage, and the University of Cambridge conducted a review of the APASTI (2016–2025) and found that the implementation of the plan resulted in 172 completed or ongoing projects, and that 35% of the projects were conducted in collaboration with Dialogue Partners.

There were 43 expected outputs defined in the Implementation Plan of the APASTI 2016–2025, however, only 42% of those were completed, with 58% either ongoing or showing no evidence of progress.

The review also found plenty of room for improvement, particularly in the monitoring, clarity and conciseness of actions.

That review suggests the next APASTI:

- Better define areas of common interest to create a united regional vision for STI.
- Leverage the region's foresight capacity to better inform the development of the next APASTI.
- Enhance and engage more STI stakeholders in the development and implementation of the APASTI.
- Include gender equality and the representation of young people and under-represented groups as a cross-cutting principle.
- Establish a monitoring and evaluation framework.

The review also examined the progress of the ASEAN region on a number of key indicators and found significant improvements on the Global Innovation Index for the region, increases in R&D expenditure as a proportion of GDP in most ASEAN Member States (although still low by international standards), increased number of researchers per million people across the region, and increased patents applications and citable publications.

3.2 What has changed since the last APASTI?

Since the current APASTI was formulated prior to its launch in 2015:

The world has experienced a global pandemic causing over 7 million deaths, according to the World Health Organisation [2]. The COVID-19 pandemic also saw the development of three viable and effective novel vaccines within 12 months – supporting global collaboration via research platforms and using AI in 3D modelling and protein sequencing in health product development and clinical trials. It also challenged public health systems and tested communications from health departments who often found themselves fighting online misinformation.

Climate change has worsened, with carbon dioxide parts per million in the atmosphere rising from 398 (January 2016) to 420 (August 2024) [3]. Average global surface temperatures have risen from 1.03 degrees above the 20th century average, to 1.18 degrees above the average. Global climate models suggest we are now on track for a 2 degree increase in global temperatures, and without a dramatic conversion to low-carbon emitting energy sources for industry and transportation, we will reach the point of no return before the end of 2035 [4]. Technologies that assist in decarbonisation are urgently being deployed to ensure energy supplies and help nations meet their net-zero targets.

Geopolitical tensions have reshaped trade and are causing tensions around trading routes shared resources and supply chains. In 2018, the US Federal Administration implemented new trade barriers for imports from China, and China took retaliatory trade action. Even though there was a reduction in those tensions with a new administration in 2020, many tariffs remained in place. This has caused an offshoring of production to other, often nearby economies in ASEAN. The recent re-election of a protectionist administration in the US may amplify some of these impacts. Militarisation of the South China Sea has also increased with the tensions between the global superpowers impacting nearby ASEAN Member States, including the Philippines, Viet Nam, Thailand, Indonesia and Malaysia.

Technological developments are reshaping industries and society. AI, including generative AI (GenAI) is changing research, scientific development and our education systems [5]. Scientific professional areas that once required extensive training and expertise – such as those in radiography, computer coding and scientific copyediting – can now be augmented with large language models (LLMs) that power GenAI [6]. Other professional areas – in prompt engineering, AI project management and detecting deep fakes – are emerging.

Quantum science, including quantum computing, is also set to disrupt science and other industries. Error-free quantum computing that can connect high-power qubits is rapidly advancing and these will reshape the world of cryptography, communications and computing more generally. Quantum sensing for use in various scientific fields, from industrial mineralogy to health science and nanotechnology, will also mean a much greater understanding of molecular processes and far greater accuracy in elemental detection.

4 Methodology

The methodology used for this report integrates the comprehensive foresight work already completed by the ASEAN Foresight Alliance and builds on it through an analysis of STI capability across ASEAN and the inputs from invited guests to two participatory workshops. Every effort was made not to duplicate the material already compiled through ASEAN processes or by the ASEAN Foresight Alliance.

The work by CSIRO's Data61 centred around two facilitated workshops to determine actions and priorities for the APASTI 2026–2035. The inputs from the workshops supplemented desktop research by CSIRO on the STI capacity of ASEAN. The aims of those workshops were to:

1. **Engage ASEAN Member State and Key Stakeholders:** Incorporate diverse perspectives, sectors and from all ASEAN member states to shape the future of STI in ASEAN through APASTI 2026–2035.
2. **Build on the significant work of the ASEAN Foresight Alliance and other existing planning and foresight documents** to identify the significant challenges and opportunities for the ASEAN region, as well as actions that may be available for COSTI to incorporate in the APASTI 2026–2035.
3. **Determine sectorial action priorities based on weighted criteria and incorporate social inclusion and diversity as a cross-cutting principle**.
4. **Determine a broad roadmap** to assist with further road mapping and the formulation of the APASTI 2026–2035.

The workshops were held in Jakarta and online on 11-13 September 2024. In total, there were over 80 attendees.

There were representatives from all ASEAN Member States, the Research and University Sector, the governments and ministries of ASEAN Member States, ASEAN-linked forums, and the industry and the private sector. A count of workshop attendees by category for the face-to-face workshop can be found in **Annex B.**

The workshops conducted by CSIRO's Data 61 added to the actions identified by the ASEAN Foresight Alliance under their identified forces of change, or megatrends [7], impacting the ASEAN region over the next decade. These actions were then grouped into broader 'strategic thrusts' and prioritised using multiple criteria decision analysis (MCDA). The actions were then put into two five-year periods: 2026–2031 and 2031–2035. Only one action was listed as being beyond 2045.

Actions and criteria for weighting the actions in MCDA align ASEAN sectoral plans with the five-year cadence of the AEC strategic plans (e.g. 2026 to 2030).

Pre-existing work by the ASEAN Foresight Alliance

The ASEAN Foresight Alliance's draft report titled ASEAN Science, Technology and Innovation Ecosystem Foresight 2025 took two years to complete. That report:

- **Identifies ten forces of change**, or what might refer to as 'megatrends' [7, 8]. These forces of change are interrelated and cover political, environmental, social, legal, technological and economic changes occurring across ASEAN over the next 5 and 10 years.
- **Creates four scenarios** for visualising the future of the ASEAN region along the axes of 'Collaboration and Sharing' and 'Robustness (well-functioning) of the Ecosystem'.
- **Defines groups of ASEAN Member States** based on the patterns of structure, behaviour, and activities that characterised their STI ecosystems: Pace-setter (Singapore), Maturing (Malaysia, Brunei, Thailand, Indonesia, the Philippines and Viet Nam), and Emerging (Cambodia, Laos, and Myanmar [and East Timor]).
- **Defines eight enablers of an innovation ecosystem**: Institutions, interaction, integrity, infrastructure, internationalisation, incentives, intellectual capital and 'infostructure' – or digital infrastructure and ICT connectivity.
- **Describes the paradigm shifts** needed to transition to a preferred scenario.
- **Describes eight key enablers** for the preferred scenario. These enablers outline the values needed for a desired future.
- **Provides illustrative case studies** that highlight the application of transformative technologies in ASEAN Member States.

The work facilitated by Data61 in this project fills in the gaps of the ASEAN Foresight Alliance report and builds on other works by the World Economic Forum, WIPO through the Global Innovation Index, the UN and UNESCO to create viable actions for ASEAN and ASEAN Member States to progress STI towards desired goals. These also align with and build on the actions of the APASTI 2016–2025 and the ASEAN AEC Plan 2026–2045.

Figure 2 outlines the broad methodology for this work while further methodology on the multicriteria decision analysis (MCDA) is described in **Annex B.**

Current state of STI capability across ASEAN Member States and the ASEAN region (broad overview)

Existing challenges and opportunities for STI across ASEAN Member States (broad overview)

Forces of change impacting ASEAN nations (AFA report) and other ASEAN documents

- Changing populations and demographics
- Health dynamics
- Environmental changes
- Food and water supply changes
- Energy production
- Growth of the digital economy and MSMEs
- Changing consumer markets
- Changing education levels and literacy
- Development of effective governance across ASEAN
- Changes to economic and social equality and inclusion

STI actions to respond to challenges and opportunities of the forces of change

Criteria creating directionality

- Technology adoption and diffusion
- STI skills and talent
- Partnerships and collaboration
- Promotion of entrepreneurship
- Innovation funding
- Research infrastructure
- Social inclusion and sustainable development
- ASEAN single market

MCDA and road-mapping exercises

Formation of new strategic thrusts

Prioritised actions on a broad roadmap out to 2035.
Actions are grouped by each 5-year period and long-range actions after 2035 noted.

- Actions facilitated by CSIRO's Data61
- Already defined by the ASEAN Foresight Alliance in *ASEAN Science, Technology and Innovation Ecosystem 2035* report or other ASEAN documents

Figure 2. Broad methodology of the work using the ASEAN Foresight Alliance report as the foundation of the foresight for the APASTI 2026–2035

5 Analysis of science, technology and innovation capability and expertise across the ASEAN region

In 2024, ASEAN Member States as a regional bloc had a combined average ranking of **65.6 on the Global Innovation Index** – up from 72.16 in 2016.

(Source: Data61 and Global Innovation Index 2024)

ASEAN Member States have 2 of the top 100 global technology clusters in 2024 – **Singapore (33th largest)** and **Kuala Lumpur (93rd largest).**

(Source: Data61 and Global Innovation Index 2024)

Singapore leads the ASEAN region in Science, Technology and Innovation but Malaysia, Viet Nam, and the Philippines are all in the top three innovation economies in their income group. These nations are leading in innovation spending efficiency.

(Source: Data61 and Global Innovation Index 2024)

Combined GDP growth across ASEAN was 4.1% in 2023, 4.7% in 2024, and is forecast to be **↑4.8% in 2025.**

(Source: ASEAN Statistics and ADB 2024)

ASEAN is the world's **5th largest economy** with a combined ASEAN GDP in 2023 was USD$3.8 trillion. This is predicted to grow to USD $4.5 trillion by 2030.

(Source: ASEAN Annual Report, and ASEC)

ASEAN conducted **>USD$3.6 trillion** in trade in 2023, or just under 10% of global trade.

(Source: ASEAN Annual Report)

Research activity across ASEAN Member States has expanded dramatically since 2000, with annual publications increasing from 9,500 papers in 2000 to 410,388 by 2023, representing a **43-fold growth.**

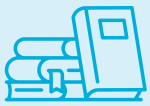
(Source: Lens Data 2024)

ASEAN Member States now contribute **>3.6% of global research output.**

(Source: Lens Data, 2024)

Over 50% of ASEAN publications involve **international co-authorship,** with Cambodia, Myanmar, and Laos exceeding 95%.

Source: Lens Data, 2024)



In 2023, ASEAN recorded **>15,000 patents** **420,000 trademarks** **≈20,000 industrial designs.**

(Source: WIPO, 2024)

Singapore, Malaysia, Indonesia, and Viet Nam, collectively account for **>95% of patents filed** from ASEAN Member States.

(Source: WIPO, 2024)

5.1 Current stage of science, technology, and innovation capacity across ASEAN

The ability of nations to harness the power of science, technology, and innovation (STI) has become a decisive factor in ongoing sustainable development and economic resilience.

ASEAN is a region marked by dynamic growth and diverse economies. The ability of ASEAN Member States to take advantage of STI developments will determine their future security and prosperity. However, ASEAN countries, like many countries globally, are facing significant challenges, including:

- The increasing costs of climate change, including climate adaptation and mitigation measures for changing weather patterns, extreme weather events and rises in sea levels.
- Attracting the required finance for technological and infrastructure investment.
- Changing geopolitical trade and other conditions.
- Emerging adverse impacts of some digital technology development.

Maintaining high and sustainable growth will require reforms that maintain competitiveness and improve productivity by uplifting the STI capacity of the entire region.

This chapter is devoted to describing the current state of STI across the ASEAN region by:

- Providing a detailed analysis of existing STI capacity across ASEAN Member States.
- Identifying key areas for potential growth.
- Evaluating the diverse STI landscapes across ASEAN Member States using cluster analysis.
- Examining factors such as research and development expenditure, innovation infrastructure, and technological capabilities.

Through detailed analysis and benchmarking against global standards, the chapter will highlight disparities and opportunities for enhancing STI development and effectiveness.

This section defines innovation capacity as a region's or country's ability to produce and commercialise new technologies over time consistently. It reflects not just current outputs but the underlying factors driving the innovation process, such as education quality, R&D infrastructure, financial support, and public-private partnerships.

Unlike scientific achievements or industrial competitiveness, innovation capacity focuses on creating an environment that supports the continuous development of new knowledge, technologies, and business models. The framework for assessing national and regional innovative capacity draws from three key areas of prior research: ideas-driven endogenous growth theory [9], the cluster-based theory of national industrial competitive advantage [10], and the literature on national innovation systems [11].

Each of these perspectives highlights distinct factors that contribute to the overall flow of innovation within a given environment.

This chapter begins with an overview of the STI capacity within ASEAN, exploring key activities, impacts, and significant challenges while also identifying critical enablers for STI development across the region.

5.2 Overview of science, technology, and innovation in ASEAN

In general, the STI capacity of ASEAN countries has steadily evolved, with recent improvements narrowing the innovation gap between Southeast Asia and Europe – see Table 1 which summarises the innovation capacity of ASEAN nations on several global scales.

The Global Innovation Index (GII)

The Global Innovation Index (GII) 2024 highlights this progress, showing seven out of ten ASEAN nations advancing in their rankings in the last two years (Figure 3). Indonesia made the most significant leap to 54th place in 2024, up from 99th place in 2011, driven by strengths in university-industry R&D collaboration, cluster development, and startup financing.

Other countries like Thailand (41st), Viet Nam (44th), and the Philippines (53rd) performed well relative to their economic development levels [12]. Brunei Darussalam is the only ASEAN country that dropped on the GII between 2011 and 2024 (from ranking 75th in 2011 to 88th in 2024).

As a regional bloc, ASEAN improved in average rankings by nearly 7 positions since 2016. This shows steady but patchy progress.

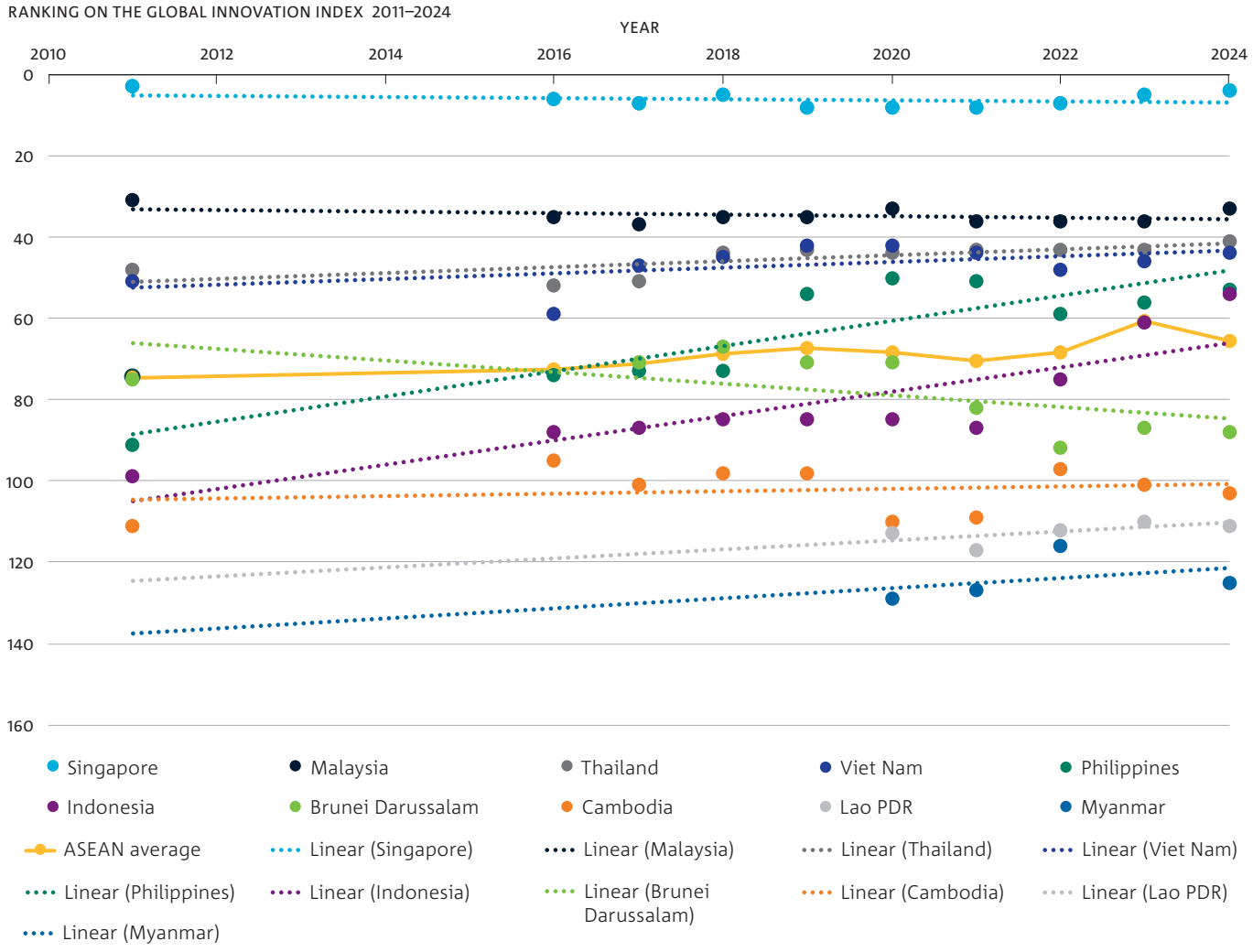


Figure 3. ASEAN Member States rankings on the Global Innovation Index 2011–2024

Source: Global Innovation Index 2011–2024

Other indicators, such as the Global Competitiveness Index (GCI) and the Global Knowledge Index (GKI), also underscore persistent disparities in STI capacity across the region (Table 1). On these indices the gap in competitiveness between ASEAN's highest and lowest performers remains substantial, more pronounced than in other global regions.

The Global Knowledge Index reveals imbalances in knowledge infrastructure, where Singapore, Malaysia, Thailand, and Viet Nam excel in information and communications technology (ICT) deployment, STEM education, and R&D, while Laos and Myanmar lag [13].

Looking ahead, the Readiness for Frontier Technology Index suggests that ASEAN has significant potential to benefit from Industry 4.0 investment, with Singapore ranking 5th globally, followed by strong performances from Malaysia and Thailand. However, countries like Laos and Cambodia face challenges due to limited R&D efforts and weak ICT access [14].

Table 1. Rankings in innovation-related indices across countries

	GLOBAL INNOVATION INDEX 2024[1]	BLOOMBERG INNOVATION INDEX 2024[2]	THE GLOBAL COMPETITIVENESS INDEX (GCI) 4.0[3]	GLOBAL KNOWLEDGE ECONOMY INDEX 2024[4]	READINESS FOR FRONTIER TECHNOLOGY INDEX 2021[5]	DIGITAL READINESS INDEX 2021[6]
SOURCE	*WIPO*	*BLOOMBERG*	*WEFORUM*	*UNDP*	*UNCTAD*	*CISCO*
Singapore	5/132	8/50	1/141	12/133	5/158	1/146
Malaysia	36/132	27/50	27/141	43/133	31/158	42/146
Thailand	43/132	46/50	40/141	52/133	46/158	51/146
Viet Nam	46/123		67/141	71/133	66/158	57/146
Indonesia	61/132		50/141	79/133	82/158	73/146
Philippines	56/132		64/141	80/133	44/158	87/146
Cambodia	101/132		106/141	104/133	113/158	92/146
Laos	110/132		113/141	109/133	127/158	115/146
Myanmar	116/132			118/133	121/158	110/146
Brunei	87/132		56/141	54/133	69/158	

1 Global Innovation Index (GII) measures the innovation performance of countries based on indicators such as R&D, education, and technology output.

2 Bloomberg Innovation Index ranks countries based on their innovation capacity, including factors such as R&D, patent activity, and high-tech density.

3 Global Competitiveness Index assesses the competitiveness of countries based on factors such as infrastructure, macroeconomic stability, and innovation.

4 Knowledge Economy Index encompassing seven composite sub-indices that meticulously measure the performance of six critical sectors: pre-university education; technical and vocational education and training; higher education; information and communications technology; research and development, and innovation; and economy

5 Readiness for Frontier Technology Index (UNCTAD) reflects the capacity to use, adopt and adapt frontier technologies: ICT deployment, skills, R&D activity, industry activity and access to finance

6 Digital Readiness Index (Cisco) assesses a country's readiness to embrace digital technologies based on infrastructure, skills, and connectivity.

7 This report utilises K-mean cluster technique. Details of the methodology can be found in the **Annex B.**

Groupings of ASEAN Member States by science, technology and innovation capability

The cluster analysis of ASEAN countries reveals four distinct groups based on their innovation capacity, reflecting their varying levels of technological and economic development[7] (Figure 4).

Singapore (red), is labelled an 'innovation powerhouse' and leads the region across numerous innovation indicators. Singapore also competes with other advanced nations at the top of the innovation rankings

The 'emerging innovators' cluster (orange) includes Thailand, Malaysia, Indonesia, the Philippines, and Viet Nam. These nations show strong and growing innovation capabilities, as well as specific areas of expertise.

The 'digital starters' cluster (light green) includes Laos, Cambodia, and Myanmar. These countries have limited patent activity, weak internet infrastructure, and shortages in human capital.

Lastly, Brunei (dark green), is categorised as a 'niche innovator' and displays strengths in specific sectors, and a lack of capability in others.

Figure 4. ASEAN countries by innovation clusters

Source: Author created

STI activities and impact

Research activity

Research activity across ASEAN Member States has expanded dramatically since 2000, with annual publications increasing from 9,500 papers in 2000 to 410,388 by 2023, representing a 43-fold growth.

ASEAN Member States now contribute over 3.6% of global research output [15]. Singapore, Malaysia, Thailand, Viet Nam, and Indonesia lead the region in research output, with Indonesia experiencing the fastest growth, surpassing Singapore in publication volume.

Singapore, Malaysia, and Thailand also lead in citation impact, with Singapore surpassing others in high-quality journal publications. Smaller nations like Cambodia, Laos, and Myanmar produce much fewer publications but have increased their research output significantly over time. Their combined output increased from 24 in 1991 to over 3,700 in 2023 (Figure 5). The most frequently published research areas in the region include chemistry, biology, computer science, and materials science, with psychology emerging in Indonesia and the Philippines.

International research collaboration on STI papers

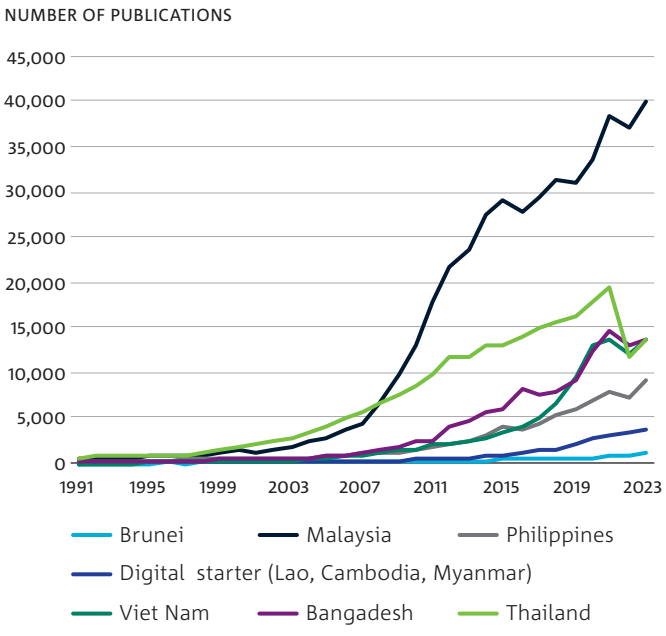
Over 50% of ASEAN publications involve international co-authorship, with Cambodia, Myanmar, and Laos exceeding 95% [15]. This high level of international collaboration is crucial for countries with developing research infrastructures, as it provides access to global expertise and resources. However, there is a notable tendency for ASEAN researchers to collaborate primarily with institutions outside the region. This underscores the need for enhanced facilitation of intra-ASEAN research collaboration to bolster regional research capabilities and integration.

IP generation

Patent, trademark and industrial design

ASEAN is becoming a recognised market for intellectual property (IP) protection, with significant growth in patents, trademarks, and industrial designs. In 2023, ASEAN recorded over 15,000 patents, 420,000 trademarks, and nearly 20,000 industrial designs (WIPO, 2024).

Most of this growth is from Singapore, Malaysia, Indonesia, and Viet Nam, collectively accounting for over 95% of ASEAN's patents. Despite this growth, the region still trails major innovation hubs like North America, Europe, and East Asia. For instance, Japan had over 400,000 patents granted in 2023, far surpassing ASEAN's numbers (15,000) (WIPO 2024).



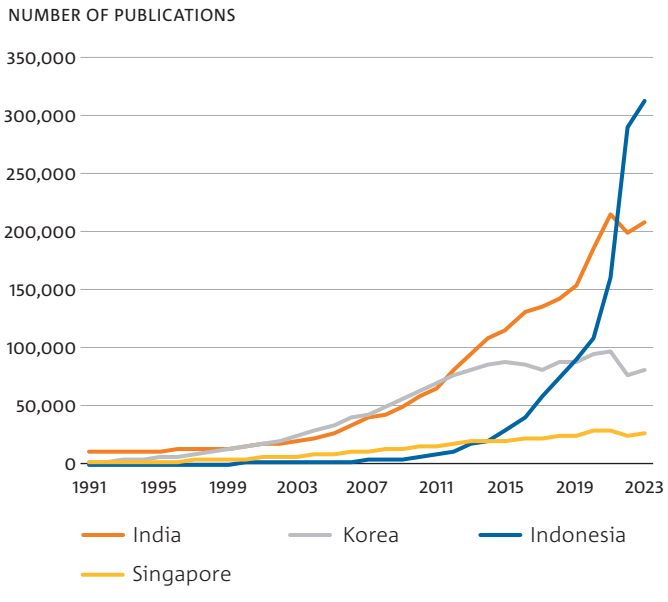


Figure 5. Publications in selected countries over time

Source: Lens, 2024

The rise in patent filings in Southeast Asia is primarily driven by international applicants, with 82% of patent filings originating from outside ASEAN, mainly from the United States, Japan, Europe, China, and South Korea (WIPO, 2024). Domestically, key research institutions like Singapore's A*STAR, Malaysia's MIMOS, and Indonesia's LIPI lead local filings. Meanwhile, trademark and industrial design filings are mostly dominated by domestic applicants, with a noticeable decrease in foreign applications over the past decade.

ASEAN patent strengths

Unlike the U.S. or the European Union, where IP generation is distributed across a wide range of industries, ASEAN Member States focus more narrowly on sectors aligned with their competitive strengths. In particular, ASEAN Member States have developed comparative advantages in sectors like electrical machinery, medical technology, and digital communication, reflecting the integration of industry in many ASEAN Member States into global value chains.

Singapore, Brunei, and Viet Nam excel in patents for electrical machinery, while countries like Indonesia and the Philippines focus on healthcare innovation. ASEAN's growing strength in digital technology is evident in the growth in patent filings related to cloud computing, AI, cybersecurity, and semiconductors.

In trademarks, ASEAN's strengths closely tie to its economic reliance on consumer goods and service sectors, especially in advertising and business management, with Indonesia, Thailand, and Viet Nam leading in filings. ASEAN also shows strength in industrial design, particularly in packaging, machinery, and cultural design elements, which are vital for its manufacturing and consumer goods industries.

Overall, ASEAN is still facing several challenges in strengthening its IP protection system, particularly as innovation evolves in response to technological advancements. Varying legal frameworks across member states and weak enforcement mechanisms create vulnerabilities, leading to issues such as counterfeiting and piracy. As innovation becomes more open, involving crowdsourcing, NGOs, and collaborations between startups, universities, and corporations, the traditional IP regime struggles to keep pace. Emerging technology markets require clear definitions of traded rights to ensure effective protection, and as digital components, software, and AI increasingly drive innovation, the need for interoperability and standard-setting grows. Furthermore, IP protection must now accommodate not just economic gains but also contributions to sustainability. Stronger coordination on standard-setting and knowledge-sharing among member states will be essential for ASEAN to maintain its competitiveness in the global IP landscape and ensure that its IP regime remains relevant in the digital age.

STI impact

Productivity

From 2015 to 2021, ASEAN's labour productivity grew by 4% annually, driven by lower-middle-income nations like Viet Nam, Cambodia, and Myanmar, though their productivity remains relatively low compared to countries like Singapore (Figure 6).

While capital input was the primary driver of productivity growth across the region, particularly in countries like Viet Nam, where over 70% of growth came from capital deepening, Total Factor Productivity (TFP) also played a role. ASEAN's average TFP growth rate was 1.37% during this period, an improvement over 2010-2015, but less developed nations, such as Brunei, Myanmar, Lao PDR, and Indonesia, experienced negative TFP contributions. In contrast, more advanced economies like Malaysia saw over 50% of their productivity gains come from TFP growth.

Energy productivity, captured by energy intensity, is a key challenge for ASEAN as it faces issues of energy security and climate change. Despite improvements over the past two decades, ASEAN's energy intensity remains higher than other regions, with higher carbon emission levels.

In 2021, Asia consumed a disproportionate share of the world's energy and contributed significantly to global CO_2 emissions compared to its economic output, much higher than regions like the European Union (Figure 7) [16]. This imbalance is exacerbated by coal consumption and rapid industrial growth, particularly in nations like Thailand and Viet Nam.

Other countries, including Indonesia and the Philippines, have lower levels of energy intensity due to their reliance on low-energy sectors like agriculture and services. However, as manufacturing sectors expand, energy productivity may decline, a pattern consistent with the Environmental Kuznets Curve.

More developed ASEAN countries, such as Singapore, have started addressing inefficiencies by removing energy subsidies and implementing higher energy taxes to reduce carbon intensity and improve energy productivity.

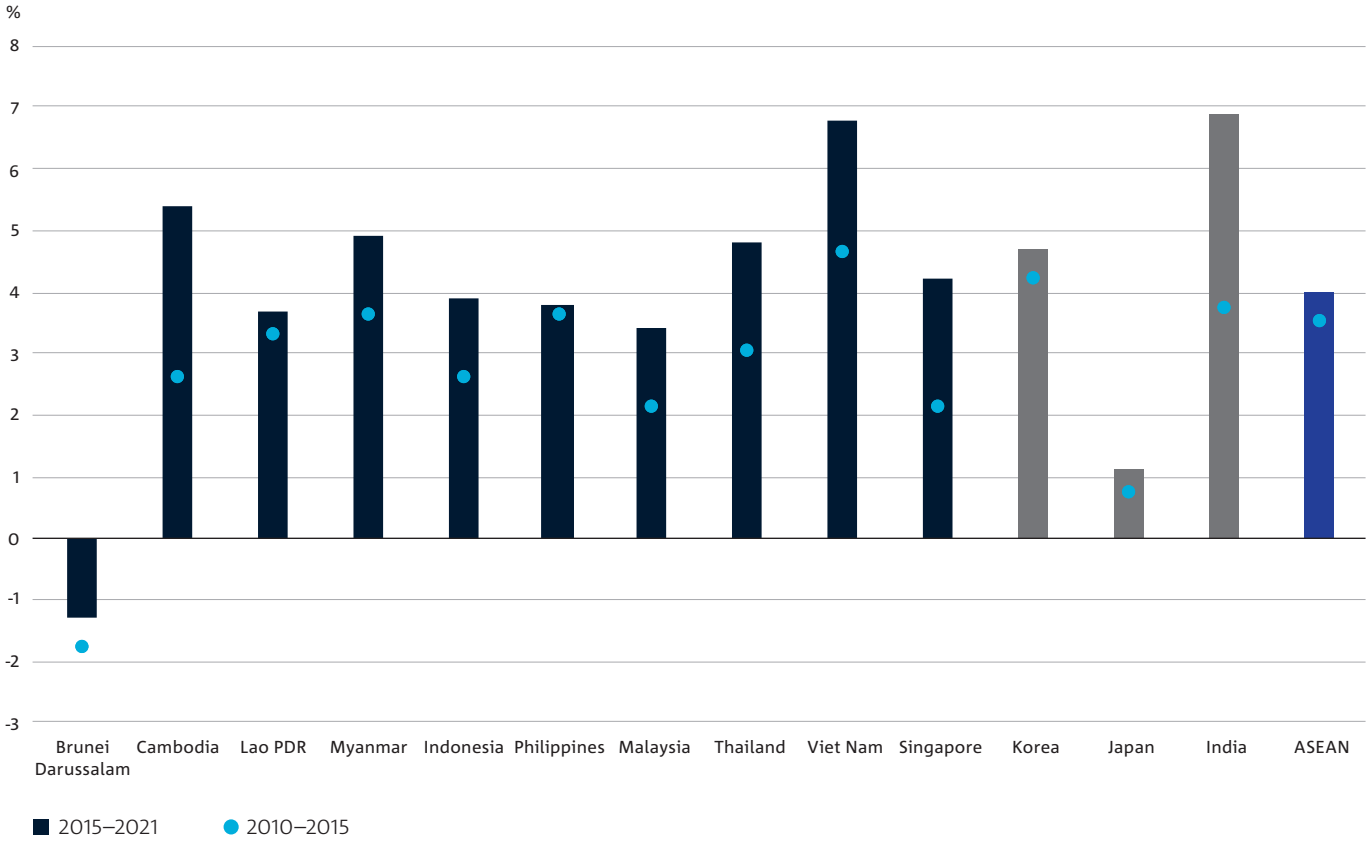


Figure 6. Labour productivity across countries over time

Source: Author calculation based on World Bank data

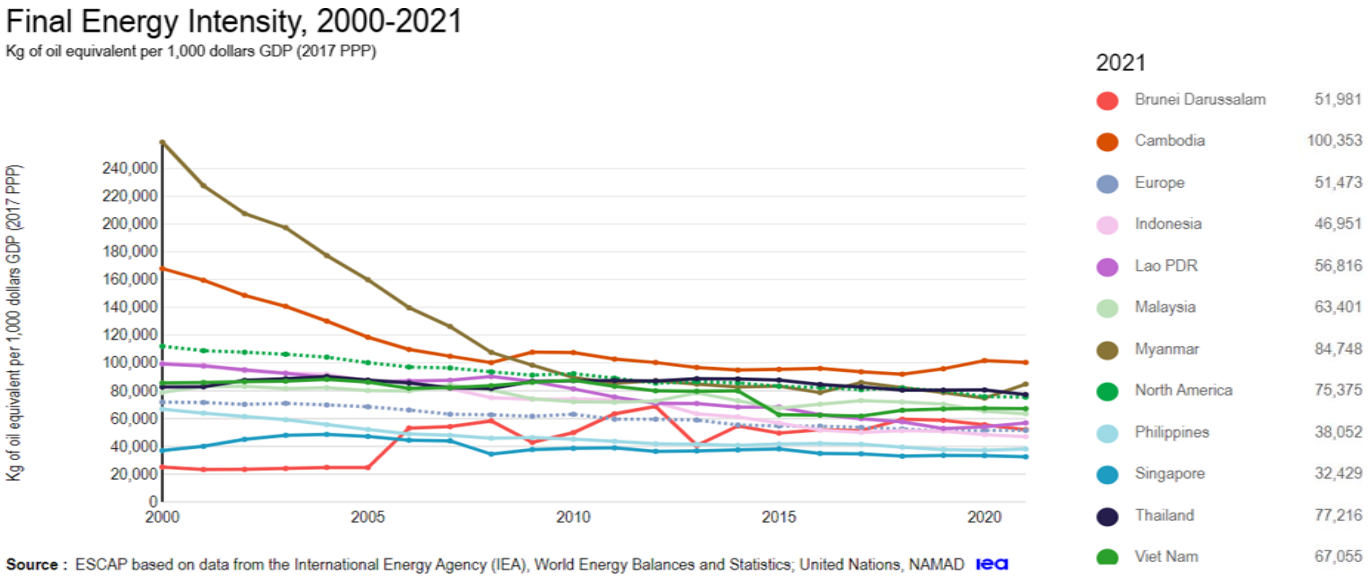


Figure 7. Final energy intensity across regions/countries (2000–2021 period)

Source: ESCAP[16]

Some key STI enablers

Economic complexity

Economic complexity serves as a critical enabler for science, technology, and innovation (STI) development in ASEAN countries, as it reflects the capacity of nations to produce a diverse range of sophisticated products that require advanced technologies and skilled labour. Countries with higher economic complexity are better positioned to integrate innovation into their economies, fostering technological advancements, job creation, and higher-value production.

The economic complexity of ASEAN countries has also risen significantly over the years, primarily due to a shift from low-end manufacturing to more sophisticated, material science-intensive industries like chemicals and electronics.

Between 1995 and 2021, ASEAN countries exhibited diverse trends in economic complexity. Cambodia and Myanmar saw the most significant improvements, with Myanmar rising from 121 to 106 and Cambodia from 117 to 84, indicating gradual diversification of their economies. Viet Nam and the Philippines also made notable progress, with Viet Nam jumping from 107 to 61, driven by its shift to electronics and machinery, and the Philippines improving from 70 to 33, fueled by growth in electronics and outsourcing. In contrast, Indonesia, Thailand, and Malaysia showed less progress, with Indonesia only improving from 77 to 64, while Thailand and Malaysia, already relatively advanced, saw minimal changes, reflecting consistent but not significantly advancing complexity (Figure 8).

One challenge for ASEAN is premature de-industrialization, which is increasingly impacting ASEAN economies, particularly in countries like Indonesia, the Philippines, and Viet Nam, which are shifting from manufacturing to lower-value service sectors at income levels typically seen in more developed nations.

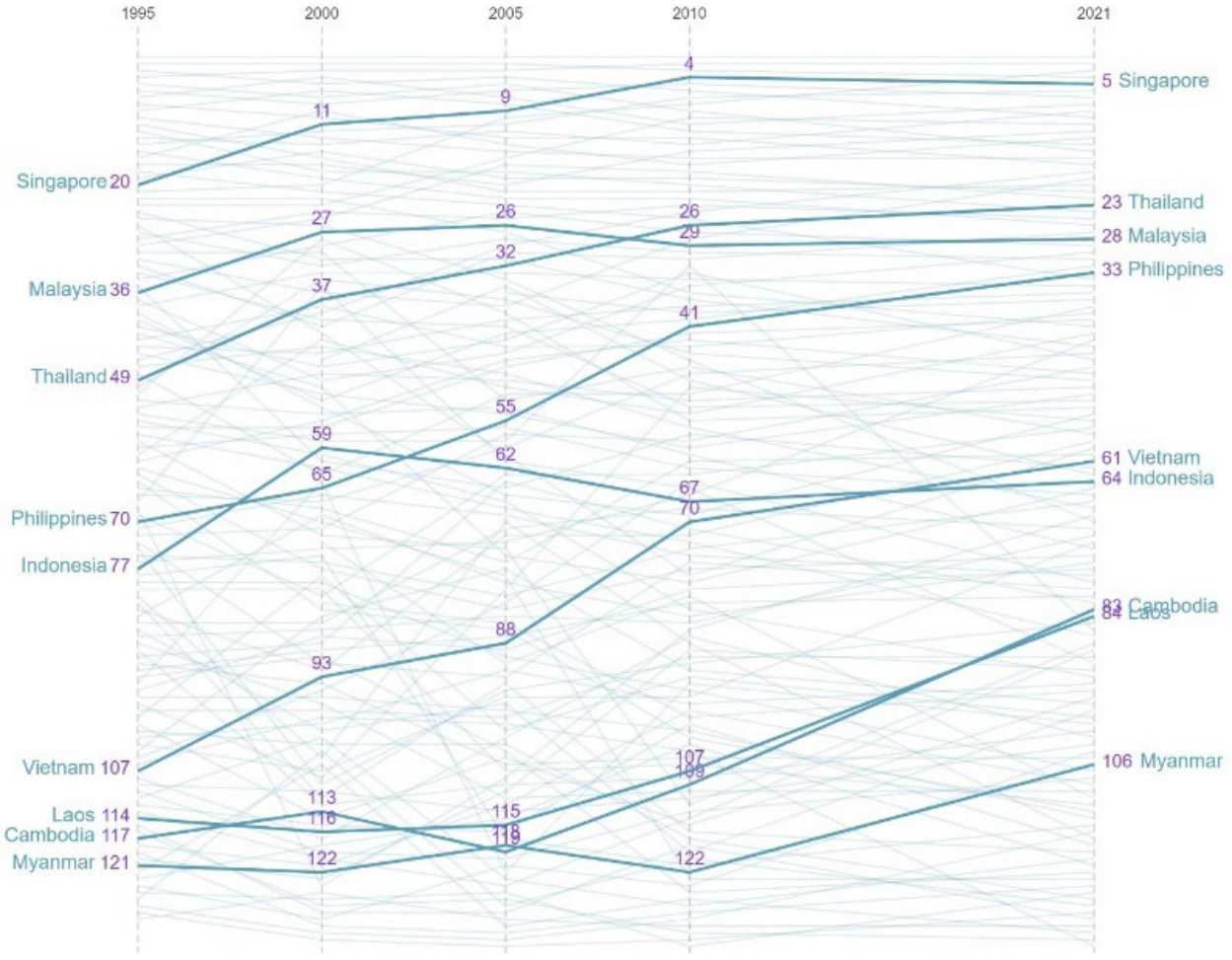
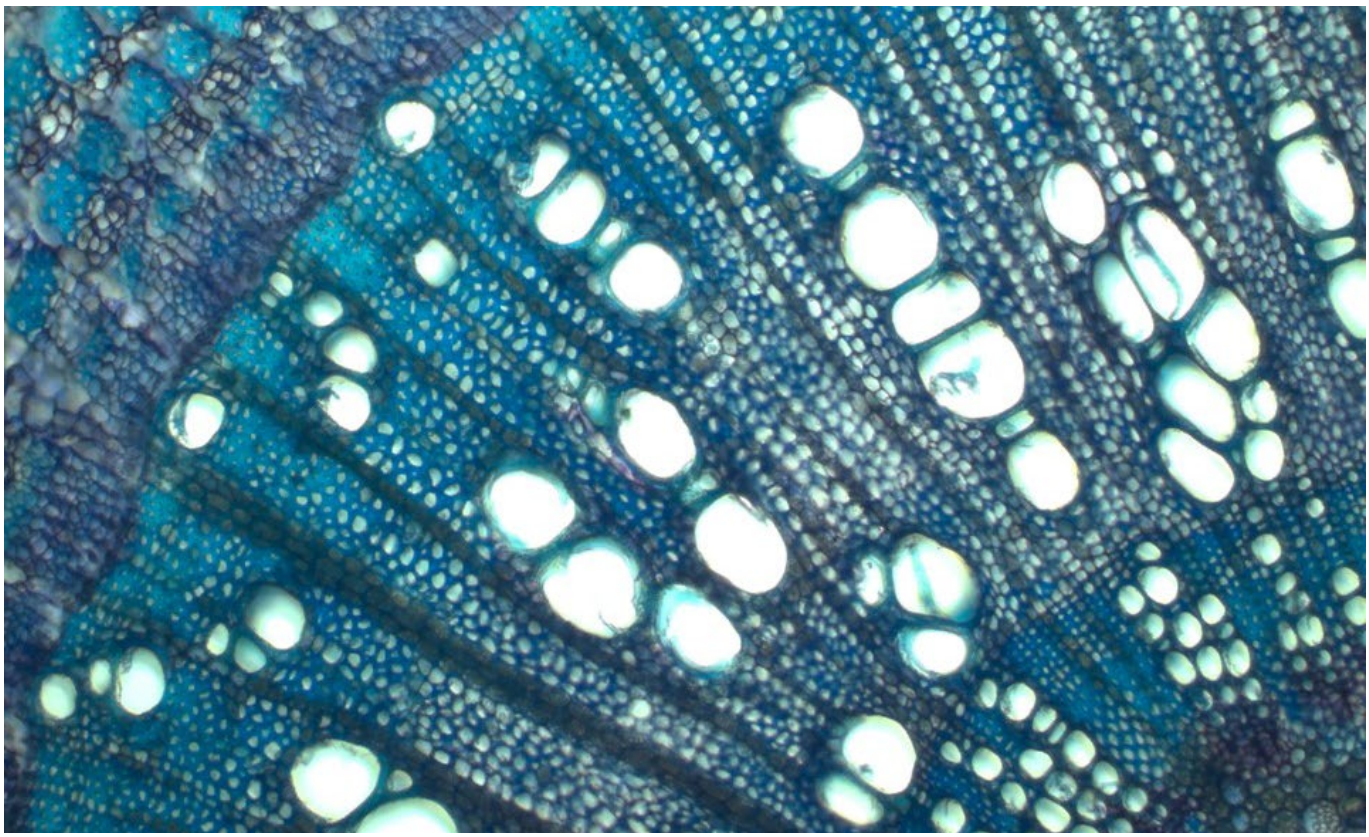


Figure 8. Economic complexity index by ASEAN country

Source: ECI 2024



This trend poses significant challenges for economic complexity and innovation, as manufacturing has traditionally been a driver of skills development, technological advancement, and productivity gains. The decline in manufacturing limits investment in research and development, reducing opportunities for workers to acquire specialised skills essential for innovation. Consequently, these economies may struggle to compete in higher value-added sectors, making it difficult to advance within global value chains.

Looking ahead, ASEAN's supply chains face major shifts as traditional offshoring and outsourcing practices that once anchored global value chains (GVCs) are reconfigured, driven by companies' strategies to decarbonise operations. Low-skilled labour is no longer a competitive advantage, making it crucial for ASEAN to participate in the decarbonisation process and develop a more skilled workforce to climb the GVC ladder. Collaboration within the region will also be essential, as ASEAN countries work together to build resilient, sustainable supply chains that can support their economic complexity and innovation ambitions.

Human resources – talent and skills

ASEAN benefits from a youthful population, with several member states having a significant portion of their population under the age of 25, providing a vast workforce potential for future economic growth. However, the region faces challenges related to skill diversity and relatively low levels of high-skill employment, which hinder its capacity to fully leverage human capital for innovation [17]. Disparities in education quality and access across ASEAN can further exacerbate the uneven development of STI capabilities.

Singapore leads the ASEAN region in innovation with a highly skilled workforce, boasting 7,224.7 researchers per million and a skill index of 0.87, surpassing local technology leaders Japan and South Korea [18]. While Brunei Darussalam mainly benefits from a specialised, skilled workforce, emerging innovators like Malaysia, Thailand, the Philippines and Indonesia have made notable progress, with Thailand doubling its researcher count between 2015 and 2021. Malaysia, though experiencing a decline in researchers, maintains an open economy, with 40% of jobs linked to exports [19]. Digital starters like Laos, Myanmar, and Cambodia remain in the early stages of development, needing strategic investments in education and skills to enhance their STI capacities.

The primary human resource development challenge for ASEAN, however, is a mismatch between population skills and industrial needs. Many workers do not have the necessary skills to capitalise on growth sectors. According to Cisco (2023), even Singapore, with its highly skilled labour force, is projected to face significant skills gaps by 2028 due to the rapid adoption of IoT and robotics.

The Philippines, Viet Nam, and Malaysia are expected to face similar challenges. ASEAN collectively will need to address skills gaps, including skills in management, IT, and foundational skills such as active learning and reading comprehension, with an estimated 1.9 million workers requiring interactive skills and 1.7 million needing foundational skills [20].

Another notable challenge lies in the inequality of ASEAN labour markets. As of 2021, an estimated 75 million workers were employed in GSCs. This is more than one in four workers in the region. While GSCs provide millions of jobs for women, some results indicate the connection between the increase in female employment and higher engagement in GSCs only existed in sectors where jobs are typically less skill-intensive and lower-paid [21].

Looking ahead, ASEAN can harness its advantages in youthful demographics by prioritising innovative solutions to enhance human capital and skills. Addressing skills mismatches through improved educational systems and lifelong learning initiatives will be crucial in preparing the workforce for high-skill employment sectors shaped by technological advancements like IoT and robotics.

Regional initiatives are needed to facilitate collaboration among member states to align training programs with industry needs in the region and ensure that workers possess the relevant skills. Additionally, promoting gender equity in labour markets will ensure that women benefit from opportunities in higher-skilled, higher-paying roles. Gender diversity in science-based teams increases the impacts of the work in terms of citations, and novel investigations

By strategically investing in education, training, and equitable labour practices, ASEAN can strengthen its capacity for innovation and economic resilience, positioning itself as a competitive player in the global landscape.

Innovation institutions

ASEAN's research infrastructure is steadily growing, yet it remains relatively underdeveloped compared to more advanced regions like Europe and North America. As of 2021, the region has about 1,200 research institutes listed in Scopus, with Singapore leading the way. Singapore houses 380 research organisations, including top-tier institutions such as the National University of Singapore (NUS) and Nanyang Technological University (NTU), which are renowned for their global research output [22].

Other ASEAN countries, such as Malaysia and Thailand, also contribute significantly. However, smaller countries like Laos, Brunei, and Cambodia lag behind, with only a handful of research centres, underscoring a disparity in research capabilities across the region.

The number of research institutes in ASEAN is still relatively limited compared to regions like Europe or North America. According to UNESCO (2021), ASEAN has about 1,200 research institutes listed in Scopus. Singapore is a leader with 380 research organizations, translating to about 10.5 institutions per million people [22, 23]. The major challenge for research affiliation in ASEAN is that there is no consistency in terms of academic quality, citizens' access to knowledge, university-industry partnerships, technological capabilities.

Digital infrastructure

ASEAN's digital infrastructure reveals both significant advancements and persistent challenges. At the forefront, Singapore excels with an impressive speed of 264.15 Mbps for fixed and 89.45 Mbps for mobile broadband, ranking number one in download speed worldwide [24]. However, progress is uneven across the region, especially in digital starter nations. Laos, for instance, has speeds of 38.73 Mbps for fixed broadband and 28.39 Mbps for mobile. Cambodia follows with speeds of 45.63 Mbps and 28.4 Mbps. Myanmar lags further behind with fixed broadband speeds of 21.36 Mbps and mobile speeds of 31.42 Mbps. There is also a limitation concerning internet coverage in these countries. For example, Laos has the lowest 3G and 4G network coverage among ASEAN nations. Less developed and rural areas of the nation grapple with inconsistent internet connectivity and low penetration rates, often relying on outdated 3G networks.

Data centres are pivotal for advancing digital technologies, including AI and generative AI, and ASEAN is rapidly emerging as a significant player in this space. While established data center markets in Europe and North America, including Northern Virginia (640 MW), London (912 MW), Frankfurt (660 MW), and Dallas-Fort Worth (737 MW), continue to dominate in terms of overall capacity, Southeast Asia is catching up [25].

According to DC Byte, data centre capacity in ASEAN could increase by more than fourfold from 1,677MW in 1Q24 to 7,589MW by 2028. Singapore is leading the charge as the premier data center hub in the APAC region, boasting a built-out critical IT load capacity of around 1,000 megawatts (MW) as of June 2023. The other emerging data hub in ASEAN is Kuala Lumpur, with a capacity of 233 MW. Malaysia and Indonesia are expected to be prime beneficiaries of the surge in data centre investment due to their locational advantage, making them the gateway for international connectivity [26].

Another critical aspect of ASEAN's research infrastructure is access to advanced laboratory equipment and facilities. Many countries, particularly in the less developed parts of ASEAN, face shortages of modern lab equipment, which restricts their capacity to engage in high-level scientific inquiry and innovation (Table 2).

Looking ahead, ASEAN's future infrastructure development could benefit from a region-wide approach that fosters greater collaboration between countries. Leveraging the strengths of nations like Singapore and Malaysia, which have advanced research and digital infrastructures, to support those with less developed systems, such as Laos, Cambodia, and Myanmar, would create a more inclusive ecosystem. Prioritising regional partnerships and shared access to resources like lab equipment, high-performance computing, and digital infrastructure could significantly boost the region's research capacity. Additionally, increasing investment in broadband and data centres while harmonising policies across Member States would help attract international investment and foster innovation, positioning ASEAN to better compete on the global stage.

Table 2. Key statistics of ASEAN's research infrastructure

COUNTRY	BROADBAND SPEED FIX	BROADBAND SPEED MOBILE	# OF INTERNET SERVER	RESEARCH AFFILIATIONS	TOP RESEARCH AFFILIATIONS	PUBLICATION BY TOP RESEARCH AFFILIATION
Cambodia	28.4	45.63	192.2319	15	Instiut Pasteur Du Cambodge	955
Laos	28.39	38.73	52.46332	5	National University of Laos	854
Myanmar	31.42	21.36	14.31962	8	University of computer studies Myanmar	865
Indonesia	29.05	31.75	1889.089	538	Universitas Indonesia	35,433
Philippines	33.18	94.52	110.918	240	University of the Philippines Diliman	9,973
Malaysia	104.8	130.59	7306.176	248	Universiti Malaya	74,570
Thailand	53.95	231.86	1863.334	457	Mahidol University	56,996
Viet Nam	55.41	146.79	3127.958	60	Viet Nam Academy of Science and Technology	14,945
Brunei Darussalam	73.05	77.21	15597.94	6	Universiti Brunei Darussalam	6,708
Singapore	108.73	290.86	128377.7	380	National University of Singapore	206,719
Korea	139.83	157.72	5939.011	1,136	Seoul National University	167,895
Germany	57.02	90.44	97517.57	3,581	Technische Universitat Munchen	193,408
India	101.8	63.88	474.294	4,756	Indian Institute of Science	72,566

Source: Speedtest [24], Scopus [22], World Bank [27]

Access to finance for STI development

The most significant challenge for STI development in ASEAN countries is access to finance. On average, ASEAN invests approximately 0.62% of its GDP in Research and Development (R&D), which is modest compared to global leaders (European Union-28 and China allocate around 2.2% of their GDP to R&D). The contribution of the private sector to GERD is another issue in the region. While the private sector plays a crucial role in many developed economies, its contribution to ASEAN is less pronounced, with a significant portion of R&D funding coming from public sources. In countries like Indonesia, Viet Nam, and Brunei, the government is the predominant funder of R&D activities.

Banks are the traditional financial channel in ASEAN and primarily support well-established business models. Finance from banks is difficult to secure for startups and companies with innovative or unproven technologies. However, in recent years, some banks have started to adapt, offering more flexible credit solutions to meet clients' evolving needs in ASEAN's fast-growing digital economy. This is evident because the percentage of domestic credit to the private sector increased in most ASEAN countries.

In one example, Cambodia's domestic credit level in 2022 was over 160% of GDP, a figure higher than that of many high-income countries [28]. Although this can be attributed to Cambodia's almost non-existent corporate bond market or a large informal sector, and putting aside the credit risk [29], the country's banking sector proves its crucial role in facilitating economic activity by supporting public-private partnership and promoting mobile financial services in Cambodia.

The digital financial services sector, including fintech, is also developing rapidly across Southeast Asia, driven by the rapid adoption of digital payments and alternative lending models. Fintech services in ASEAN have also expanded beyond payment to include investment, insurance, mobile money and others, with projections of annual increases between 13% and 38% in payments, remittances, loans, and investments from 2022 to 2030 [30]. Despite the rapid growth of digital financial services, access remains uneven across the region. Only 21% of ASEAN's digital generation uses all three advanced financial products – credit, investment, and insurance – highlighting the potential for further expansion.

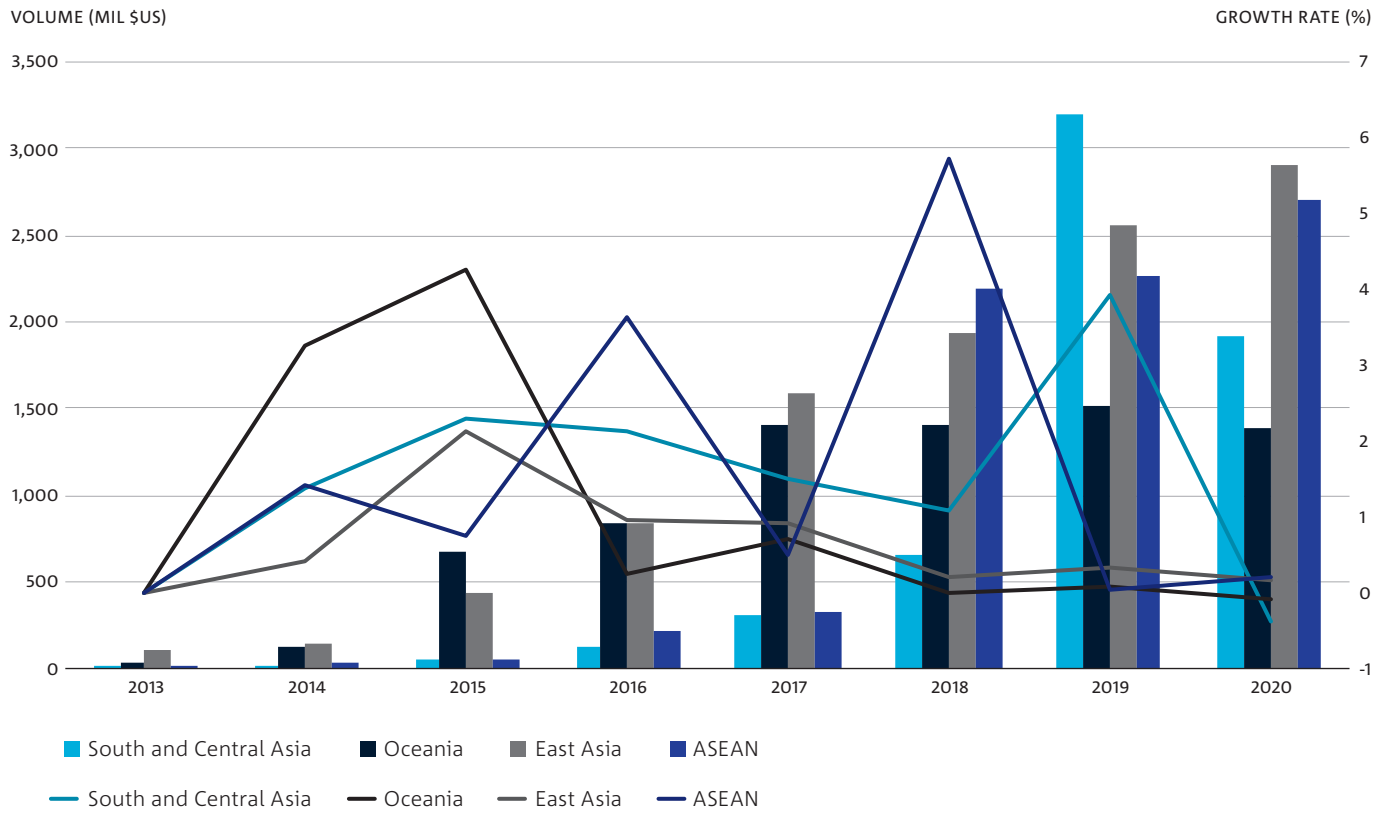
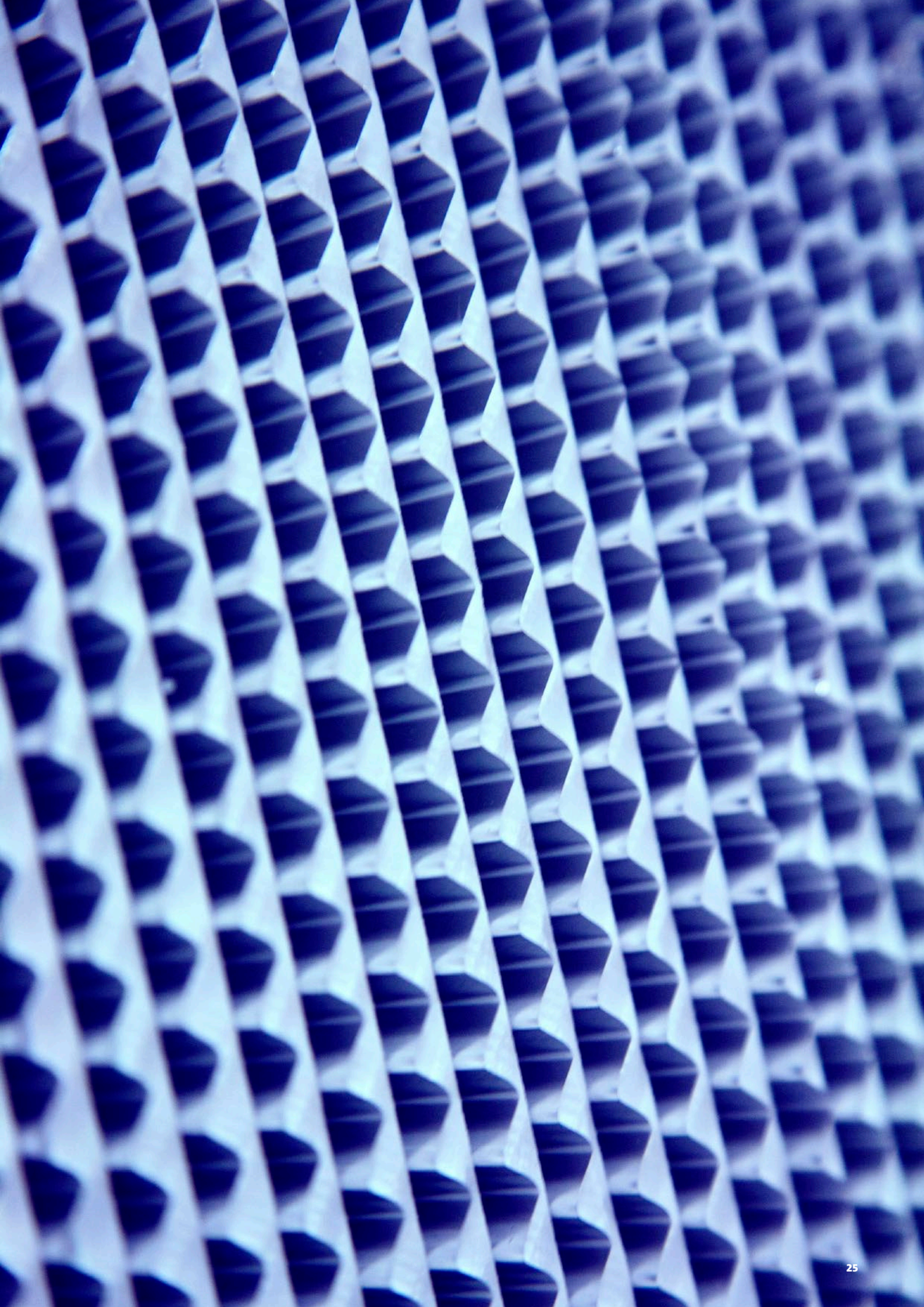


Figure 9. Alternative finance across regions overtime

Source: Cambridge Center for Alternative Finance [1]



Venture capital

Venture capital in ASEAN is nascent yet demanding and fast growing. According to Statista, between 2017 and 2023, the deal count within the region increased by more than 30%. The total capital raised in ASEAN reached 5.8 $US billion in 2023. Among sectors, software and B2C have been best positioned for venture capital. Much of the venture capital activity is concentrated in Singapore, which serves as a gateway to the broader region due to its business-friendly environment and established financial infrastructure [31].

Viet Nam and Indonesia are quickly becoming alternatives to Singapore, thanks to their larger population, growing tech ecosystem and supporting government policies. One significant challenge facing the venture capital ecosystem in the region is the lack of growth-stage capital. While there is a healthy pipeline of early-stage startups, only 8.5% of funds closed since 2015 have been above $250 million in capital commitments [32]. This gap creates hurdles for mature startups seeking substantial investment to scale.

Looking ahead, enhancing private sector involvement and creating a more supportive environment for private R&D investment could be pivotal in boosting the region's overall R&D performance and global competitiveness. Moreover, as more SMEs in the region embrace digital transformation, alternative finance models will likely play a crucial role in providing accessible and affordable credit, particularly in markets where traditional banking services remain limited.

Emerging transformative technology and ASEAN STI capability

Technological developments have transformed economies and daily life worldwide, including in ASEAN. Since the start of the century, Information and Communication Technologies (ICT), including mobile internet, and cloud services, have enhanced international trade and economic growth in ASEAN [33, 34]. We are currently living through a period of rapid AI expansion, including generative AI, and observing how the technology is transforming industries. The current wave of AI adoption is impacting all industries and all fields of science [5], and there are many more transformative technologies on the radar.

While we cannot estimate the potential impact of the emerging transformative technologies, we can foresee that they are beginning to change the structure or operations of multiple industries and economies. The ASEAN Foresight Alliance report [35] provides an example of how technology adoption can impact the science, technology and innovation ecosystem and trigger the emergence of some scenarios. For the Dystopia Scenario 2050, for example, the report shows that the adoption of advanced technologies, such as higher-order AI with quantum computers, can enable sophisticated hacking and decryption, opening the door to improper use of personal and government data, surveillance, corporate espionage and other undesired uses, triggering the emergence of undesired scenarios with a breakdown of trust in digital systems, economic turmoil, and financial collapses [35].

In the following section, we consider three technologies of such potentially transformative nature – AI and high-performance computing, quantum and 6G. Based on the research and industry literature, we discuss the potential impact of these technology developments and their adoption on the industries of the ASEAN member states.

Quantum technology

Quantum technology harnesses the principles of quantum mechanics, such as superposition, entanglement, and quantum tunnelling. It is believed to have the power to revolutionise computing, communication, and sensing by enabling vastly more powerful processing, ultra-secure data transmission, and highly precise measurement capabilities beyond classical systems [36].

Quantum technologies are among the priority technology investment areas in the region [37]. Singapore has been expanding its investment in quantum since 2022, naming it one of the key research areas for the nation [38]. Quantum offers the potential to transform industries such as agriculture, manufacturing, mining, and healthcare across ASEAN.

Quantum sensors can provide real-time monitoring of environmental conditions, optimising agriculture in key-producing nations like Thailand and Viet Nam. In manufacturing, quantum computing will enhance supply chain management, material science, and production processes, creating more efficient systems and supporting the growth of innovation hubs in Malaysia and Viet Nam. Quantum sensing can revolutionise mining by detecting mineral deposits with higher accuracy [39], reducing environmental impacts, and increasing profitability in resource-rich nations like Indonesia and the Philippines.

In healthcare, quantum computing and AI are expected to accelerate drug discovery and improve diagnostics and personalised medicine, which can elevate healthcare services in ASEAN countries. Quantum communication, which allows secure data transmission through entanglement, will play a critical role in protecting financial and health data, a crucial factor for tourism, e-commerce and banking industries [40].

AI and high-performance computing

AI and high-performance computing (HPC) are also set to transform ASEAN's industries [41, 42]. The potential of AI to lift the ASEAN economy is estimated to be 10 to 18% of GDP by 2030 [43]. In agriculture, AI-driven analytics can enhance precision farming by analysing weather, soil, and crop data, improving efficiency for major agricultural producers like Thailand and Viet Nam.

In manufacturing, AI and HPC allow for predictive maintenance, supply chain optimisation, and automation, increasing productivity in key hubs like Malaysia and Indonesia. AI's integration into mining will allow for smarter resource extraction and machinery maintenance, reducing operational risks and environmental impacts. In healthcare, AI is revolutionising diagnostics and treatment, with generative AI and machine learning enabling more personalised healthcare services in countries like Singapore [44]. AI-driven tourism applications, such as virtual tour guides and personalised travel recommendations, can enhance the visitor experience, a vital development for ASEAN's booming tourism sector.

6G technology in ASEAN

6G technology will be a game-changer for ASEAN economies. It promises faster speeds, ultra-low latency, and enhanced connectivity, which will support innovations like real-time AI processing and advanced IoT applications [45]. For agriculture, 6G will enable more precise farming by integrating AI and IoT for real-time crop monitoring, improving yields and sustainability in countries like Thailand and Viet Nam. In manufacturing, 6G will support automation through robotics, real-time analytics, and digital twins, enhancing efficiency in production hubs like Malaysia and Indonesia.

Moreover, 6G will significantly improve healthcare by enabling telemedicine, remote surgeries, and health monitoring with ultra-reliable, low-latency communications, making healthcare more accessible across the ASEAN region. Tourism will also benefit from 6G's ability to power immersive virtual and augmented reality experiences, offering enhanced, personalised services in key destinations like Thailand and Indonesia. However, challenges like infrastructure costs, data privacy concerns, and security risks will need to be addressed to fully harness the potential of 6G technology.

The emerging technologies are expected to encourage greater collaboration between academia, industry, and government in the region, fostering an innovation ecosystem that prioritises cutting-edge research and commercialisation [46]. They offer the potential to enhance automation in industries such as manufacturing, healthcare, and logistics, allowing ASEAN countries to position themselves as leaders in high-tech sectors and move toward smarter, more efficient economies. However, as these technologies become integral to ASEAN economies, addressing their ethical, regulatory, and infrastructural challenges will be crucial. These technologies will also necessitate upskilling and reskilling of the workforce, as well as stronger regional collaboration on regulatory frameworks, intellectual property rights, and ethical considerations, all of which will be essential for maximising the benefits of these transformative innovations and narrowing the gap in readiness to technology adoption within the region [42].

A SWOT (strengths, weaknesses, opportunities and threats) is on the following pages at Table 3.

Strengths

1. **Diverse Talent Pool**: ASEAN is a very diverse region and comprises countries with unique strengths in various fields of science and technology. This diversity fosters a collaborative environment for addressing a wide range of scientific challenges and provides economic resilience in times of technological uncertainty.
2. **Growing Investment in R&D**: Countries like Singapore, Malaysia, Indonesia and Thailand are increasing their investment in research and development, lifting publications and creating centres of excellence and innovation hubs. The digital financial services sector is also growing rapidly in several ASEAN Member States.
3. **Regional Collaboration**: ASEAN countries have strong ties to global STI networks, mainly through collaborations with Japan, South Korea, the European Union and Australia. COSTI also plays a leading role in coordinating STI collaborations for cross-border outcomes between ASEAN nations with targeted committees focused on areas such as gene editing, biotechnology, marine sciences, space technologies and sustainable energy.
4. **Emerging Tech Adoption**: The region is rapidly adopting technologies like AI, biotechnology, nanotechnology, and renewable energy, which are aligned with global trends and sustainable development goals.
5. **Strong Focus on Sustainable Development**: With its megadiverse regions, diverse populations with ancient knowledge and economic reliance on marine biodiversity, ASEAN is uniquely positioned to lead in research on climate change, conservation, and sustainable resource management.
6. **Young and Dynamic Population**: The region, as a whole, has a relatively large, youthful population and targeted programs to encourage participation in STEM (science, technology, engineering, and mathematics) education and careers. Myanmar, Lao PDR, Cambodia and the Philippines have the youngest populations.

Weaknesses

1. **Uneven Development Across Countries:** There is a significant disparity in scientific infrastructure and R&D capacity among ASEAN countries, with Singapore being far ahead of emerging nations like Myanmar, Lao PDR and Cambodia.
2. **Limited Funding:** While some nations are increasing investments, overall funding for science and technology in ASEAN is relatively low compared to global leaders like the U.S., European Union, and China.
3. **Brain Drain:** Talented scientists and researchers often migrate to higher-income nations for better opportunities, leading to a loss of expertise and talent in the region. However, improved lifestyles and economic stability in many ASEAN nations are drawing back trained experts.
4. **Inconsistent Policy Frameworks:** The lack of harmonised policies and regulatory frameworks across ASEAN countries can hinder regional collaboration and the movement of researchers and resources. It can also inhibit the scaling up of new ventures and enterprises in some Member States.
5. **Insufficient Industry-Academia Linkages:** Collaboration between academic institutions and industries remains underdeveloped, limiting the practical application of research. There is also a reported mismatch between STI skills and industrial needs.
6. **Lack of High-Quality Research Outputs:** Despite rapid growth in the number of publications, the global impact and citation rates of research from ASEAN Member States are still relatively low.
7. **Vulnerability to Climate and Economic Instability:** The region is highly vulnerable to climate-related risks and economic fluctuations, which can disrupt scientific initiatives and funding**.**
8. **Aging populations:** Some ASEAN Member States have rapidly aging populations despite the relatively young median age in 2024. This includes Thailand, Viet Nam and Singapore. This increases the focus on the health applications of STI.

Table 3. SWOT (strengths, weaknesses, opportunities and threats) analysis to STI in ASEAN

Opportunities

1. **Expanding STEM Education and Talent Development:** A youthful and dynamic population provides a strong foundation for STI growth. Investments in STEM education, scholarships, and training programs can equip the workforce with skills for the future. Initiatives like the ASEAN University Network (AUN) and COSTI scientific committees foster regional academic collaboration.
2. **Leveraging Digital Transformation:** ASEAN's digital economy is growing rapidly, with increasing internet penetration and mobile connectivity. The adoption of AI, big data, IoT, and blockchain can drive innovation and productivity across sectors like retail, healthcare, agriculture, and finance and develop new export industries. The region's growing startup ecosystem, fuelled by incubators, accelerators, and venture capital, offers opportunities to commercialise research and innovation. Innovation hubs like Malaysia's Cyberjaya and Thailand's Eastern Economic Corridor promote tech entrepreneurship.
3. **Advancing Green and Sustainable Technologies:** With megadiverse regions and vulnerability to climate change, ASEAN can become a leader in renewable energy, sustainable agriculture, emergency systems, and conservation technologies. Developing green tech aligns with global sustainability goals and regional needs and can incorporate local knowledge from Indigenous populations.
4. **Enhancing Agricultural Innovation:** Agriculture remains a significant sector in most ASEAN Member States. STI can drive smart farming, biotechnology, and supply chain optimisation, addressing food security and productivity challenges. Diffusions of innovation in agriculture is impeded in some countries due to the densities of smaller entreprises. Examples of technological adoption in agriculture include Viet Nam's adoption of AI in agriculture for predictive analytics and Indonesia's investments in marine technology for sustainable fisheries.
5. **Building STI Infrastructure and Connectivity:** Expanding access to existing and planned research facilities, supercomputing centres, cyber security systems and shared databases can bridge gaps between ASEAN countries.
6. **More Collaborative Innovation Funding for Regional Priorities:** This may include more funding like the Agrinnovation Fund, the ASEAN Blue Innovation Challenge, The Asian Development Bank's ASEAN Infrastructure and the ASEAN Catalytic Finance Facility.

Threats

1. **Political Instability and Governance Challenges:** Political instability in some ASEAN countries can disrupt STI initiatives, deter investment, and undermine long-term planning. Corruption and bureaucratic inefficiencies further complicate progress. In some cases, there may be STI solutions to inefficient STI investments – such as blockchain-based audit systems and fintech in grant administration
2. **Climate Change and Environmental Risks:** ASEAN is one of the global regions most vulnerable to climate change, facing frequent natural disasters like typhoons, floods, and droughts. These events can disrupt STI projects, damage expensive STI or digital infrastructure and divert resources to immediate recovery efforts.
3. **Cybersecurity Threats:** As ASEAN countries embrace digital technologies, they become targets for cyberattacks. Cybersecurity breaches can compromise sensitive research data and undermine public and commercial trust in digital systems. There have been increased attacks on institutions across ASEAN in recent years, and cyber secure systems are limited across some ASEAN Member States.
4. **Dependency on Foreign Technology:** Heavy reliance on imported technologies and expertise limits the development of local capabilities. This dependency can leave ASEAN institutions vulnerable to external disruptions. Many ASEAN countries depend on imported semiconductors and software for their tech industries.
5. **Global competition:** ASEAN Member States faces stiff competition from global leaders in STI, such as the U.S., European Union, China, and Japan. Without significant advancements, ASEAN risks falling behind in global innovation. ASEAN's innovation outputs, such as patents and high-impact publications, still lag behind these global leaders.
6. **Unequal Access to Technology:** Rural and underserved communities in ASEAN often lack access to technology and internet connectivity, exacerbating the digital divide and limiting the inclusive impact of STI. For example, remote areas in Indonesia and Cambodia have limited access to the internet, hindering education and innovation.
7. **Pandemics and Health Crises:** Health crises like COVID-19 can disrupt STI activities by shifting focus and resources to immediate healthcare needs, delaying research in other areas. For example, during the COVID-19 pandemic, many research projects unrelated to the crisis were deprioritised.

6 Workshop outputs: Challenges and opportunities under the forces of change identified for the ASEAN region

The ASEAN Foresight Alliance lists 10 forces of change, or megatrends, that will impact all areas of life across ASEAN nations in the decade to 2035 (Figure 10, Table 4). Workshop participants were asked to identify challenges and opportunities under each force of change, and then STI actions to address them. The results are below.

Table 4. Workshop participants were asked to rank the 10 forces of change in terms of their impact and uncertainty over the coming decade (n=36)

	GREATEST IMPACT	GREATEST UNCERTAINTY
1	Environment and planet	Environment and planet
2	Politics and governance	Politics and governance
3	Food and water	Health demographics
4	Health demographics	Population dynamics
5	Education and talent	Economics and industry competitiveness
6	Population dynamics	Food and water
7	Economics and industry	Energy
8	Energy	Society – justice, equality and equity
9	Society – justice equity and equality	Consumer market dynamics
10	Consumer market dynamics	Education and talent

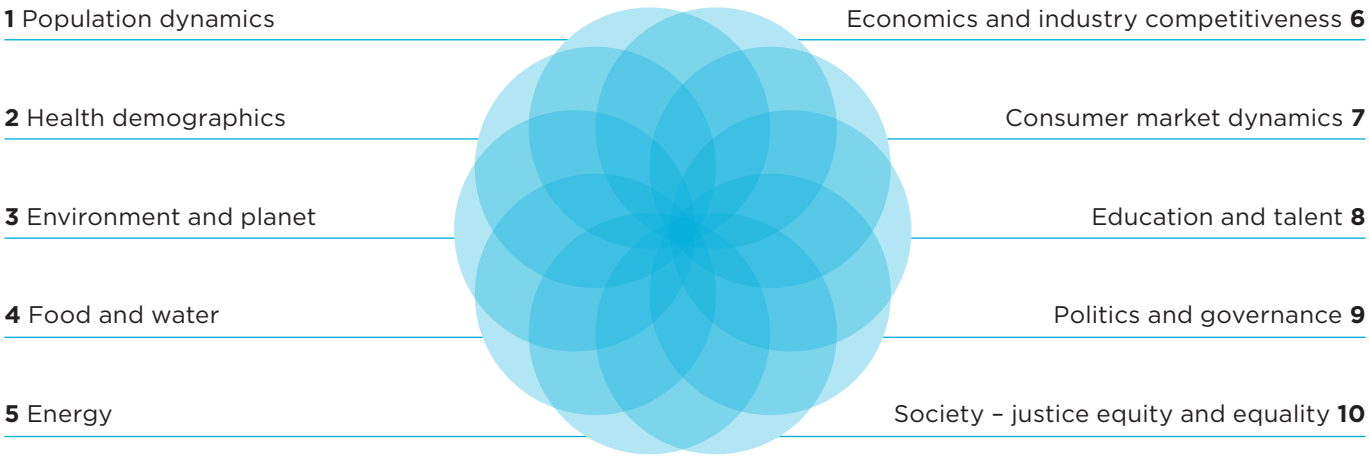


Figure 10. The ten forces of change listed by the ASEAN Foresight Alliance in the report *ASEAN Science, Technology and Innovation Ecosystem Foresight 2025*

6.1 Population dynamics

OVERALL ISSUE	CHALLENGES	OPPORTUNITIES
Aging populations (Most affects: Singapore, Thailand, Viet Nam, Brunei, Malaysia)	• Rising cost of health care per citizen • Low digital literacy	• Preventative health measures • Superannuation/pension savings schemes • Innovation in health insurance • E-health services and online communities • Self-study options and AI-assisted online learning
	• Labour shortages	• Robotics and use of technology • Automation of care
Youthful populations (Most affects: Myanmar, The Philippines, Lao PDR, Cambodia)	• Youth service provision • Youth unemployment • Tech/knowledge gaps • Digital infrastructure gaps	• Education and skills services • Self-study options
Population mobility	• Employment for unskilled migrants • Recognition of skills/qualifications and mechanisms for employment aboard • Cultural differences • Remote voting	• Remittances to other countries – inter-country wealth distribution
Urbanisation	• Rapid and destructive urbanisation	• Efficient city planning for the future through population modelling
Gender imbalances in education and work		• Promotion of equal access to employment

Suggested STI actions for the next APASTI to address the challenges and opportunities of population dynamics

- Life-long learning promotion and initiatives for reskilling.
- R&D on precision health care and healthy aging.
- Remote working on STI projects.
- Mechanisms to share information, including on job opportunities via ICT platforms connecting ASEAN Member States.
- Early population modelling for each ASEAN Member State.
- The promotion of gender equality through various programs aimed at providing incentives for employers to improve their gender representation.

6.2 Health demographics

OVERALL ISSUE	CHALLENGES	OPPORTUNITIES
Diverse health systems	• Difficulty in integrating region-wide health initiatives	• Regional health platforms, data tracking and better visibility of medical supplies
Communicable diseases	• Increases in prevalence of mosquito-borne diseases – Dengue fever, malaria	
	• Rates of TB, measles, hepatitis, diphtheria, pertussis and tetanus remain a health burden	• Good vaccination rates across most of ASEAN – creates opportunities for other health servicing
	• Vaccine and medical supplies	• Blockchain and traceability for medical supplies
Non-communicable diseases	• Malnutrition and undernutrition: falling but persistent in some areas	• Screening services and identification of areas
	• Cardio-vascular disease, cancer, diabetes, chronic respiratory conditions	• Many are caused by undernutrition or malnutrition, particularly in early life
	• Increase in cancer rates	• Cleaner environment and lower environmental carcinogens
	• Changing diets and lifestyles including the greater availability of fast and processed foods	• Food for health and better knowledge of using diet and lifestyle as medicine • Well-being industry development
Health funding and public health infrastructure	• Low compared to other parts of the world. Uneven across ASEAN countries	• New and efficient, adaptive systems for service delivery over distance
Workforce shortages create a high dependency on foreign workers and the impact on the health systems	• Declining healthcare systems • A lack of health system innovation • Brain-drain from health and medicine	• Health innovation and biotechnology
Health care access and integrity	• Elderly susceptible to extreme weather events and heatwaves • Communicating health messages at a grassroots level	• Personalised medicine • Regional collaboration on health security

Suggested STI actions for the next APASTI to address the challenges and opportunities of health demographics

- ASEAN Diagnostics Development Initiative – a current initiative that is working to improve diagnostics capabilities and capacity-building. This could be included and improved in the next APASTI.
- Support for AI-assisted advice and monitoring of diet/medicine.
- Nutritional information and actions at a local level: nutritional guides, gardens, food, natal care.
- Guidance on regulation for advertising and safe levels of fat, salt, sugar and vitamin fortification in foods.
- Examining how social media can be regulated for better mental health, and in regards to health misinformation.
- Investment in R&D and regional health infrastructure to bring down the cost of healthcare and the burden of aging populations.
- Programs to encourage tech investment in food science for health.
- A focus on neuro-science mental health research.

6.3 Environment and planet

OVERALL ISSUE	CHALLENGES	OPPORTUNITIES
Biodiversity and protecting mega-diverse regions	• Deforestation and regulatory enforcement	• Satellite monitoring of forestry activity • AI, drones and camera vision recognition software to protect forested areas, track ecosystems including animals
	• Unstable government and conflict	
Climate change	• Rising sea levels	• Adaptive urban and other planning
	• Increased salinity of productive river deltas	• New agricultural species and adaption of farming for new climate conditions
	• Impacts on food and water supply	• Early planning for water capture and storage • Adaption of farming techniques to changing climate (e.g. prawn farming for saline areas instead of rice)
	• Extreme weather events and natural disasters	• Better use of AI and other systems for earlier emergency responses • Early warning systems across the region
	• Heat waves	• Renewable technologies – solar, geothermal and other – to provide energy, particularly during heatwaves
	• Displacement of animals and people – climate and epistemic justice.	• Reforestation investment and attraction of foreign support
	• Loss of oceanic and other ecosystems	• Fluid and reactive infrastructure
Pollution and human pressures	• Marine and river plastic pollution	• Materials science and plastics recapture and recycling. • Biodegradable plastics and advanced fermentation
	• Air pollution and carbon emissions	• Electrification of low-emissions vehicles and installation of renewable power plants, preservation of carbon sinks

Suggested STI actions for the next APASTI to address the challenges and opportunities of environment and planet

- Review Indigenous practices – particularly regarding forest management, water use, and conservation.
- Promotion of regional investment and a regional plan for climate resilience and adaption, including the goals and targets for ASEAN.
- ASEAN Climate Fund to support R&D solutions and infrastructure.
- Region-wide foresight on the impact of climate change on agriculture and food production, particularly in the river deltas.
- Better planning for natural disasters.
- Regional integration of warning systems, energy systems and biodiversity monitoring.
- ASEAN R&D and standards for green building technologies: green cements, pollution-filtering technologies.
- Protocols and agreements that avoid conflict to respond to waves of climate refugees.
- Promotion of regenerative economy and lifestyles (blue, green and circular). STI for inclusive growth.
- ASEAN Member States can collaborate in research and mass production of developing materials that are easy to recycle.
- Battery recycling – particularly Li-ion batteries used in EVs.
- Improve and expand the support for electric vehicles and facilities in public places to minimise air pollution and carbon emissions.

6.4 Food and water

OVERALL ISSUE	CHALLENGES	OPPORTUNITIES
Clean water availability	• Rapid increase in water use by humans for drinking water and sanitation	• Better water capture and storage in both urban and rural areas
	• Safe water for urban populations	• Water grids for supply redundancy, pollution controls and monitoring
	• Increase in water demand for food production	• Modelling of agricultural lands for future management
Climate change and carbon emissions from agricultural activities and deforestation	• Declining crop yields (30% less by 2050) • CO_2 emissions from farming and forestry contribute to global warming	• New production methods – vertical farming, plant-based proteins, closed-systems farming • Alternative ways to introduce climate resilient agricultural activities • Lab-grown foods • Bio-circular economics
	• Altered crop and rainfall patterns	• Modelling and management on a regional level
	• Extreme weather creating unpredictability	• Coordinated food response to extreme weather events
Changing land-use	• Shift to higher-value crops (palm oil, sugar and protein) that diminish self-sufficiency in staple carbohydrates – like rice	
	• Rapid growth of urban areas	
Changing diets and the increase in food waste	• Increase in demand for food and high-protein food	
Trans-border management issues	• River delta management for food, water, hydro-power	• Trans-boundary governance frameworks, sensor networks and monitoring systems, pollution controls
	• Insufficiencies in water for some countries	• Water technologies – desalination, water recycling, local capture and storage
The sustained use of tacit/ local knowledge	• Threatened local knowledge due to changing lifestyles and natural disasters	• Rich narratives and oral folklores and tacit knowledge sources for local wisdom
Regulatory Framework and Guideline Differences		
Food safety: meat and animal disease emergence	• A lack of vaccines and limited R&D funds for disease/virology studies	

Suggested STI actions for the next APASTI to address the challenges and opportunities of food and water

- Management of local knowledge associated with place through documentation.
- Regulatory harmonisation relating to the production and distribution of food and food safety.
- Practise a ‘One Health’ approach to R&D/STI activities.

6.5 Energy

OVERALL ISSUE	CHALLENGES	OPPORTUNITIES
Energy demand rising	• Increasing energy use across ASEAN nations as part of economic development	• Integrated and over-arching ASEAN energy market
	• Energy accessibility variable across ASEAN Member States. Remote, isolated and regional communities have lower energy accessibility	• Energy security – greater self-reliance within countries and energy accessibility • Renewable energy now lower capital costs
	• Fast growth in energy deficits across nations	• New industries in energy production
	• Energy deficits produce energy reliance on other nations	
Regulatory Frameworks	• Unequal awareness and political will for energy-related innovation and preservation	• Tools for greater commitment to energy transition
Net-zero targets	• Fossil fuels make up 84% of the energy production in ASEAN (2024)	• Cleaner air, environment and lower carbon emissions
Financing and technology for decarbonisation	• Financing and securing investment in energy transition to renewables • Technical limitations for decarbonisation	• Technology transfer, finance and capability-building assistance from advanced nations based on the Principle of Commons but differentiated responsibilities with respective capabilities
	• Not currently meeting renewable energy or net-zero targets	• Small-scale energy systems in remote areas – use of solar energy to pump and store clean water
Energy Access	• Energy access is a question of economic status and availability of sources (for dependent countries)	• ASEAN Grid integration promoting low-carbon options and green feed-in, and solving the accessibility concerns

Suggested STI actions for the next APASTI to address the challenges and opportunities of energy

- Map the value chains and ecosystem development on energy grids among ASEAN Member States.
- Regional initiatives for e-vehicles.
- Regional policy recommendations and a binding commitment document signed by all ASEAN Member States.
- Regulation and compliance with technical tools for automated enforcement.
- Agreement or negotiation on carbon credits and trading among ASEAN nations.
- Cultivate a favourable political environment and access funds for infrastructure and coordinated technology development.
- Working with local governments to implement and sustain local solar-hydro systems.
- ASEAN incentives for energy transition to renewable sources to make them more of a priority.

6.6 Economics and industry competitiveness

OVERALL ISSUE	CHALLENGES	OPPORTUNITIES
Competitiveness as a region	• Regionalism and localism in supply and value chains • ASEAN trading bloc	
	• Geopolitical tensions and their impact on trade	
	• Digital and other infrastructure	
	• Cybersecurity	• New technologies for better cybersecurity
	• Global dependencies for supply chains and markets	• Better identification of competitive supply capability
	• Industry susceptible to automation and AI disruption	
Proportion of MSMEs and their ability to innovate	• Access to finance and credit	• New and innovative access to credit – from micro-loans to innovation vouchers
	• Information diffusion to MSMEs	• ASEAN industry associations work with research institutions
Transport and trade efficiencies	• Waiting times for products have increased • There is an increase in equipment costs	
Technology sovereignty and the lack of locally developed technology	• There is an immature R&D ecosystem • Technology is not translated and tested locally • Experimental R&D is not strong enough • There are local trust issues	• Much greater collaboration on digital technology • Regional data-sharing agreements • Establishing more centres of scientific excellence

Suggested STI actions for the next APASTI to address the challenges and opportunities of economics and industry competitiveness

- Strengthening of the ASEAN preferential trading arrangements, ASEAN Free Trade Agreement, Regional Comprehensive Economic Partnership.
- Enhance cooperation within ASEAN countries and beyond.
- COSTI and the APASTI to take a more significant role in economic growth through enabling innovation and technology adoption.
- Mapping the STI and human resource needs of each industry sector.
- An ASEAN focus/research on behavioural change and the rationality between high-demand/consumption and longer-term positive and negative impacts. A greater focus on sustainable behaviours.
- Transport and re-routing efficiency R&D for ASEAN trade.
- Facilitate regional data-sharing agreements and the establishment of centres of excellence.

6.7 Consumer market dynamics

OVERALL ISSUE	CHALLENGES	OPPORTUNITIES
Change in buying patterns	• Social media and AI-targeted marketing creating trust issues and concentrating power in social network providers • There are different platforms for communication and social media within ASEAN	• Greater targeting of consumers for less marketing expenditure • Wider marketing reach • Opportunity to streamline social media platforms
	• Privacy and the use of personal data	• Better data sovereignty networks and platforms built on trust • Regulatory frameworks for the collection and use of personal information
	• Waiting times have increased • Increased equipment costs	
	• Information barriers on how to harness AI for reaching customers – particularly in international markets	• Community training and education programmes
Values-based consumers	• Authentication of claims of sustainability (greenwashing) and other values • Quality assurance and digital trust • Certification schemes can be biased	• Certification schemes and audit networks

Suggested STI actions for the next APASTI to address the challenges and opportunities of consumer market dynamics

- A home-grown ASEAN social media platform.
- Incorporate AI-assisted options in decision-making about products and services.
- Harmonise product standards across ASEAN in certain areas.

6.8 Education and talent

OVERALL ISSUE	CHALLENGES	OPPORTUNITIES
Quality and consistency of education across ASEAN Member States **Education gap and accessibility**	• Investments required for quality education systems • The digital divide and the slow adoption of technology in education. Affected by geography within and between countries	• Collaborations with international and other ASEAN organisations and data sharing • Private sector involvement in corporate social responsibility (CSR)
	• Low levels of tertiary education in some countries and areas leading to limited capacity to develop value-added industries	• New education delivery models, connections and digital classrooms
Low-skilled populations are vulnerable to automation technologies – particularly in agriculture and manufacturing		• Transition to green energy jobs, jobs in service sectors such health care, education and elderly support and eco-tourism • Collaboration and training in interdisciplinary subjects • AI training for ASEAN by the Singapore Government
Declining proportion of the working-age population in most ASEAN nations	• Adoption of automated processes and robotics for many manual tasks • Lifelong learning	• Education for skills for the 4th Industrial revolution
Matching industry needs and education provided **Interdisciplinary skills**	• Adjusting education to industry needs • Lack of talent related to interdisciplinary work • The curricula are not interdisciplinary	• Using AI to better assess education needs and develop learning materials
Impact of AI and digital learning		• May fill the low skills gap by assisting people to gain skills through personalised learning or supporting them in language, coding or technical proficiency.
ASEAN 'brain drain'	• Talented and skilled scientists and researchers are leaving ASEAN Member States for positions in other countries	• More opportunities for STI experts within ASEAN Member States

Suggested STI actions for the next APASTI to address the challenges and opportunities of education and talent

- Strengthening the ASEAN University Network AUN and ASEAN Qualifications Reference Framework (AQRF).
- ASEAN-supported mapping of human resources and industry needs – especially as industries transition. Some countries have very low levels of skills in certain critical sectors, so an ASEAN-wide skills program could assist them.
- ASEAN to promote digital literacy for both the general population and also for policymakers so they can determine appropriate regulations for digital tools.
- ASEAN to implement 'brain circulation' initiatives.

6.9 Politics and governance

OVERALL ISSUE	CHALLENGES	OPPORTUNITIES
Political interference	• Weak administrations are vulnerable to external pressures • Impacts on FDI and regional security • The influence of the super-power nations on ASEAN • The erosion of democratic institutions	• ASEAN-led support for stronger administrations
Weak enforcement of law and order	• Escalation of violence and organised crime, including cyber crime • Destruction of industries such as tourism and education	• Better support and coordination for crime fighting across police agencies
Divergent approaches to anti-corruption measures	• Anti-corruption measures used politically • Nepotism and political interference in public processes	• Harmonisation of tools for anti-corruption measures
Transboundary issues	• Mismanagement of natural resources (such as river deltas and seas) • Uncoordinated action on infectious diseases • Territorial issues on maritime boundaries and fishing rights. Disputes in the South China Sea	• Greater technological investment in ASEAN military and security measures
Persecution of minority groups	• Refugees fleeing violence, human trafficking and social instability	• Protocols for human rights abuses
Climate change	• Will restrict resources, displace populations and may cause instability	

Suggested STI actions for the next APASTI to address the challenges and opportunities of politics and governance

- ASEAN-led support for stronger administrations through technology and networks.
- Leverage the super-power nations and localise their technology.
- Promote open-government initiatives through technology.
- Provide more support for the newer member states of ASEAN to advance technologically.
- Provide awards to appreciate public service operators and for the adoption of technology to lower corruption.
- Strong and harmonised laws for 2035 targets and rewards for agile and clean government.

6.10 Society – justice, equity and equality

OVERALL ISSUE	CHALLENGES	OPPORTUNITIES
Universal access to basic services – health, education, power and water	• The population of ASEAN nations is dispersed. Rural populations have less access to basic services • Disparities in access to services by gender • Lack of transparency of governments • Youth disenfranchisement	• Expansion of basic services with adaptable and flexible models • Expansion of childcare and other targeted services to progress women's education and work • Greater inclusivity
Technological change	• Technological change may promote greater wealth inequality • The digital divide in services, infrastructure, devices and data coverage • Digital inclusivity • Women in STEM and higher education • Information and misinformation	• Newer taxes to ensure fair and equitable contributions to the funding and provision of services by big tech. • FDI programs to help fund digital infrastructure and devices and education programs – particularly for women and minority groups
The infrastructure gap	• The need for infrastructure for basic services and improved services is greater than the funding available (public sector capital) • Will slow economic and social progress	
Impacts of the history of colonialism		• Active measures to support decolonisation

Suggested STI actions for the next APASTI to address the challenges and opportunities of society – justice, equity and equality

- More ways to invest in ASEAN-led initiatives to create universal access to basic services.
- ASEAN to include more women in key decision-making roles and the promotion of gender equality.
- Sharing more examples of best practices among ASEAN Member States and the creation of a standardised system for every country.
- More support for ASEAN civil society.
- Create more ASEAN youth programs in STI areas and involve them in professional science programs.
- More forums for open discussion and information-sharing.
- Targeted digital literacy programs.
- Providing support programs/funding/opportunities for women and minority groups in STEM.
- A review of generative AI to ensure that it provides benefits for all groups.
- Incorporate Indigenous knowledge and perspectives in STI advancement policy papers.

6.11 Action areas of focus

The CSIRO team also attempted to place the workshop actions into broader subject areas of focus. Although this was not a codified process and could have been influenced by the initial megatrends, there did appear to be a distinct emphasis on actions in the four areas below.

Actions under Health mostly responded to the *Health Demographics* and *Population Dynamics* forces of change; actions under Climate adaptation, net-zero and pollution reduction were primarily derived from the *Planet and Environment, Energy* and *Food and Water* forces of change, while those under Digital and Diversity/ Indigenous knowledge systems were actions from a range of forces of change (cross-cutting).

The existing ASEAN Priority areas of cooperation for STI include Biotechnology, Food Science & Technology, Marine Science & Technology, Materials Science & Technology, Meteorology & Geophysics, Microelectronics & Information Technology, Science & Technology Infrastructure & Resources Development, Space Technology & Application, and Sustainable Energy Research.

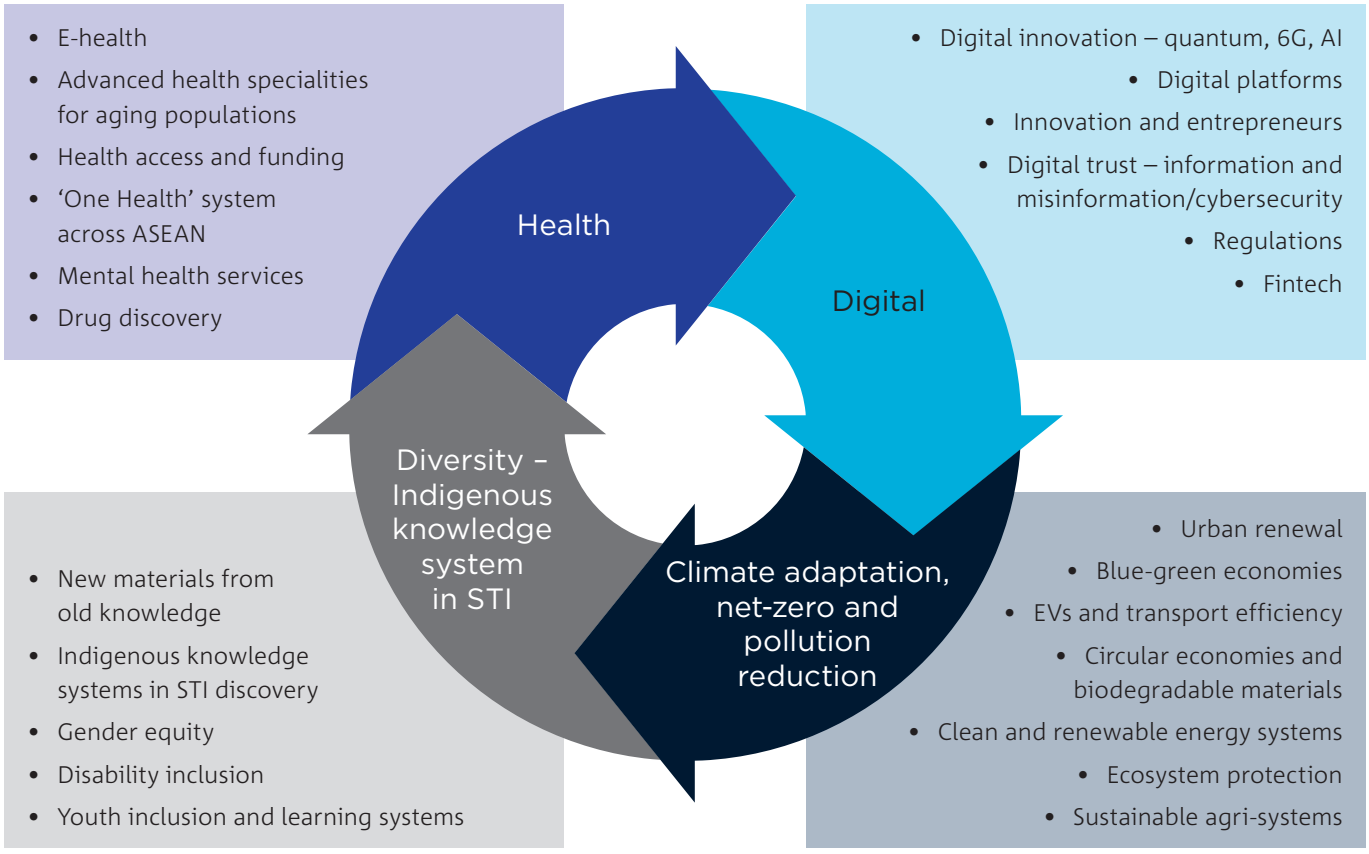


Figure 11. Action areas of focus

7 Workshop outcomes

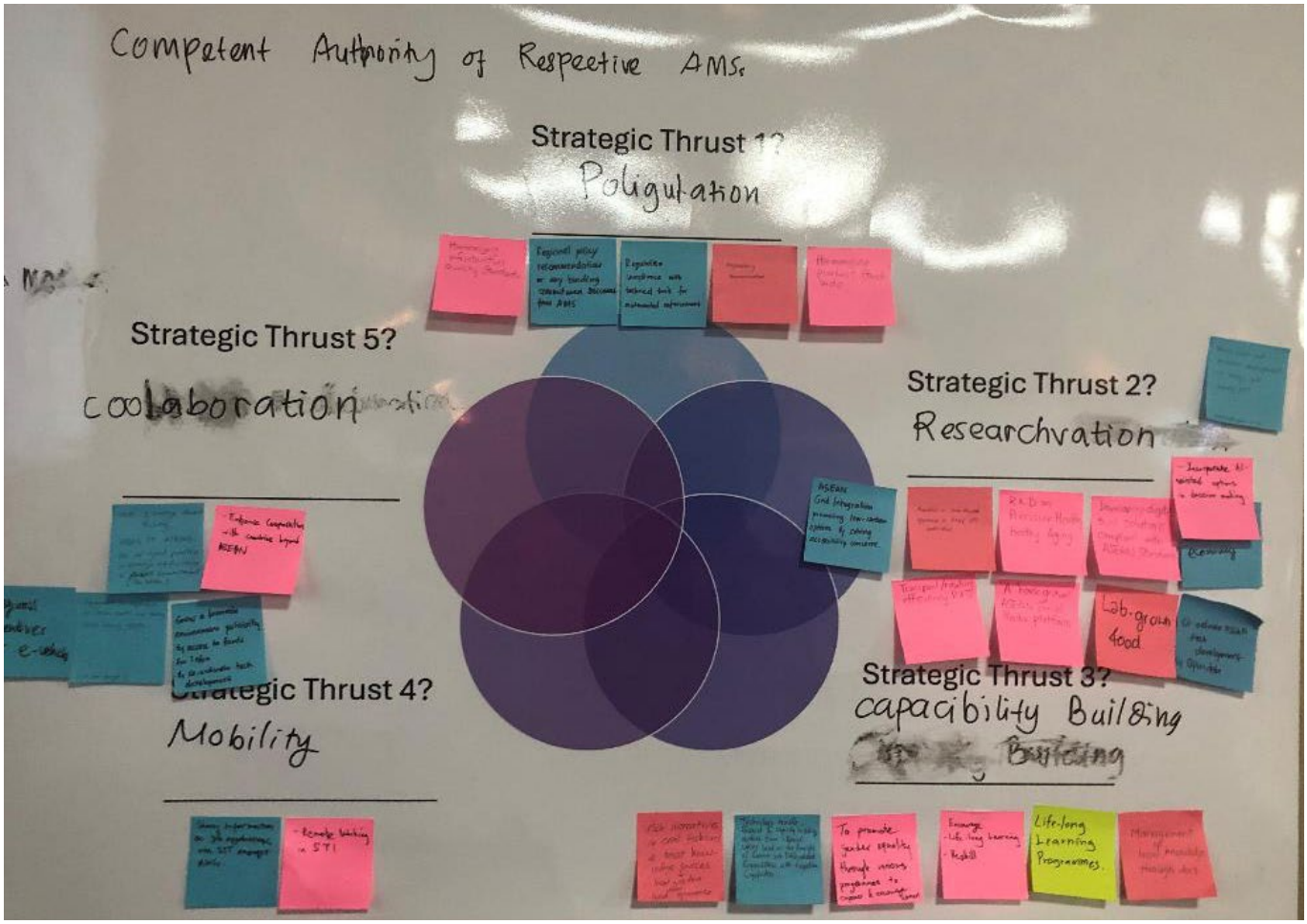
7.1 Defining a set of strategic actions

Process

Workshop participants were asked to move the actions they had created under the ten forces of change and group them under six untitled 'strategic thrusts.' These were grouped by common themes.

Participants did this in three groups – so three groups of six strategic thrusts were formed.

Overnight CSIRO examined the actions under the three groups and combined them to form one set of six strategic thrusts that covered all the actions generated for STI action in the next APASTI (Figure 12).



Results

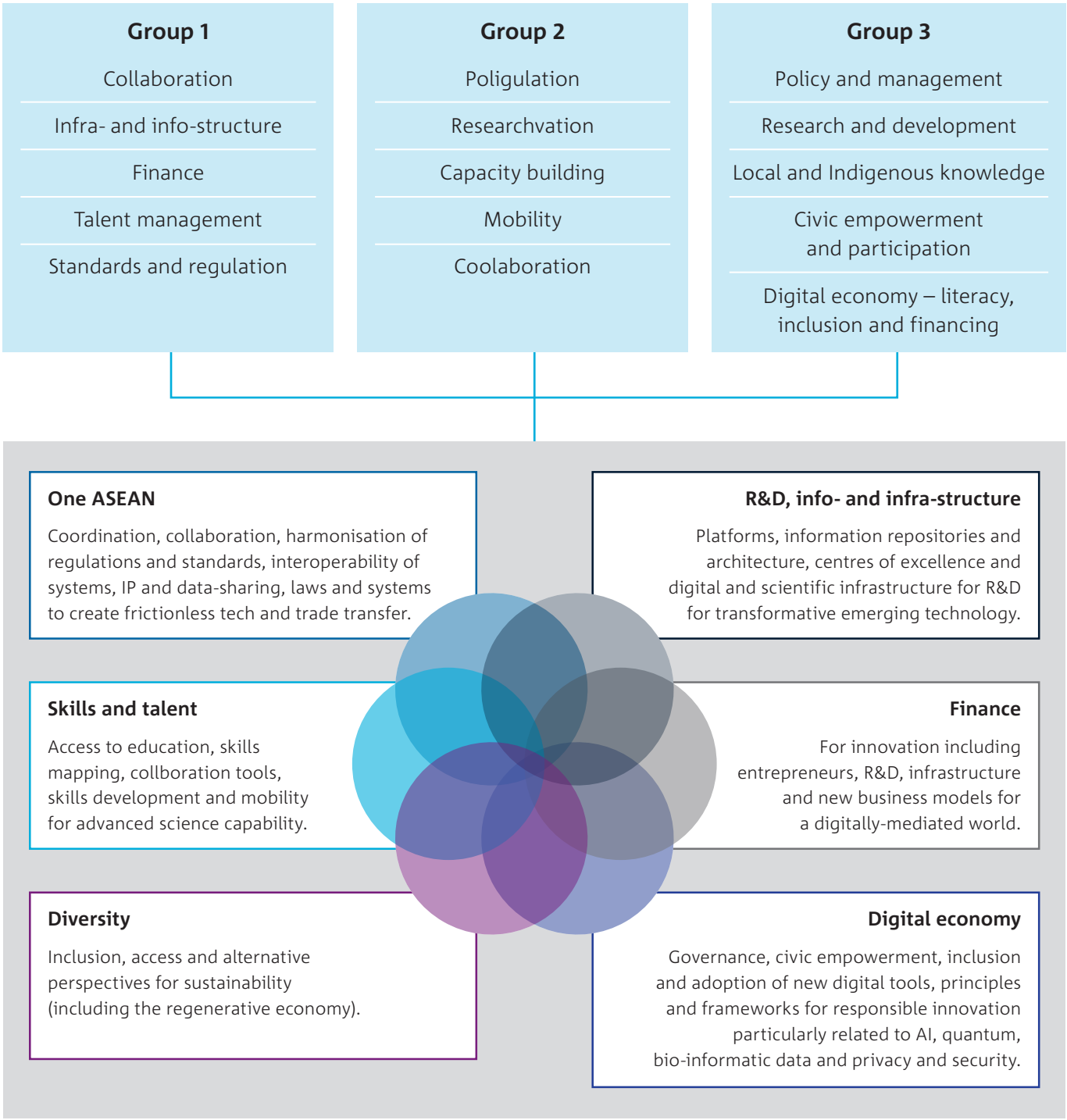


Figure 12. Strategic thrusts developed by workshop participants and the combined set of strategic thrusts

7.2 Prioritisation of the new strategic thrusts using multiple criteria decision analysis (MCDA)

MCDA is a family of decision support techniques that has been widely applied since the 1960s across various industries and decision problems [47]. In the last decade, its applications have surged, particularly in the health sector, including patient prioritisation on waiting lists, health technology assessments, and ranking health investment options [48, 49]. National governments and international organisations have published guidelines endorsing MCDA for public sector decisions, highlighting its effectiveness as a decision-support tool [50].

The primary goal of this MCDA application is to prioritise strategic responses to the forces of change in developing and enhancing the STI ecosystem across ASEAN nations. The process considers the priorities and key criteria of both public and private stakeholders. Using the ASEAN Foresight Alliance's (AFA's) forces of change (megatrends) study, supplemented by data analysis and literature review, we identified a set of decision criteria and strategic response options – thrusts. These were further refined through stakeholder engagement. More details on the MCDA methodology can be found in **Annex B.**

Defining the criteria

The first step involved defining and weighting the decision criteria. A set of eight criteria was developed based on the objectives of ASEAN STI cooperation (established since the ASEAN Science and Technology Committee's inception in 1970), the strategic thrusts in the current APASTI 2016–2025, and discussions from the start of the workshop, where participants shared their expectations for the new APASTI. The set of eight criteria is provided in Figure 13.

After introducing the criteria, participants were asked to rank them based on their perceived importance to the success of the new strategic thrusts and the new APASTI. This ranking was conducted via an online poll using the Microsoft Forms platform Figure 15.

The poll conducted at the in-person workshop received 41 responses and was followed by a discussion on whether it would be fair and efficient to drop the two lowest-ranked criteria – Criterion 1 and Criterion 7 (Figure 13).

During the discussion, participants generally supported the poll results. There was a consensus to drop Criterion 7. However, Criterion 1 sparked debate, and after several participants voiced their opinions, it was collectively decided that Criterion 1 should remain in the set, albeit in the last position.

The online workshop returned similar results, with eight responses received for the online poll. It was debated whether Criterion 4 and Criterion 7 should be excluded from the set of decision criteria. The participants agreed to retain Criterion 4 and drop Criterion 7 (Figure 14).

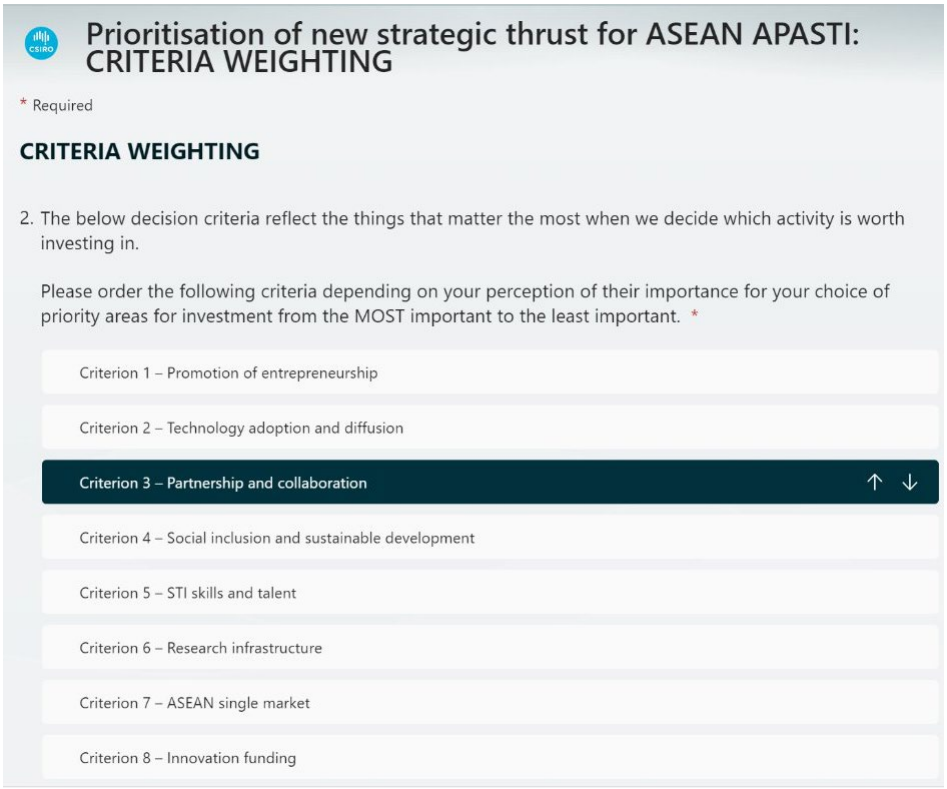


Figure 13. Criteria weighting poll

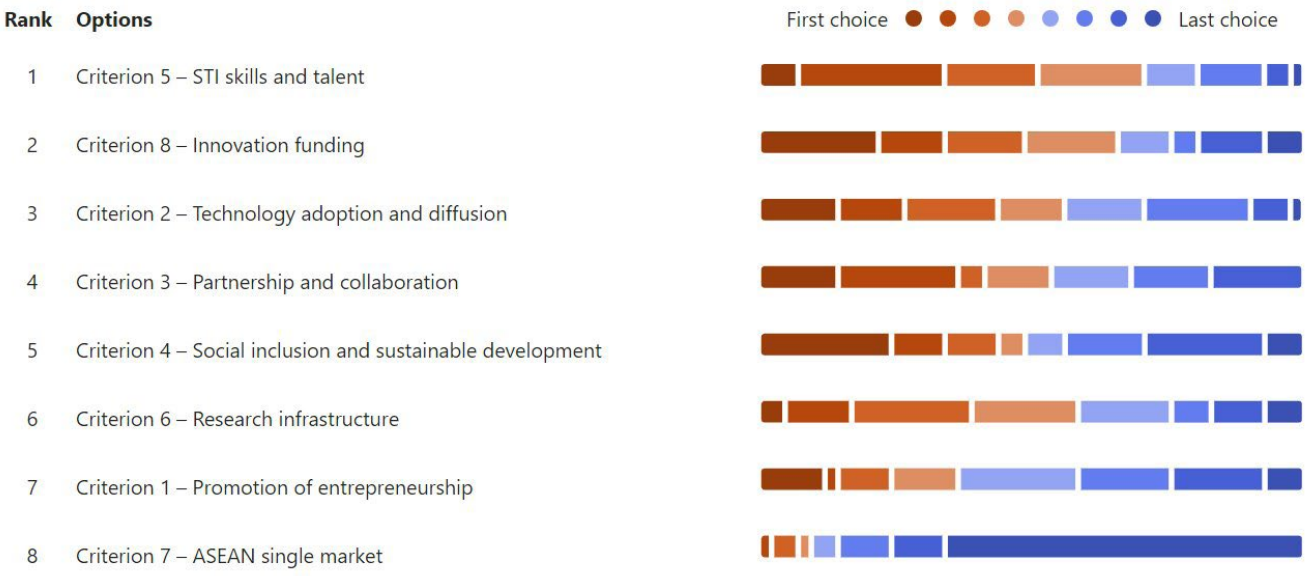


Figure 14. Criteria weighting: in-person workshop

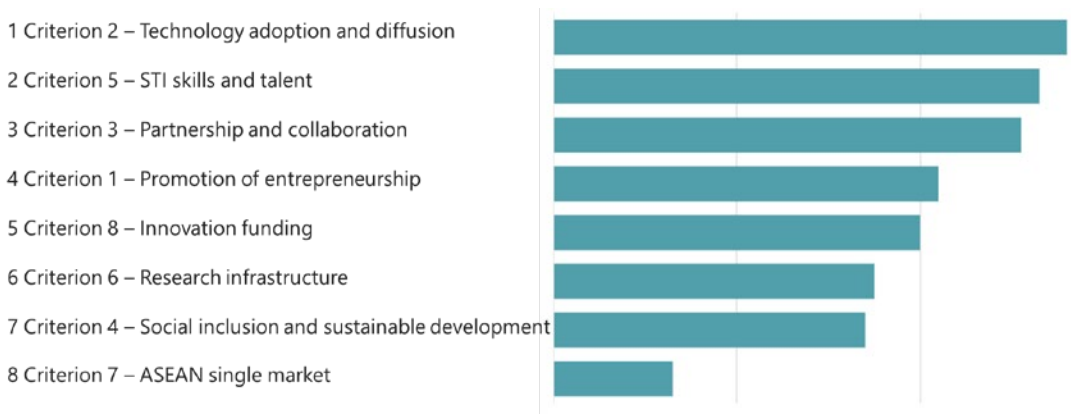


Figure 15. Criteria weighting: online workshop

1 Promotion of entrepreneurship Will the thrust promote entrepreneurship through tech transfer, centres of excellence, increased venture capital availability and other avenues?	**HIGH**: It is the key focus of this thrust	**MEDIUM**: It is among the goals of the activity	**LOW**: The thrust is likely to contribute, but not lead the way
2 Technology adoption and diffusion To what extent will the thrust help the adoption and diffusion of digital and other technologies in key industries?	**HIGH:** Significant acceleration of tech adoption	**MEDIUM:** Some promotion of tech adoption	**LOW:** Maintaining but not actively promoting it
3 Partnership and collaboration (P&C) Will this thrust promote partnerships across the ASEAN innovation system, between ASEAN and development partners and between public and private sectors?	**HIGH:** Accelerating P&C	**MEDIUM:** The thrust promotes some P&C	**LOW:** Active P&C is not essential for this thrust
4 Social inclusion and sustainable development To what extent does this thrust promote social inclusion, equity (gender, disability, marginal groups) and sustainability as a cross-cutting principle?	**HIGH:** Thrust will enhance equity and sustainability as the primary goal	**MEDIUM:** Actively addressing social inclusion and sustainability	**LOW:** Social inclusion and sustainability are among many other goals
5 STI skills and talent Will this thrust grow STI talent pool and promote labour mobility in the ASEAN region?	**HIGH:** Focus on skills and talent growth and mobility	**MEDIUM:** Skills and talent growth is among many goals	**LOW:** Some skills and talent growth is expected but not actively promoted
6 Research infrastructure (RI) Will this thrust enhance soft and hard research infrastructure (RI), ranging from well-established research institutes to governance frameworks for AI and quantum technologies and data sharing?	**HIGH:** Substantial enhancement of RI	**MEDIUM:** Some enhancement of RI	**LOW:** Maintenance of existing RI
7 ASEAN single market Will this thrust enhance the ASEAN single market through technology interoperability, fluid investment and collaboration across national borders?	**HIGH:** Focus on ASEAN single market	**MEDIUM:** ASEAN single market is among many goals.	**LOW:** Some developments towards ASEAN single market
8 Innovation funding (IF) Will this thrust develop new and enhance existing adaptive channels for innovation funding, including venture capital, procurement funding and digital financing?	**HIGH:** Substantial enhancement of IF	**MEDIUM:** Some enhancement of IF	**LOW:** Maintenance of existing IF

Figure 16. The set of eight decision criteria

Prioritisation of new strategic thrusts based on the criteria

The next step in the MCDA process for prioritising the new strategic thrusts involved workshop participants scoring the six new thrusts against the seven selected decision criteria. Both the in-person and online workshops were conducted via an online poll on the Microsoft Forms platform. An example of the poll interface provided to the participants is shown in Figure 17.

At the in-person workshop, the poll received 43 responses, while the online workshop's poll received 9 responses.

We used linear summation to calculate the resulting scores for the new strategic thrusts and determine the priority ranking. In this method, 'high' responses were assigned 3 points, 'medium' responses 2 points, and 'low' responses 1 point, based on the performance of each option against each criterion. The scores were then summarised and averaged across participants.

Next, the criteria weights were applied based on the rankings determined in the previous step. The scores for each option and the criteria weights formed a performance matrix. We calculated the final score for each new strategic thrust as a policy option using a simple linear weighted scoring method.

The performance matrix and the final rankings of the new strategic thrusts, as determined by the in-person and online workshops, are shown in Figure 18 and Figure 19, respectively. The prioritisation results were presented to workshop participants to facilitate discussion. The feedback indicated that the results accurately reflected the shared perceptions and thinking in the room.

The final ranking of the new strategic thrusts was consistent across both workshops, with slight deviations. The top-performing thrust in both cases was 'Skills and talent.' This was followed by a group of three thrusts: 'Digital economy,' 'R&D info and infrastructure,' and 'Finance,' though their order varied in the online workshop results.

The last two options in both workshops were 'One ASEAN' and 'Diversity.' While they occupied the same positions in the ranking, their order within this group differed in the online workshop.

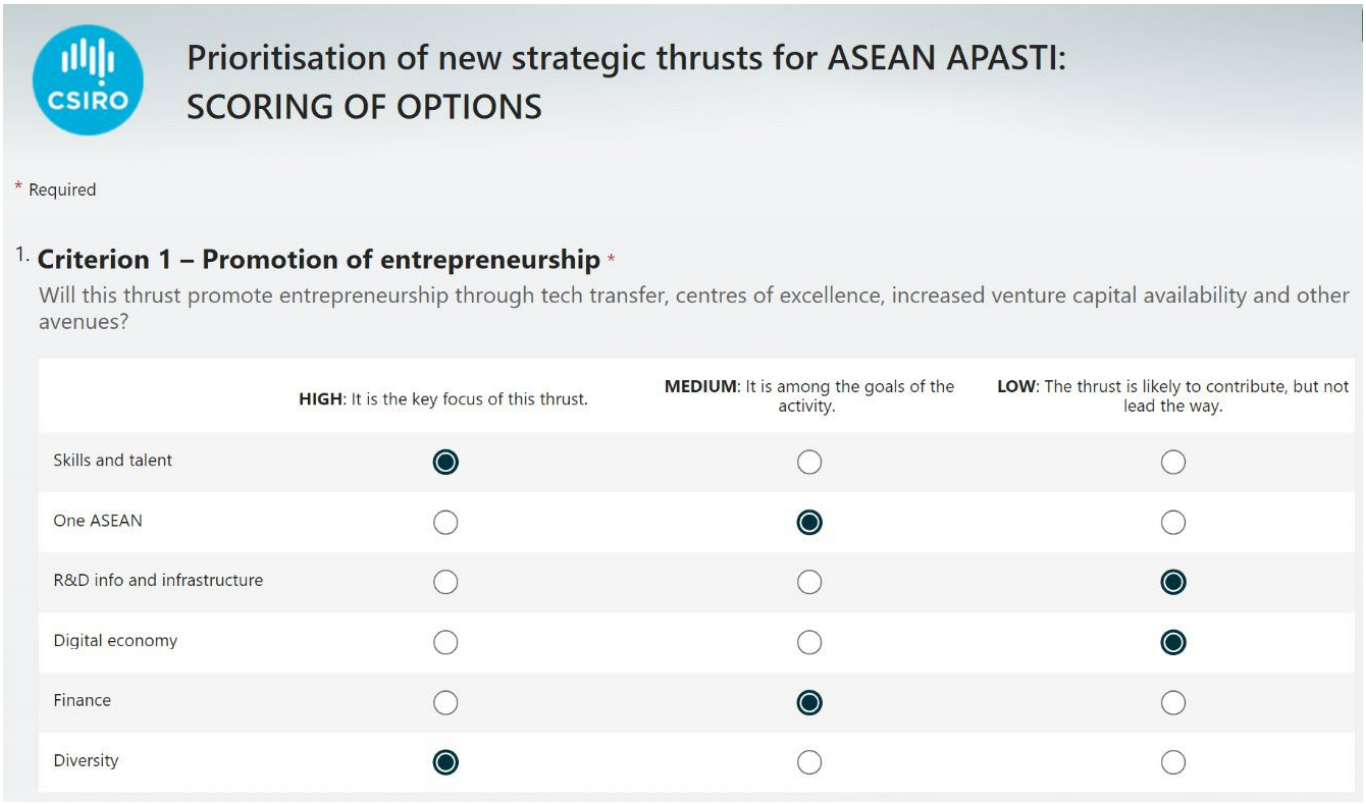
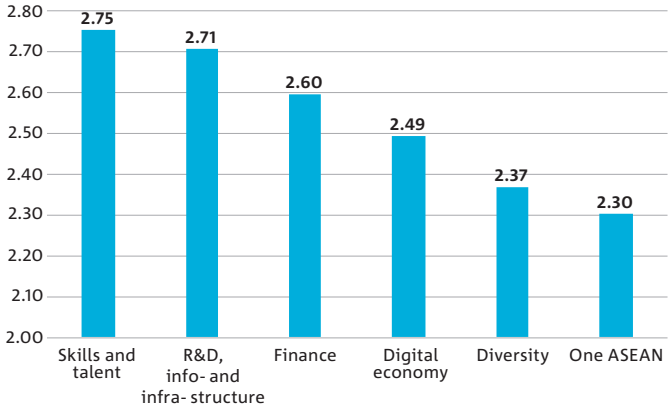


Figure 17. Prioritisation of options against criteria poll (example)

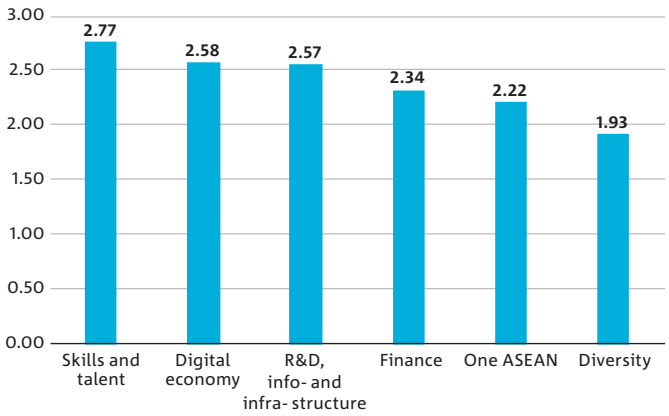
New strategic thrusts	Criterion 1: Promotion of entrepreneurship	Criterion 2: Technology adoption and diffusion	Criterion 3: Partnership and collaboration	Criterion 4: Social inclusion and sustainable development	Criterion 5: STI skills and talent	Criterion 6: Research infrastructure	Criterion 8: Innovation funding
Skills and talent	2.65	2.93	2.61	2.54	3.00	2.79	2.54
One ASEAN	1.98	2.19	2.79	2.54	2.19	2.19	2.19
R&D, info and infrastructure	2.60	2.79	2.54	2.28	2.79	2.91	2.81
Digital economy	2.60	2.68	2.44	2.26	2.47	2.42	2.54
Finance	2.72	2.74	2.42	2.17	2.46	2.70	2.91
Diversity	2.16	2.21	2.44	2.67	2.42	2.23	2.33
Weights	**4%**	**18%**	**14%**	**11%**	**25%**	**7%**	**21%**

Figure 18. Prioritisation of new strategic thrusts: results of the in-person workshop



New strategic thrusts	Criterion 1: Promotion of entrepreneurship	Criterion 2: Technology adoption and diffusion	Criterion 3: Partnership and collaboration	Criterion 4: Social inclusion and sustainable development	Criterion 5: STI skills and talent	Criterion 6: Research infrastructure	Criterion 8: Innovation funding
Skills and talent	2.78	2.78	2.56	2.89	3.00	2.67	2.67
One ASEAN	1.89	1.56	2.67	2.67	2.56	2.33	2.56
R&D, info and infrastructure	2.22	2.89	2.56	2.45	2.33	2.78	2.67
Digital economy	2.78	2.67	2.33	2.45	2.56	2.56	2.67
Finance	2.22	2.33	2.22	2.11	2.33	2.33	2.78
Diversity	1.78	1.78	2.11	2.56	2.00	2.00	1.78
Weights	**14.3%**	**25.0%**	**17.9%**	**3.6%**	**21.4%**	**7.1%**	**10.7%**

Figure 19. Prioritisation of new strategic thrusts: results of the online workshop



Discussion of results and consideration of limitations of the MCDA

The workshops highlighted that the top strategic priority for the new APASTI is investment in developing STI skills and talent, including access to education and talent mobility. Following this, three additional thrusts emphasised the importance of financial and infrastructure support and the proper resourcing of STI capacity-building activities. While integrity and diversity were less prioritised, they remained within the range of shortlisted thrusts.

The MCDA process used in the workshops facilitated open and transparent discussions. Although alternative analytical methods could have been applied, MCDA with a linear summation model was chosen for its simplicity and transparency, two aspects which are particularly important in the online workshop setting. However, it's crucial to understand that MCDA serves as a framework for further development and discussion, not a final solution. The success of any thrust will depend on various factors, such as investment, timing, leadership, and support – basically, on the 'who' and 'how' of the implementation of the thrust's activities.

When interpreting the results of this analysis, several other limitations should be considered:

1. **Differences in workshop format**: Although participants in both workshops received the same information, the online workshop was conducted in one day, whereas the in-person workshop spanned two days, allowing participants more time to understand the criteria and alternatives. Some participants could not attend the entire sessions, and group dynamics may have influenced individual responses and prioritisation. These factors should be considered when comparing the results across the two workshops.
2. **Participant engagement and representation:** The MCDA results are limited by the expertise and engagement of the participants. Not all invited stakeholders could attend, and some participants showed limited interest in the MCDA evaluation. This may have skewed the range of perspectives represented.
3. **Summarised poll results:** The poll results were automatically summarised and averaged without accessing individual responses to maintain anonymity and provide real-time feedback. However, this prevented the identification of potential biases among respondents. A pre-workshop survey could have provided insights into participants' backgrounds, expertise, and preferences, helping to manage potential vested interests.
4. **Lack of advanced preparation:** Participants were not informed of the MCDA process in advance or provided with background materials or an overview before the workshop. This encouraged spontaneous responses but may have led to some participants voting without full awareness of the options.
5. **Limited consideration of synergies:** While the MCDA revealed individual stakeholder preferences, it did not account for potential synergies between priority thrusts. The combined impact of developing multiple thrusts together could provide additional benefits and should be explored through further analysis, such as portfolio analysis.

7.3 Road mapping the implementation of the prioritised actions

Workshop attendees were asked to 'signpost' a timeline with known planned events and committed targets for 2035.

Included in this were global commitments on net zero emissions by 2030 and 2045, ASEAN events, country-based events – such as the opening of Indonesia's new capital at Nusantara, and technology predictions – such as an error-free quantum computer.

Underneath the signposts, attendees were asked to place all the actions from the previous work in the two main five-year groupings: 2026–2030 and 2031–2025. There was also a section for 'Beyond 2035'.

Actions sorted by strategic thrust are grouped by 5-year periods in the detailed roadmap in **Annex A.**

Despite several activities signposted beyond 2035, there was only one STI action placed in the 'beyond 2035' sheet of the timeline- 'Well-being cities'

Actions combined with the MCDA have been listed on the following page in order of prioritisation on a broader sequence graphic.

Talent and skills

- Mapping STI skills and capability to areas of growing industry need and technology gaps
- Developing networks, partnerships and linkages across ASEAN and with external STI leaders in emerging science areas
- Investing in skills for green jobs and the healthcare sector
- Improving STEM and digital literacy skills across the population

1

R&D and infrastructure

- Centres of Excellence in areas of scientific advantage
- Digital and data-sharing platforms for scientific research and collaboration
- Greater assistance for technology transfer and commercialisation from the research sector

2

Finance

- Set national goals for R&D expenditure across ASEAN Member States
- Examine new taxes for R&D development for transition (e.g. carbon taxes or credit schemes for a climate fund)
- Examine circular economy initiatives
- Support venture capital attraction and new funding models for digital entrepreneurships

3

4

Digital economy

- Invest in new e-government and digitally delivered services including using AI, blockchain, robotics and sensor networks, and quantum technologies
- Support AI incubators and business support centres
- Examine dedicated digital platforms for – e-Health, humanitarian assistance, data-sharing, talent, ASEAN social media, STI collaboration
- Tech clusters to support entrepreneurs

Diversity – inclusion, access and alternative perspectives for sustainability (incl. the regenerative economy)

5

- Greater appreciation and use of Indigenous knowledge systems – particularly in natural resource management (water, forest systems, ocean resources)
- Inclusion of people with disability in STI planning and funding
- Targeted STEM activities for gender equity
- The inclusion of local economies in STI actions and funding

One ASEAN

6

- ASEAN-wide data-sharing platforms and systems
- Integrated STI resource-sharing and collaboration
- Interoperability in IT and payment systems
- Laws and regulations to create frictionless transfers of skills, IP, and knowledge to enable greater STI gains across ASEAN Member States

Figure 20. The broad roadmap. See Annex A for the detailed set of actions

8 Foundational actions

Several foundational actions were identified that may support the broad development of science, technology, and innovation across ASEAN Member States over the next 10 years. These are listed below:

Talent and skills

- A deeper understanding of the STI skills and capabilities, movements and mobility, collaborations, and pipeline of talent within the ASEAN Member States, and the development of mobility programs and broad foundational education and curricula to feed into STEM careers from all levels and age groups.
- An exercise to map STI skills being developed through the education systems across industry sectors within ASEAN Member States to reduce the gap between graduate skills and industry needs and promote greater efficiency in expenditure in STI training and skills development.

Digital economy and R&D infrastructure

- The development of a joint framework and position paper on the responsible and ethical use of AI within STI institutions across ASEAN, as well as for citizens of ASEAN nations. This may include a regional digital rights charter for citizens and organisations, similar to the European Digital Rights and Principles Charter (2022),[8] or Thailand's AI Ethics Guidelines (2021). [9]These documents broadly outline rights and guiding principles for personal or commercial digital content development and use within AI systems, encouraging digital development to support sustainability and citizen safety.
- A further review of government regulations impacting the development and deployment of new and emerging digital technologies across ASEAN Member States, with recommendations for areas of collaboration. These may include data-sharing frameworks, guidelines for use and protocols for interoperability.
- An audit of critical ASEAN digital infrastructure including the region's data centres, networks and cybersecurity required for the coming decade, as well as the current and planned research infrastructure needed for emerging digital technologies, including quantum computing and 6G networks. Much of this development may also be sensitive to energy availability.

Finance

- Boosting the funding available for prioritised cross-border collaborative STI ventures – possibly through the ASEAN Science, Technology and Innovation Fund (ASTIF) administered through the ASEAN Science and Technology Network (ASNET). International development partners are usually aligned with specific actions through the APASTI process. However, a flexible and adaptable fund to invest in new and emerging cross-border priorities would allow ASEAN the ability to steer STI outcomes and provide a contingency fund to resource unexpected events requiring an STI response – such as pandemics or natural disasters.
- Examine R&D investment, taxation and savings legislation across ASEAN Member States and globally, to ensure ASEAN can advise on world's best practice in relation to regulatory settings for investment in STI for development phases.

One ASEAN

- The foundational work here relates to communal assets for STI across the ASEAN regional bloc: Funds, trading schemes for transformation, investment vehicles, interoperability of digital protocols and guidelines for use – particularly as they relate to data-sharing, IP use and units of measurement for various schemes in the developing circular economy.
- The development of an ASEAN Innovation Dashboard to monitor and regularly report on progress towards the goals and objectives of the next APASTI and as part of the monitoring and evaluation framework.
- The development of strategic goals specifically for STI development in ASEAN as a regional bloc. These have previously been articulated in the APASTI along with the strategic thrusts, but there has been criticism that previous goals are not measurable or explicit enough to incentivise STI progress in ASEAN Member States. Goals that align to measurable actions – such as increases in IP generation, income and use, increases in regional STI collaboration, numbers of skilled STI workers and clustering of expertise, or diversity of the STI workforce – may offer greater regional insight and actionable intelligence on STI progress over the coming decade.

8 https://digital-strategy.ec.europa.eu/en/policies/digital-principles

9 https://www.etda.or.th/getattachment/9d370f25-f37a-4b7c-b661-48d2d730651d/Digital-Thailand-AI-Ethics-Principle-and-Guideline.pdf.aspx?lang=th-TH

The current APASTI contains six goals or objectives:

1. *ASEAN Science, Technology and Innovation (STI) addressing the grand challenges of the new millennium.*
2. *Economically integrated ASEAN involving active collaboration between the public and private sectors especially SMEs and enhanced mobility of talents.*
3. *An innovation-driven economy with a deep STI enculturation and a system of seeding and sustaining STI by leveraging ICT and the resources of our talented young, women and private sectors.*
4. *Deep awareness of STI and the beneficial impacts of STI on the bottom of the pyramid; An innovation-driven economy with a deep STI enculturation and a system of seeding and sustaining STI by leveraging ICT and the resources of our talented young, women and private sectors.*
5. *Active R&D collaboration, technology commercialisation and entrepreneurship and network of centres of excellence.*
6. *An enhanced STI management system in the new AEC so as to support ASEAN innovation reaching global markets and that promotes innovation, integration and narrowing of development gaps across ASEAN Member States.*

These are broad guiding principles. The feedback from the APASTI Foresight workshop was that they may be too broad and not explicit enough to track progress and achievements. Creating measurables to track the goals and objectives would help achieve this.

Diversity and sustainability

- Integrate the UN SDGs into the monitoring and evaluation framework for the next APASTI along with specific goals related to diversity, inclusion and sustainability that apply to ASEAN regional ambitions.
- Develop principles for engagement with Indigenous peoples from ASEAN Member States and the use of their knowledge (IP) and moral rights in STI systems. These may be similar to those of Australia's CSIRO[10].

10 Indigenous Cultural and Intellectual Property Principles; https://www.csiro.au/en/research/indigenous-science

9 Conclusions and a recommendation

This work seeks to fill the gaps in the significant foresight work already conducted for the APASTI 2026–2035 by the ASEAN Foresight Alliance in their report *ASEAN Science, Technology, and Innovation Ecosystem Foresight 2035*. It achieved this by asking a group of representatives from all ASEAN Member States to describe the Science, Technology, and Innovation (STI) actions needed to meet the significant challenges and opportunities of the forthcoming decade, as outlined under identified megatrends or forces of change.

These actions were then grouped into broader categories to inform the APASTI 2026–2035 and organised into a timeline spanning five-year intervals. When integrating this work into the APASTI, it should be cross-referenced with the initial work of the ASEAN Foresight Alliance, as that foresight report also describes strategies to help the region achieve the optimal scenario, referred to as 'Blue-Green Utopia.'

The coming decade will witness increasing impacts from climate change, including the risks of heatwaves, extreme weather events, ecosystem collapse, and food and water shortages. Additionally, there are indicators that the risk of regional conflict may be rising. However, these challenges present significant opportunities, such as leveraging STI capabilities to address climate change, energy transitions, food and water production, regional coordination, and developing new economic models for more circular and efficient regional economies. With coordinated effort and establishing both long and short-term goals, the ASEAN region could become a global leader in innovation.

When this work was presented to representatives of ASEAN Science Ministers at the 86th annual meeting of COSTI in Singapore on October 10, members expressed a desire for the next APASTI to provide more precise direction, including specific benchmarks and progress targets – particularly for STI translation and local impact. There was also a call for improved visibility on how ASEAN, as a regional bloc, is performing relative to the rest of the world so that members can better monitor progress and implementation between reviews. This need was similarly identified in the review of the current APASTI 2016–2025, conducted by Cambridge Industrial Innovation Policy, IfM Engage, and the University of Cambridge.

To that end, we would suggest that ASEAN innovation indicators and a dashboard be established as a management, monitoring, and evaluation tool. Similar dashboards are currently being developed for other regions such as the European Union.

Recommendation for an ASEAN innovation dashboard

ASEAN-specific indicators would provide useful detail for policy and feedback to the ASEAN Member States. Current innovation dashboards and indexes, such as the European Innovation Scoreboard (EIS) and the Global Innovation Index (GII), provide valuable insights but are insufficient to fully capture the complexities of innovation across ASEAN. These tools tend to focus heavily on quantitative metrics, like the number of publications, patents, or R&D expenditure, which may not reflect the true depth of innovation, particularly in less developed ASEAN members such as Laos and Cambodia. For example, the number of publications from these countries might be misleading, as they are often led by international researchers rather than local experts. This undermines an accurate assessment of the region's internal innovation capabilities and collaboration patterns. Therefore, relying on such indices alone cannot provide a full picture of the diverse and collaborative innovation landscape across ASEAN.

Another critical issue with current innovation indices is the lack of attention to skills development, particularly soft skills that are essential for sustaining innovation. Most dashboards fail to address the growing skill gaps across ASEAN, especially in foundational and interactive skills, which are essential for driving innovation at all levels. For instance, a 2023 CISCO report highlights that 1.9 million workers in ASEAN will need intermediate skills, and 1.7 million will require foundational skills such as active learning and reading comprehension. To address these gaps, ASEAN needs an innovation dashboard that tracks not only technological progress and collaboration but also skills development across member states.

There is also a need for a framework, such as an innovation maturity model, to evaluate current innovation capabilities, identify gaps, and prioritise strategies for improvement. This would inform efficient spending in the various contexts of development. An innovation maturity model is based on the idea that innovation evolves in stages, each with increasing levels of complexity, requiring different approaches to progress. For ASEAN, implementing a maturity model could provide a structured way to assess innovation ecosystems, monitor collaboration, and ensure that both technological advancement and skills development are aligned. This model would also facilitate cross-country dialogue, allowing member states to share lessons learned and develop more strategic, data-driven policies.

Introducing an ASEAN-specific innovation dashboard, combined with the Innovation Maturity Model, would be instrumental in addressing these challenges. Such a dashboard would provide regularly updated data to monitor and track innovation progress and collaboration internally across ASEAN, while also offering a tool for benchmarking against other regions like the European Union or North America. This comparative view would allow ASEAN to gauge its global standing and identify areas where member states can improve or learn from international best practices. Furthermore, by adopting the Innovation Maturity Model, ASEAN Member States can systematically assess their progress through various stages of innovation development. The model helps pinpoint gaps, offers strategies for capacity-building, and ensures that all innovation efforts are aligned with broader economic, social, and environmental goals.

Most importantly, the dashboard and maturity model would serve as critical tools to ensure that ASEAN is moving toward the goals outlined in the ASEAN Plan of Action for Science, Technology, and Innovation (APASTI) by 2035. APASTI's objectives emphasise fostering innovation-driven growth, deepening regional collaboration, and ensuring that innovation contributes to sustainable development.

An ASEAN Innovation Dashboard may also consider STI contributions towards the UN Sustainable Development Goals, and the social and other implications of the use of technology across ASEAN Member States.

By continuously monitoring innovation capacity and collaboration, and benchmarking ASEAN's performance globally, the maturity model ensures directionality – pushing ASEAN not just to innovate, but to do so in ways that deliver long-term benefits across economic, environmental, and social dimensions. This will ensure ASEAN's innovation landscape evolves in line with the APASTI targets, creating a robust, future-ready region.

With clear and achievable actions that address prioritised needs and the ability to track progress more frequently and regularly, there is no doubt the next APASTI 2026–2035 can greatly assist ASEAN Member States in further building significant science, technology and innovation capability.

In doing so, the APASTI can also steer the application of STI capability to address the considerable challenges and opportunities of the next decade and build a prosperous, inclusive and sustainable future.

Annex A. Detailed roadmap

	2026	2027	2028
Skills and talent Access to education, skills mapping, collboration tools, skills development and mobility for advanced science capability	• Diaspora talent forums • Innovation entrepreneurship ecosystem (2026-2030) • Map STI skills and talent pipeline in areas of growing industry need • Investment in skills for sustainability and green economies • Identify and bridge technology gaps across ASEAN Member States through targeted societies and collaborative partnerships	• Promote university linkages, cooperation and technology transfer from STI-leading nations beyond ASEAN	• ASEAN-led skills partnerships – quantum computing, cybersecurity, 6G technologies, new plastics and bio-synthetic compounds, climate science and green energy
R&D, info- and infra-structure Platforms, information, centres of excellence, digital and scientific infrastructure for R&D for transformative emerging technology	• More forums for open discussion and information sharing • Regional incentives for e-vehicles (adoption and infrastructure) • R&D on precision-health and healthy aging	• AHA Centre for STI cooperation • Advanced data science analytics centre for ASEAN countries • e-Health and remote health infrastructure investment alongside community-based healthcare • Centre of Excellence on water in the Asia Pacific is established • Measures and actions to reduce pressure on water availability are implemented	• ASEAN-wide data-sharing platform • Platforms for greater tracking of zoonotic transferable diseases • R&D in brain sciences and visualisations • R&D in cancer treatment for aging populations
Finance Finance for innovation including support for entrepreneurs, R&D infrastructure, and new business models for a digitally-mediated world	• Work within local governments to access funds for infrastructure and coordinate tech development • Targets on government and other R&D as a proportion of GDP across ASEAN • ASEAN carbon taxes	• Increase investment in R&D in priority areas such as biotechnology and transport efficiency • The creation of regional partnerships for scientific funding and development	• ASEAN Climate Fund to invest in usable R&D • Health tourism to fund local health initiatives • Grow a favourable environment to access funds for infrastructure and coordinated tech development

2029	2030	2031	2032	2033
• Capacity-building in healthcare and R&D skills and inter/intra-disciplinary skills	• Great support for ASEAN for civil society involvement in plans and actions • Advance technologies for climate adaptive health and other systems • Plan early for sustainable urban development and haze-free cities • Promote remote work in STI to access greater talent from around the world		• Encourage life-long learning within ASEAN populations – particularly aging populations	• CHW (health worker) empowerment with AI avatar experts
All 2020s: • Enhance regional digital infrastructure – Fibre-optic cable, 5G and 6G – including experimentation with virtual worlds and holographic representations • Assistance for greater technology transfer from research papers and universities out to industry • ASEAN Action on neuroscience and mental health – particularly for ASEAN youth. Greater training of healthcare professionals in mental health	• Climate-resilient health systems including developing early warning systems for health-related risks (e.g. through mobile health apps and real-time health information) • Infrastructure and a plan for lab-grown food	• R&D in green building technology and urban heat islands	• Infrastructure and a plan for lab-grown food • Distributed innovation and remote STI	• Promote Open Government initiatives • Leverage the superpower nations to localise their technology
• Find ways to attract greater investment in the blue-green technology needed to reduce carbon emissions	• Developing technology for the circular economy • ASEAN intervention/ affirmation programs on STI for inclusive growth	• Systems to provide greater affordibility and accessibility to public and private healthcare • Technology transfer, financial assistance and capacity building from advanced nations based on the prinicple of Common but Differentiated Responsibilities with Respective Capabilities	• ASEAN common currency	• Creation and agreement on ASEAN-wide carbon credits and trading system

Annex A. Detailed roadmap (continued)

	2026	2027	2028
Digital economy Governance, civic empowerment, inclusion and adoption of new digital tools, particularly related to AI, quantum, bio-informatic data and privacy and security	• Work on digital health systems and services • AI Incubators and advanced research centres • Government as a customer – develop and incorporate AI to assist in creating options for decision-making	• Regulation of social media • Regulation on compliance with technical tools for automated enforcement • A home-grown (ASEAN) social media platform • Development of platforms for e-Health and STI information sharing • Build the world's biggest data centre	• Use of digital networks for information and controls on misinformation • Develop digital trust solutions compliant with ASEAN standards
Diversity Inclusion, access and alternative perspectives for sustainability (including the regenerative economy)	• Management of local knowledge through documents • Seminars and discussions for Indigenous communities to share their knowledge. ASEAN Member States to adopt through open discussion • Implement programs to promote gender equity in science and tech	• Greater use of Indigenous knowledge and knowledge systems • Revitalise and revisit traditional foods • Monitoring protocols for each ecosytem and monitoing biodiversity using the latest digital technologies – drones, AI satellite mapping	• More ASEAN youth programs • Indigenous knowledge acknowledged as part of STI advancement in policy papers • Introduce country-level incentives to enhance recycling and plastics control
One ASEAN Coordination, collaboration, harmonisation of regulations and standards, interoperability of systems, IP and data-sharing, laws and systems to create frictionless tech and trade transfer.	• Standardised monitoring analytics and procedures for microplastics and other pollutants across ASEAN • Digital platforms for sharing STI employment opportunities across ASEAN Member States to lessen the brain-drain	• Create a 'One Health' system and approach to R&D/STI activities across ASEAN • ASEAN agreement to allow all ASEAN citizens to access health services at affordable prices • Harmonise infrastructure quality standards	• Regulatory harmonisation across a range of industries • System to share best practice/s among ASEAN Member States to create a standardised system for every country • A focus on well-being cities

2029	2030	2031	2032	2033
• Shared databases and repository for ASEAN data • ASEAN-wide data-sharing platforms • AI-assisted nutritional information and monitoring of diet and medicines		• Utilising AI for the accurate prediction of landslides and natural disasters		
• Indigenous practice to be revisited and adopted for water management and conservation • STI for evidence-based circular economy development and new business models for circular waste management	• Rich narratives and oral folklores and tacit knowledge sources for local wisdom • Create pathways for digital inclusion through the financial industry and access to public services • Targeted digital literacy programs		• Advanced technologies for climate adaptive health systems and sustainable urban development	
• Document best practice in relation to energy-efficiency and ASEAN targets (like the SDGs)	• Protocols to respond to refugees from climate and natural disasters	• An integrated ASEAN healthcare system • Laws on fat, salt and fortication within foods	• ASEAN common currency and single market • Harmonise water quality criteria and standards – appropriate to the tropics	• ASEAN protocols for energy grid integration to promote low-carbon options and solve accessibility concerns • Map the ASEAN value chain and promote the ecosystem for renewable energy systems within ASEAN Member States (energy demand is rising)

Annex B. Further notes on methodology

9.1 Workshops

One of the aims of the workshops was to engage ASEAN Member States and key stakeholders.

The workshop was designed to incorporate diverse perspectives, sectors and from all ASEAN Member States to shape the future of STI in ASEAN through APASTI 2026–2035.

Recruitment for the workshops

Data61 contacted over 260 businesses, funding institutions, academic institutions, industry bodies and non-government organisations with an STI focus across all the ASEAN Member States and asked for interest in attending the workshops and the appropriate contact for an email invitation. These organisations were identified from stakeholder networks, academic or research institutions, industry associations, and entities involved in the development of the digital economy.

Of those initially contacted, Data61 sent 113 official workshop invitations via email to representatives from:

- 23 Academic and research institutions
- 14 Government representatives
- 16 Industry and private sector groups
- 18 NGO and community research groups
- 45 ASEAN-associated groups and bodies

The ASEAN Foresight Alliance and ASEAN S&T division sent additional invitations.

Attendance at the workshops

In-person workshop in Jakarta 11-12 September 2024

There were 41 registered attendees at the two-day face-to-face workshop in Jakarta 11-12 September.

39 attended the first day, and approximately 35 attended the second day.

Representatives from all 10 ASEAN Member States were present. A representative from Timor Leste also registered but unfortunately could not attend due to air services disruption.

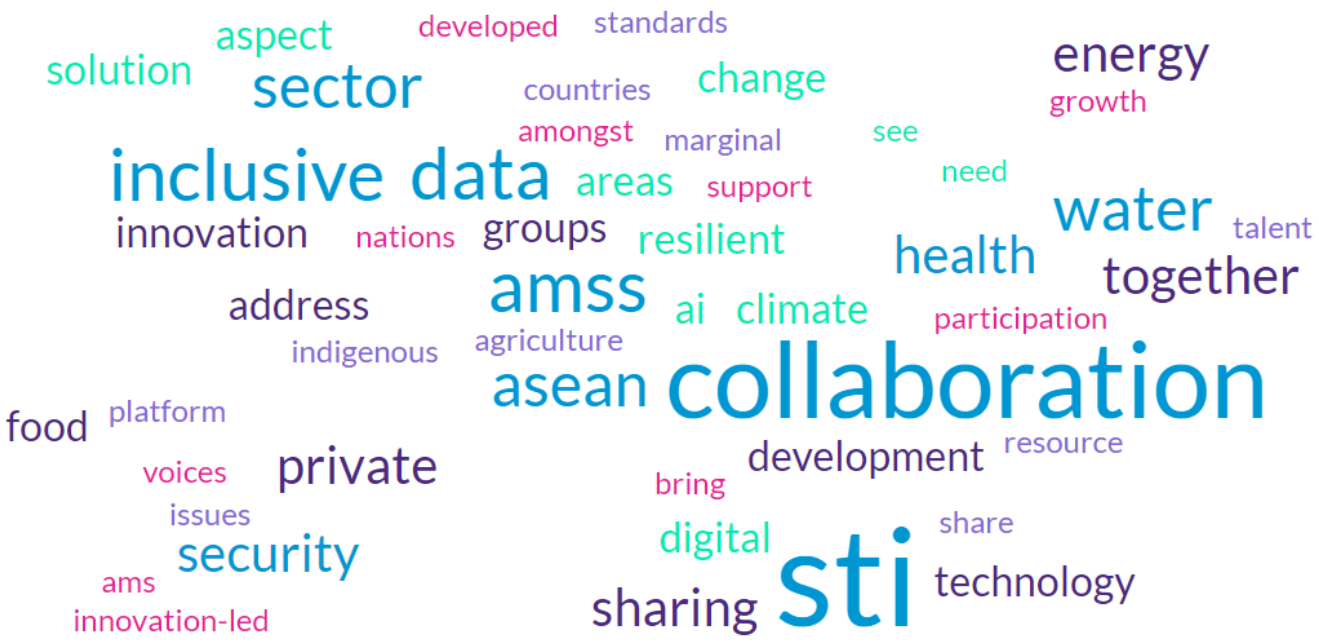
Representation by country

- Brunei Darussalam 4
- Cambodia 8
- Indonesia 9
- Lao PDR 2
- Malaysia 5
- Myanmar 2
- Philippines 4
- Singapore 2
- Thailand 1
- Viet Nam 4
- Timor Leste 1 (not in attendance)

Representation by sector

- Research and the University Sector 15
- Government and Ministries 15
- ASEAN-linked forums (Economic and Disability) 2
- Industry and the private sector 2

Between three and six people attended the face-to-face meeting remotely via a video link at any one time.



Expectations for the next APASTI

Workshop attendees were asked: *'What are your hopes and expectations of the next APASTI?'*. The combined responses (n=39) were used to create the word cloud above in MSForms.

Online workshop 13 September 2024

41 representatives registered for the online workshop. Three participants attended both the face-to-face workshop and the online workshop.

There were 28 participants logged into the Teams meeting. This included one room of five people located in Cambodia.

There were three CSIRO personnel and three ASEAN personnel on the call.

Not all attendees stayed on the call all day. The numbers dropped to only 16 participants just before lunch, and it was suggested that some had left to attend Friday prayers before the long weekend. The meeting broke for lunch early, and the number returned to between 18 and 24 participants after a 40-minute lunch break.

9.2 Clustering analysis

Table 5. ASEAN member clusters summary statistics.

VARIABLE	BRUNEI	LAOS, CAMBODIA, MYANMAR		THAILAND, MALAYSIA, VIET NAM		PHILIPPINES, INDONESIA		SINGAPORE	
	MEAN	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	TEST
Cluster	Niche innovator	Digital starter		Rising Tech hubs		Emerging innovators		Innovation powerhouse	
Patent (per mil people)	11.2	0.1	0.2	31.3	21.074	5.7	0.6	1,790.8	F=4003.367***
Trademark (per mil people)	1,654.8	4.4	4.4	938.1	302.6	342.6	17.5	19,308.1	F=2170.2***
Industrial design (per mil people)	0.0	0.0	0.1	41.3	23.0	8.9	3.6	2,805.7	F=8161.5***
Publication (per mil people)	1,915.2	29.0	20.0	528.8	522.3	326.8	366.0	5,349.5	F=44.3***
Researcher (per mil people)	513.6	23.2	6.5	1,068.3	546.9	293.8	149.6	7,224.7	F=85.7***
Skill index	0.7	0.2	0.1	0.4	0.1	0.4	0.1	0.9	F=15.9***
Year school (year)	13.7	11.3	1.0	13.9	1.5	13.4	0.8	16.9	F=4.6*
Broadband speed fix (Mbps)	73.1	25.2	6.8	144.6	64.5	59.7	44.4	264.2	F=6.4**
Broadband speed mobile (Mbps)	85.1	26.4	2.6	51.4	13.5	26.5	2.6	89.5	F=17.6***
Internet server (per mil people)	15,597.9	86.3	93.7	4,099.2	2,848.4	1,000.0	1,257.4	128,377.7	F=1000.3***
GERD (% GDP)	0.3	0.1	0.1	0.9	0.4	0.2	0.1	2.2	F=13.9***
Venture capital ($US mil)	56.6	7.3	2.5	16.2	7.7	5.9	2.0	293.4	F=667.1***
Domestic credit to private sector (%GDP)	36.3	72.1	81.7	138.5	22.2	43.5	9.2	129.1	F=18.4**
Digitally deliverable service (index value)	0.5	0.4	0.1	0.7	0.1	0.8	0.2	0.9	F=6.6**
Productive capacity index	53.5	35.2	3.3	53.0	2.3	44.9	2.0	54.0	F=21.1***
ICT export (% GDP)	0.1	0.2	0.2	0.5	0.4	0.9	1.0	5.4	F=19.3***
High tech export (% GDP)	1.0	5.4	2.5	29.5	8.5	37.3	41.5	55.0	F=1.9**

Cluster analysis – methodology

To assess the heat stress vulnerability across ASEAN regions, we conducted a cluster analysis, ensuring methodological rigor and robustness throughout the process. The main steps in the clustering process are demonstrated in Figure 21.

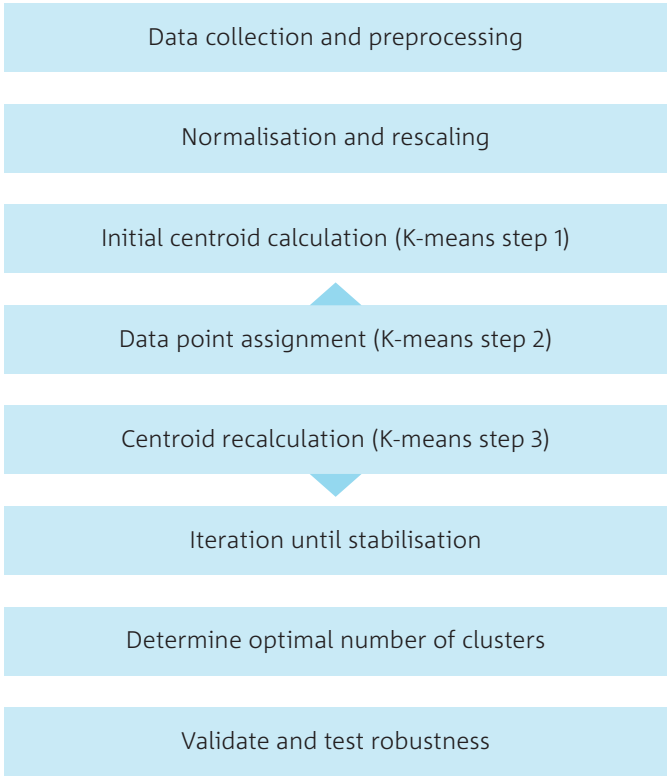


Figure 21. Steps in the clustering process

Clustering is a widely used unsupervised learning algorithm that can categorise observations into meaningful homogeneous groups. The distance between clusters (between-cluster variance) should be maximised, while the distance among a cluster's members (within-cluster variance) should be minimised [51].

Cluster analysis can be classified into hierarchical methods, partitioning methods, grid-based methods and density-based methods [52]. In this study, we used K-means – one of the most popular partitioning methods – to partition data points into three clusters.[11] We chose this method because it is less susceptible to outliers in the data, the choice of distance measures and the inclusion of irrelevant variables.

The K-means algorithm consists of three separate steps. In the first step, the centroid is calculated. In the second step that data point that has nearest centroid from the perspective data point is taken to the cluster. Once the cluster grouping is established, the algorithm is used to recalculate the new centroid for each cluster and a new distance between the centre and each data point. This assigns the point to the cluster which has the minimum distance. The process is repeated until the clusters are stable (i.e. no movement of data points across clusters in subsequent iterations).

We chose the Euclidean distance to measure distances between entities. The distance between two countries is calculated as follows:

$$d_{ij} = \sqrt{\sum_{k=1}^{n} (x_{ik} - x_{jk})^2}$$

where x_{ik} and x_{jk} are the parameter values of characteristic k for country i and j.

11 Running the analysis using a hierarchical method does not significantly change the findings.

We chose the optimal number of clusters based on the comparison of the clustering structure and other clustering schemes, resulting from the same algorithm but with different parameter values (e.g. the number of clusters) and using different clustering validity indices [53]. The optimal number of clusters suggested is three (for the whole SA2 regions) and two for the top 20% regions with highest Vulnerability Index (see Figure 22).

To evaluate the consistency of the number of clusters, we also checked the variance in the sum of square errors (SSE) of each cluster. We also conducted various tests to check the robustness of our approach.

First, we checked the robustness of the choice of variables through two tests: We tried different distances such as Manhattan, Maximum or Minkowski.

We removed each variable from the original variables and recalculated the cluster algorithm. We checked whether our cluster solutions are robust if we exclude SA2 regions with the highest value for each variable and recalculated the cluster algorithm. The cluster results did not change significantly with the two tests.

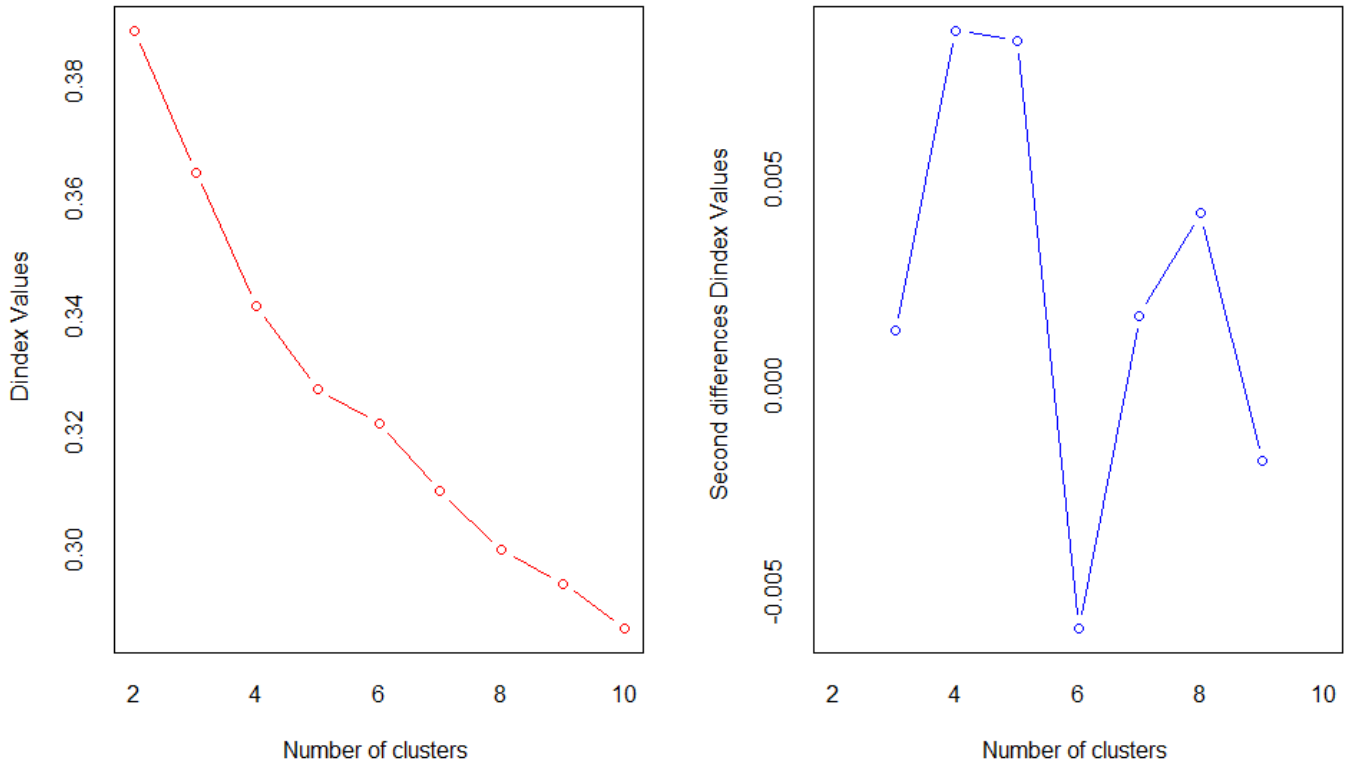


Figure 22. Choosing the number of clusters using Dindex method

9.3 Multiple criteria decision analysis for the prioritisation of STI response areas for APASTI by ASEAN member countries

Research aims and methods

The focus of this analysis is to assist in the development and prioritisation of strategic responses to the forces of change. These strategic responses will help form the basis of actions under APASTI 2026–2035 for the ten ASEAN member countries.

As part of the study, we will develop and apply a decision support tool based on Multiple Criteria Decision Analysis (MCDA). This tool assists in the assessment and evaluation of strategic responses to the forces of change. MCDA, also referred to as MCA (Multiple Criteria Analysis), is a family of decision support techniques that has been increasingly applied since the 1960s to support decisions across various industries and decision problems [47]. The last decade has seen an explosion of MCA applications across various sectors, particularly in the health sector, including the prioritisation of patients on health waiting lists, health technology assessment, and the ranking of health investment options [48, 49]. More recently a number of studies applied MCDA to COVID-related decision problems including prioritisation of patients for hospital admission [50]. National governments and international organisations published guidelines on the use of MCA in public sector applications and settings, underlining the effectiveness of the tool for decision support in health [54-56]. The research team recently applied MCDA for priority setting in international trade for Australia and Indonesia [57] and for prioritisation of investments in R&D [58]. The major steps of MCA application are demonstrated in Figure 23.

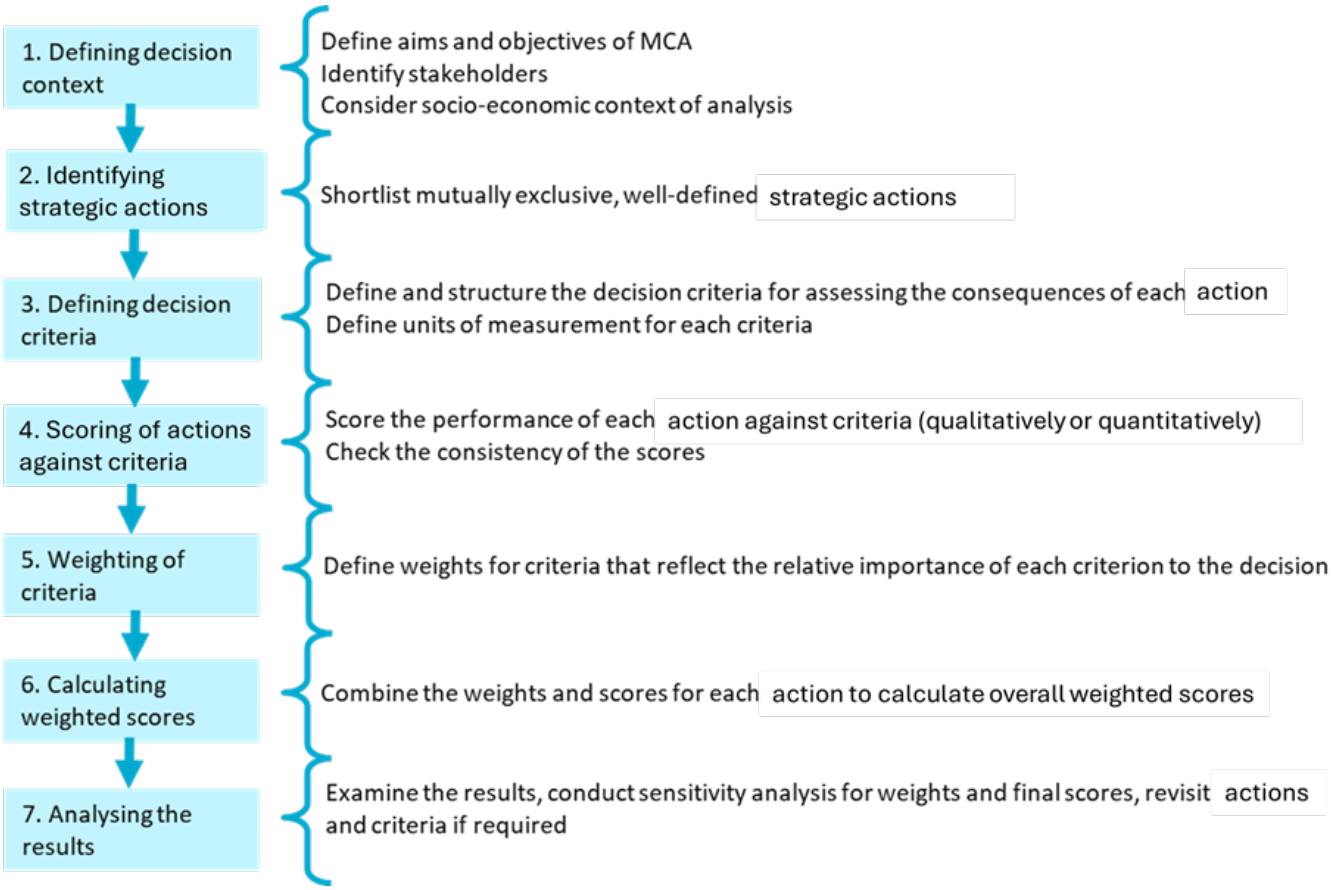


Figure 23. MCA approach – major steps with definitions

Source: Adopted from UK Department for Communities and Local Government (2009).

Priority areas for STI action in the ASEAN region

Identification of strategic responses and criteria

The objective of this MCDA application is to prioritise strategic responses to the forces of change in building and growing the Science and Innovation Ecosystem across ASEAN nations. The process is designed to consider the priorities and important criteria of both public and private stakeholders. Based on the forces of change (megatrends) study by AFA, complemented by data analysis and literature review, we will identify a list of criteria and strategic response options (priority areas) that will need to be refined through stakeholder engagement.

The first workshop will be designed to seek feedback on these lists of options and criteria, while the second workshop will be set up to prioritise them.

Prioritisation of strategic responses

		CRITERIA					
		1	2	3	4	5	6
Options (Priority areas)	1						
	2						
	3						
	4						
	5						

Once the responses and criteria are refined, we will be able to complete the performance matrix, and perform the MCDA to produce the final evaluation scores for each strategic response based on the selected criteria.

We will most likely use the simple additive model to obtain the final scores. To test for consistency and biases we will conduct a sensitivity analysis. A sensitivity analysis will include changing the weights and scores to ensure the analysis results are robust and consistent. As a result of the MCDA we will obtain a final score and a rank for every strategic response.

If the scope of work allows, we will consider setting separate performance metrics and evaluations for groups of three countries and prioritising in various timeframes in response to urgency/implementation (5, 10, 15, and 20-year time slots).

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