Engineering X

Global Engineering Capability Review

ROYAL ACADEMY OF ENGINEERING

Lloyd's Register Foundation

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Engineering skills where they are most needed

Engineering skills where they are most needed seeks to support the delivery of skills and education programmes that will lead to the development of much needed engineering skills capacity, enhanced safety standards, and infrastructure that remains safe and fit for purpose.

The programme is part of Engineering X, a new £15 million funding partnership and international collaboration founded by the Royal Academy of Engineering and Lloyd's Register Foundation that brings together some of the world's leading problem solvers to address the great challenges of our age.

Objectives of *Engineering skills where they are most needed*

- To deliver skills and education programmes that enhance engineering capacity, safety standards, and infrastructure that remains safe and fit for purpose
- To develop the existing engineering workforce skills capacity
- To bring the engineering community together in order to identify the most impactful and sustainable interventions

The Engineering X community will bring together partners from around the world, building on a network of global alliances to tackle the most pressing engineering, safety and sustainability problems, and developing practical, sustainable and accessible solutions for the engineering profession worldwide.

www.raeng.org.uk/engineering-x

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Foreword

By the Lloyd's Register Foundation

Every day around the world more than 1000 people die due to an accident at work. Moreover, the latest available data from the International Labour Organisation (ILO) shows that fatal occupational accidents are increasing in many developing economies. The relatively rapid construction of new critical infrastructure is thought to be a causal factor; low income and newly-industrialised countries are investing huge amounts in infrastructure upgrades and the adoption of (new) technologies to accommodate their increasing populations and to support their growing economies. For example, the Asian Development Bank forecasts Southeast Asia will need US$2.8 trillion in infrastructure investment between 2016 and 2030.

The full impact of these large-scale investments cannot be reached if countries do not also develop the capability and capacity to maintain and operate such infrastructure safely. Today, there is a severe lack of such engineering and technical capacity; a skills gap that is exacerbated by the introduction of new and emerging technologies, and by infrastructure developments that do not include and involve local workforces.

So, without intervention, the pattern of increasing occupational accidents and fatalities is likely to continue.

We need evidence and insight to better understand the areas where engineering capacity and capability to address safety challenges is most lacking, and to identify areas where we can make a real difference.

As a first step, this report provides a broad assessment of the extent to which nearly 100 countries are able to do safe and innovative engineering and offers additional insight to specific capability issues in six countries.

There is a clear need for a stronger evidence base and further insight. Nevertheless, it is hoped that this report will provide a starting point for education, policy and industry communities to convene around common challenges, and engage wider society in understanding the importance of engineering education to meet the demand for the skills to build, operate and maintain infrastructure safely.

Dr Tim Slingsby, Director Skills and Education Lloyd's Register Foundation

About Lloyd's Register Foundation

Our vision

Our vision is to be known worldwide as a leading supporter of engineering-related research, training and education, which makes a real difference in improving the safety of the critical infrastructure on which modern society relies. In support of this, we promote scientific excellence and act as a catalyst working with others to achieve maximum impact.

Lloyd's Register Foundation charitable mission

- To secure for the benefit of the community high technical standards of design, manufacture, construction, maintenance, operation and performance for the purpose of enhancing the safety of life and property at sea, on land and in the air.
- The advancement of public education including within the transportation industries and any other engineering and technological disciplines.

Foreword

By the Royal Academy of Engineering

This review of global engineering capability is the first formal output of Engineering X, a £15 million funding partnership and international collaboration between the Royal Academy of Engineering and Lloyd's Register Foundation. Engineering X aims to bring together some of the world's leading problem-solvers to address the great challenges of our age, to share best practice, explore new technologies, educate and train the next generation of engineers, build capacity, improve safety and deliver impact.

Engineers have always played a pivotal role in driving economic and social development and continue to do so by designing and delivering safe systems that facilitate education and healthcare, enhance quality of life and safeguard critical infrastructure.

One strand of the Engineering X programme focuses on ensuring that engineering skills are fostered and deployed appropriately where they are most needed. In order to do that effectively it is necessary to establish a baseline of current skills and capability, which this review sets out to assess.

By sharing how countries are faring in building the necessary technical capacity to tackle some of the evolving and complex challenges they face, our hope is that this review will contribute towards a better understanding of the world's current engineering capabilities, the likely future demands for engineering and the skills required by engineers to meet them safely.

In the course of compiling the review we discovered significant issues with the collection and reporting of accurate data in different countries. We invite our network of contacts around the world to join the Community of Practice being formed around this report to explore how we can build on this evidence to develop a fuller picture with more instructive, global examples of how engineering can further drive safer, more sustainable development.

We are grateful to the Economist Intelligence Unit for compiling the review. We also thank our partners at the Foundation for their continued support and guidance and look forward to working with them and other allies to address some of the most pressing safety and education challenges highlighted by the report.

Professor Peter Goodhew CBE FREng, Chair of the Engineering skills where they are most needed programme board

Acknowledgements

This report summarises the key findings of the Global Engineering Capability Review research programme, developed by The Economist Intelligence Unit (EIU) with support from the Royal Academy of Engineering and the Lloyd's Register Foundation.

The findings are based on an extensive literature review and a comprehensive interview programme conducted by The EIU between June and October 2019. In total, more than 30 representatives from engineering associations, non-governmental organisations (NGOs), the private sector and academia were interviewed.

The EIU bears sole responsibility for the content of this report. The findings and views expressed herein do not necessarily reflect the views of the partners and experts.

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Executive summary

- The field of engineering is broad, evolving and integral to the promotion of human development and economic growth. Engineers play a critical role in designing and developing infrastructure, systems and processes that make the world safer, and ultimately support the achievement of broader social milestones such as the United Nations' (UN) Sustainable Development Goals (SDGs). As we enter the fourth industrial revolution, engineering will also drive innovation and help grow the digital economy.

- However, policymakers, educators and business executives face two key challenges: first, understanding their country's relative engineering strength; and second, identifying and addressing engineering capability gaps.

- This report begins by providing a broad assessment of countries' engineering strength using the Engineering Index 2019. This framework measures the extent to which 99 countries are able to conduct engineering activities in a safe and innovative way. We highlight top performers for each category or indicator, helping to explain unexpected successes and transferable lessons.

- **Top performers per category or indicator**:

  – Knowledge – Malaysia

  – Labour force – Iran

  – Engineering industry – Rwanda

  – Infrastructure – Panama

  – Digital infrastructure – Estonia

  – Safety standards – Singapore

- Of course, each country will have to determine its own engineering priorities, based on its domestic circumstances. Engineering capability gaps will also differ depending on national goals, as well as a country's education system, income level and economic structure. Addressing these gaps *could* require more engineering graduates, but it will more likely require interventions in education programmes, graduate training and professional development. To bring this diversity of challenges and solutions to life, we have examined specific engineering capability issues in six different countries: India, China, Colombia, Ethiopia, Thailand and Jordan. In section 3, we discuss the context and drivers of engineering capability gaps in these countries, as well as potential thoughts on how to address them.

Findings from the country case studies

- There is a **lack of collaboration between industry and academia**, resulting in coursework or research that fails to address relevant industry challenges and few opportunities for students to gain hands-on work experience.

- Employers are **concerned about the quality of engineering education**, with recent graduates being seen as lacking the basic technical and soft skills needed to perform their jobs effectively.

- There is a **lack of both professional development opportunities and globally agreed upon standards for engineering qualifications**, further contributing to concerns about engineers' technical capabilities and long-term career prospects.

Recommendations

- **Strengthen the evidence base**. Countries struggle to collect and report accurate data on a variety of indicators related to engineering. Strengthening the evidence base will help policymakers, international funders and the global engineering community to design more effective and targeted interventions that support safe and innovative engineering activities. They can do this by:

  – Enhancing data collection and reporting accuracy using labour force surveys;

  – Addressing alignment issues on the definition and categorisation of the term 'engineer'.

- **Focus on quality not quantity**. Many countries have a sufficient number of engineers; the challenge is producing high-quality engineers who are able to conduct the work required of them. Policymakers, international funders and the global engineering community should develop initiatives that enhance engineering capabilities to support safe and innovative engineering practices both at school and the workplace. These include:

  – Providing opportunities for collaboration between academia and the private sector;

  – Developing a more hands-on and interdisciplinary engineering curriculum;

  – Enhancing on-the-job training opportunities for engineering graduates and experienced professionals;

  – Developing professional certifications and standards.

Introduction

The evolving nature of engineering

Perhaps you are reading these words on a screen. Or maybe you are holding a physical copy, looking at ink on paper. Either way, how did this report reach you? The immediate steps might seem simple: a link in an email or an envelope pushed through your letterbox. But these actions are only small parts of much longer chains, such as your thumb communicating with an email application in a digital operating system, powered by a lithium-ion battery charged via the plug in your kitchen; or a postwoman driving over paved roads, in a van running on petrol distilled from crude oil extracted from the North Sea. At work in all of these processes is engineering.

The field of engineering is broad and evolving. In a diversity of areas, engineers develop solutions that support human well-being, drive economic innovation and enhance safety. Yet many countries struggle to understand the factors that can contribute to engineering strength, and to develop a pipeline of engineering talent that can match growing and diverse needs.

Defining engineering: From skill sets to mindsets

The term 'engineering' captures a wide and growing set of activities. What remains constant is the core function of the discipline: the use of scientific principles to investigate a problem, and to then develop, implement and manage the solution.

Traditionally, an engineer is someone who has completed a professional engineering degree that is grounded in theory in order to understand and apply these principles. Further study and workplace experience hone the problem-solving skills necessary to handle complex challenges. These take place in seven main sub-disciplines of engineering: agricultural, mining, civil, chemical, electrical, mechanical and the newer field of digital or software engineering.[1]

As digital technologies develop, so too does our understanding of the modern engineer. The digital economy is increasingly woven into all aspects of business, requiring massive amounts of energy and new infrastructure. These technological advances have led to a rethink of the skills and abilities that engineers need. Engineers remain central to industrial sectors such as manufacturing and mining, but they are now active in other sectors too, including professional services, the media and medicine. This reflects the strength of engineers to "make 'things' that work or make 'things' work better".[2]

The evolving landscape of engineering presents a need for corresponding change in engineering capabilities. Engineering education and routes into the field can recognise this by focusing on the innate critical thinking and problem-solving skills all engineers share, regardless of identity or background. To support this, the Royal Academy of Engineering has identified six "engineering habits of mind" that all successful engineers should be able to demonstrate.

1 www.raeng.org.uk/publications/reports/thinking-like-an-engineer-implications-summary
2 www.raeng.org.uk/publications/reports/thinking-like-an-engineer-implications-summary

Six engineering habits of mind

1	2	3	4	5	6
Systems thinking: Seeing whole systems and parts (and how they connect), pattern sniffing, recognising interdependencies, synthesising	**Problem finding**: Clarifying needs, checking existing solutions, investigating contexts, verifying	**Visualising**: Moving from abstract to concrete, manipulating materials, mental rehearsal of physical space and of practical design solutions	**Improving**: Trying to make things better by experimenting, designing, sketching, guessing, conjecturing, thought experimenting, prototyping	**Creative problem-solving**: Applying techniques from different traditions, generating ideas and solutions with others, generous but rigorous critiquing, seeing engineering as a "team sport"	**Adapting**: Testing, analysing, reflecting, rethinking

Enhancing growth and development

Engineering activity boosts economic growth in diverse ways, from the archetypal provision of roads and bridges that allow supply chains to function, to biomedical advances that improve public health and productivity. Associated tasks range from product and factory design to the development of public transportation and waste management systems. All of these activities remain critically important for developed and developing countries alike. In the UK, for example, manufacturing enterprises accounted for 26% of the country's GDP and employed about 19% of the total workforce in 2015. In Ethiopia, manufacturing is the sector of choice for the country's planned industrialisation (see section 3).[3]

The scope of work and the number of fields in which engineers are required have vastly expanded. This is particularly apparent in the growth of the digital economy, where engineers are focused on developing new architectures for business, telecommunications and the public sector. This includes designing systems that automate previously manual tasks, constructing hardware for cellular networks and developing software to power commercial operations.[4]

Driving innovation

Engineers play a critical role in driving innovation. Findings from the UK Innovation Survey show that businesses that are determined to be highly innovative "have a significantly higher share of employment accounted for by science and engineering (STEM) graduates." This has also been shown to have a large, positive influence on various performance metrics.[5]

This ability to drive innovation makes engineers valuable in a growing digital economy. A combination of rigorous research and readily available skills can attract private-sector investment in pursuit of disruptive technologies, which can help to pioneer new methods for tackling some of the world's most pressing challenges. With the potential mass application of new technologies comes the responsibility to implement them ethically, particularly in unequal economic or social contexts. These new technologies include:

- **Renewable technology**: Engineers are helping to find new ways to make our energy systems more efficient and sustainable.
- **Robotics**: Engineers are designing and developing robots that will have a huge impact on how we live and work. Robots will improve the efficiency, safety and productivity of everything from agriculture to nuclear energy.
- **3D printing or additive manufacturing**: Engineers have supported developments in 3D printing technology. These innovations have already changed safety and efficiency in sectors such as medical care and manufacturing.
- **Fifth-generation wireless (5G) technology**: Engineers are developing the latest in mobile network technology. With speeds 10 times faster than 4G, 5G's capacity to transmit enormous amounts of data creates opportunities for governments, businesses and consumers alike. 5G holds great promise for data-heavy initiatives the internet of Things (IoT) and activities such as remote surgery.

Making the world safer

Engineers improve safety in a variety of ways, from the development of smart sensors in cars to the inspection and maintenance of industrial machinery. Engineering also plays a central role in the growth of circular economies, which move away from the industrial model of consuming finite resources and towards using and recycling natural materials instead.

In 2017, Lloyd's Register Foundation released a study identifying global safety challenges where engineers and engineering skills could have a significant impact. These challenges included electronic waste and safety at sea.[6,7]

3 www.engineeringuk.com/media/1576/7444_enguk18_synopsis_standalone_aw.pdf; www.engineeringuk.com/media/1355/enguk-report-2017.pdf
4 www.tomorrowsengineers.org.uk/media/75896/leaflet-from-idea-to-career.pdf
5 assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/289234/bis-14-643-uk-innovation-survey-highly-innovative-firms-and-growth.pdf
6 www.lrfoundation.org.uk/en/publications/insight-report-on-global-safety-challenges/
7 As a result of this study, two additional research programmes were developed: *Complex Systems* and *Safety at the End of Engineered Life*

- **Electronic waste**: Electronic waste (or e-waste) has become one of the fastest growing waste streams in the world. Developing countries receive the bulk of electronic waste, much of which is recycled and repurposed for local industry. However, when broken down, e-waste emits toxins that can be highly dangerous. Engineers can design technology that is less harmful when recycled and can help to design cost-effective solutions that reduce workers' exposure.
- **Safety at sea**: The shipping industry still faces major safety challenges, despite a long-term decline in fatalities. These include the safety of lifeboat-lowering mechanisms, enclosed spaces on ships and mooring systems. Engineers continue to design solutions that improve safety, from more durable ropes to better breathing apparatus.

Supporting the greater good

Engineering can be used to remedy broader natural and social issues that are not captured by economic metrics. For instance, engineers support human livelihood and dignity, the improvement of systems and the avoidance of harm. Our collective future also requires engineering interventions to facilitate more sustainable environmental practices, such as reducing air pollution in cities and expanding access to potable water.

Many of these issues are identified in the United Nations' (UN) Sustainable Development Goals (SDGs). The work of engineers is crucial to achieving these SDGs, which rely on the development of innovative technologies, tools and processes to improve the living conditions of people around the world.[8] Similarly, the growth of digital technologies requires engineering skills to integrate those without internet access into the digital world.

Although safety is not an explicit consideration in the SDGs, it is an important component of their successful achievement. Addressing these safety considerations now will help to manage need in the future. In 30 years an additional two billion people will need access to safe food, water, employment and sustainable infrastructure. Currently, two billion people around the world lack access to safe drinking water and experience reduced access to freshwater resources.[9] By 2050, one in four people will live in a country affected by shortages of freshwater.[10] In 2018, 21% of young people were not in employment or training.[11] Increasing levels of automation threaten low-skilled jobs all over the world, and by 2030 millions of new, safe jobs will be needed to meet demand, along with adequately trained workers to fill them. The share of renewable energy in final energy consumption increased by just 0.4% between 2012 and 2014.[12] To ensure access to affordable, clean energy, the world will need to triple annual investment in sustainable energy infrastructure from $500 billion to $1.25 trillion by 2030.[13] Engineering skills are required to ensure that the solutions to these problems embed safety considerations at each stage in the design and implementation process.

Finally, by developing circular economies or closed-loop systems, engineers can reduce the consumption of finite resources and ensure the long-term sustainability of natural ecosystems. A salient example is the creation of sustainable alternatives to the extraction of riverbed sand in the production of concrete, which we examine in greater detail in this report in the Thailand country profile. Engineers have long contributed to sustainable development and the public good and are instrumental to making further progress.

About this report

The role of engineers continues to evolve in the face of rapid technological, economic and social change. In order to adapt to these changes, policymakers, educators and business executives must address two key challenges:

1. Understanding their country's relative engineering strength, and
2. Identifying and addressing engineering capability gaps.

In the remaining sections of this report, we examine these challenges more closely. First, we discuss findings from the Engineering Index 2019, which outlines each country's relative engineering strength. We then explore specific engineering capability gaps for six countries around the world – Thailand, Ethiopia, Colombia, Jordan, India and China – brought to life through case studies. We conclude the report with general recommendations based on findings from the research programme.

8 The importance of engineering to the achievement of the SDGs is the subject of another RAE report, Engineering a Better World, www.raeng.org.uk/publications/other/engineering-a-better-world-brochure
9 www.un.org/sustainabledevelopment/water-and-sanitation/
10 www.un.org/sustainabledevelopment/water-and-sanitation/
11 www.un.org/development/desa/dpad/publication/world-economic-situation-and-prospects-april-2019-briefing-no-125/
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The Engineering Index 2019

Spotlight on top performers

The landscape of engineering is evolving and its benefits are more diverse than ever. Policymakers need to understand their current engineering strengths and draw on other countries' experiences to identify which elements of the vocation can contribute to the practice of safe and innovative engineering.

What is the Engineering Index 2019?[14]

The Engineering Index 2019 (hereafter referred to as the Index) measures the extent to which countries are able to conduct engineering activities in a safe and innovative way. The Index is a tool for understanding the factors that determine overall engineering capability across countries.

To provide this comparative measure, the Index assesses 99 countries in six categories. Across the six categories, the Index's 23 indicators are designed to capture metrics against which countries can measure their performance and paint a picture of their overall engineering capability.

1. **Knowledge**: A measure of contribution to and advancement of knowledge in engineering and technology

2. **Labour force**: The availability and diversity of engineers in the economy

3. **Engineering industry**: The strength and sophistication of the engineering industry

4. **Infrastructure**: The ability of infrastructure to support and demonstrate engineering activities

5. **Digital infrastructure**: The ability of digital infrastructure to support and demonstrate engineering activities

6. **Safety standards**: Safety in engineering-intensive sectors

14 Countries are the same as those measured in the previous Centre for Economics and Business Research (CEBR) report, *Engineering and Economic Growth: A Global View*, published in September 2016. Indicators were developed by The EIU in collaboration with the Royal Academy of Engineering and the Lloyd's Register Foundation. For more information, please refer to the methodology document.

Engineering Index 2019 Framework

1. Knowledge	2. Labour Force	3. Engineering Industry	4. Infrastructure	5. Digital Infrastructure	6. Safety Standards
A measure of contribution to and advancement of knowledge in engineering and technology	Availability and diversity of engineers in the economy	Strength and sophistication of the engineering industry	Ability of infrastructure to support and demonstrate engineering activities	Ability of digital infrastructure to support and demonstrate engineering activities	Safety in engineering intensive sectors
1.1 H index rankings (# of citations and # of papers in engineering)	2.1 Availability of scientists and engineers	3.1 Medium to large-sized companies in engineering fields, as a % of all medium to large-sized companies in the country	4.1 Quality of infrastructure	5.1 Number of servers per 1 million people	6.1 Number of injuries (fatal) per 100,000 in economic activities: mining and quarrying, manufacturing, electricity, water supply and construction
1.2 R&D spending (% GDP)	2.2 Graduates in engineering, manufacturing and construction programmes	3.2 Total value of engineering exports ($): Product: 84 Machinery, mechanical appliances, nuclear reactors, boilers; parts thereof. Product: 85 Electrical machinery and equipment and parts thereof; sound recorders and reproducers	4.2 Extent and quality of road network	5.2 Internet speed (average)	6.2 UL Safety Index – Safety Outcomes (a)
1.3 Number of universities in the top 500 for engineering	2.3 Female graduates in engineering, manufacturing and construction programmes	3.3 Medium and high-tech industry (including construction) (% manufacturing value added)	4.3 Extent and quality of rail network	5.3 Digital Adoption Index	
1.4 Resident patent applications	2.4 Mean performance in science among 15-year-olds	3.4 Economic Complexity Index	4.4 Quality of ports' infrastructure		
	2.5 Mean performance in math among 15-year-olds		4.5 Quality of air transport infrastructure		

(a) The UL Safety Index quantifies the relative state of safety for more than 180 nations
Source: The Economist Intelligence Unit

Results: **Spotlight on top performing countries**

The table in the Appendix summarises the results from the Index, across all countries and categories. Each country has a different history and context, so to offer useful insights we have identified one country per category or indicator that outperforms others and offers lessons for policymakers elsewhere.

Category 1

Knowledge

The knowledge category measures a country's contribution to and advancement of knowledge in engineering and technology using four indicators. These include research and development (R&D) spending as a percentage of GDP, and the number of universities in the top 500 for engineering.

Malaysia: State research entities and engineering advocacy

Malaysia ranks 23rd in the world for investment in R&D as a percentage of GDP (1.44%), and 24th in the world for patent applications, with 1,116 filed in 2018. It also punches above its weight (19th) for the number of universities ranked within the world's top 500 for engineering. This belies a global GDP ranking of 41[15] and reflects a strong emphasis on engineering in education.

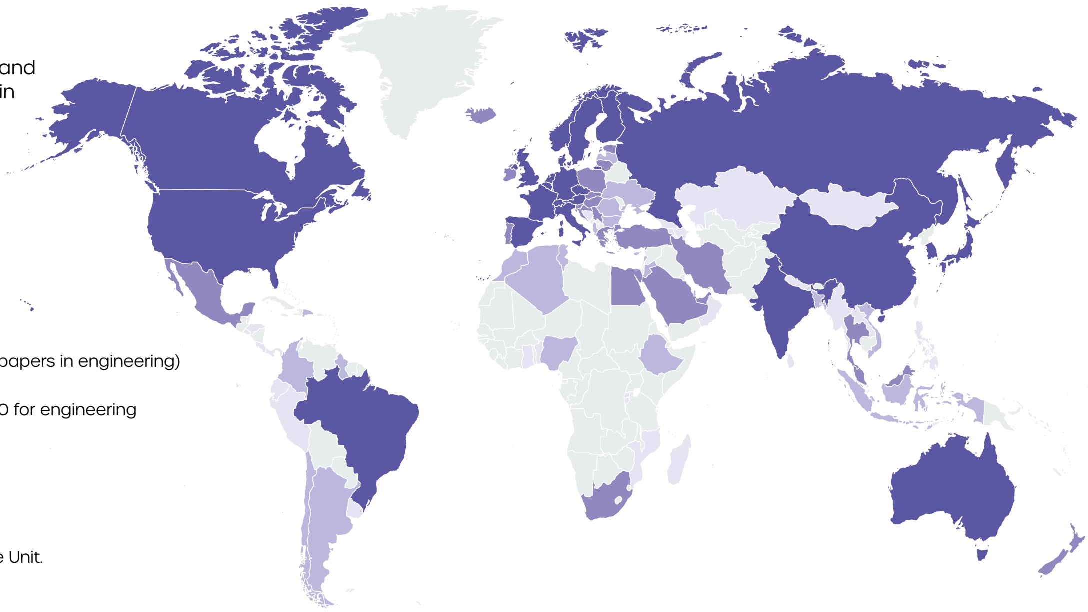
Malaysia's engineering education programmes mostly date from the 1980s and 1990s. The 1996 decision by the Ministry of Education to reduce the length of study in engineering in public universities from four years to three (in order to supply a growing labour market) has since been reversed, as part of a broader agenda to improve R&D.[16] In 2006-2007 the government also launched the Malaysian Research Universities (MRU) programme, designating five state universities as research entities, an initiative modelled on similar schemes in Singapore and South Korea. Under the programme, MRUs gain financial autonomy, allowing for funding for research activities and related needs, as well as independence regarding long-term research agendas. The state set out to provide 90% of required funding and to facilitate partnerships with various ministries. MRUs can use the funds for the development of facilities and infrastructure, the purchase of equipment, and payment for researchers and support staff. These universities then give priority to R&D, commercialisation and graduate studies. The programme has produced favourable results, boosting publication rates and Malaysia's reputation for engineering excellence.[17]

Malaysia also has a proactive independent body to advance engineering education, the Society of Engineering Education Malaysia.[18] The group organises conferences and seminars, and it co-hosted the 2017 World Engineering Education Forum and the 2017 Global Student Forum. This commitment to enhancing domestic engineering education is reflected in the country's strong ranking (18th) in the labour force category of the Index, as well as its success in the knowledge category.[19]

Knowledge
A measure of contribution to and advancement of knowledge in engineering and technology

Country ranking
- 1–25
- 26–48
- 49–71
- 72–99

Indicators
- H index (# of citations and # of papers in engineering)
- R&D spending (% GDP)
- Number of universities in top 500 for engineering
- Patent applications, residents



Source: The Economist Intelligence Unit.

15 www.datacatalog.worldbank.org/dataset/gdp-ranking
16 www.peer.asee.org/malaysian-engineering-education-model.pdf; www.thestar.com.my/opinion/online-exclusive/whats-your-status/2016/12/23/10-things-about-malaysias-research-development-landscape-you-need-to-know
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18 www.seem.my
19 www.nst.com.my/education/2019/06/497519/engineering-countrys-future

Category 2
Labour force

The labour force category measures the availability and diversity of engineers in an economy using five indicators, including mean mathematics and science scores among 15-year-olds, and the percentage of graduates who come from engineering disciplines.

Iran: Relative job security in the face of high unemployment

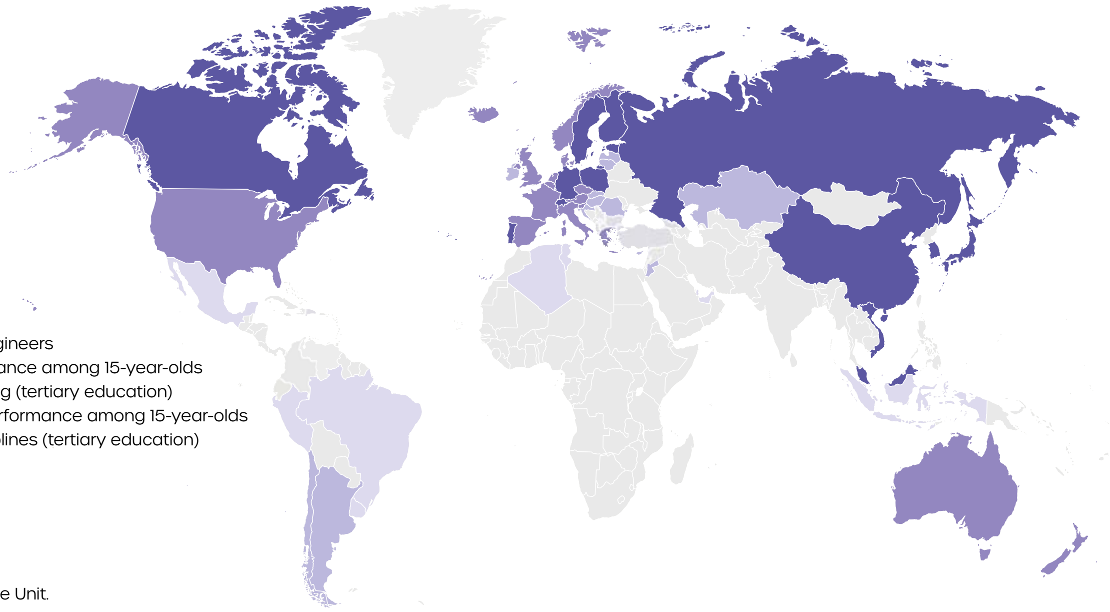
Iran tops the index for the highest percentage of graduates (of both sexes) from tertiary education in the fields of engineering, manufacturing and construction, at 30%. The field has long been highly regarded in the country, reflecting a rich history of contributions to mathematics and the sciences. Prior to the 1979 revolution, the state supported the training of engineers abroad. Following the revolution, the focus shifted to improving domestic engineering education; this produced strong results at the undergraduate level, but it had limited success at the research level because of funding constraints and the academic isolation caused by international sanctions.[20] However, many Iranians who received higher engineering degrees outside Iran before or at the beginning of the 1979 revolution ultimately returned to the country, ensuring strong faculties at the major technical universities.

The popularity of engineering as a subject reveals some hard truths about the Iranian economy, which is unable to absorb the number of students graduating from higher education, particularly in non-STEM fields.[21] Unemployment is a particular concern for female graduates, and this has led to greater interest in fields seen as more employable, such as engineering.[22] Experts have suggested that the education system needs to better prepare students to address the country's growing industrial development or technical needs, citing the dearth of environmental engineering courses relative to other countries as an example.[23]

Labour force
Availability and diversity of engineers in the economy

Country ranking
- 1–16
- 17–31
- 32–48
- 49–64

Indicators
- Availability of scientists and engineers
- Mean score in science performance among 15-year-olds
- Female graduates in engineering (tertiary education)
- Mean score in mathematics performance among 15-year-olds
- Graduates in engineering disciplines (tertiary education)



Source: The Economist Intelligence Unit.

20 www.newsweek.com/surprising-success-irans-universities-87853
21 blogs.worldbank.org/arabvoices/iran-education-crises
22 ijwr.ut.ac.ir/article_21840_865e26d79b40f5b0a574d39eeddb5712.pdf
23 www.sciencedirect.com/science/article/pii/S1877042813043127

Category 3

Engineering industry

This category measures the strength and sophistication of the engineering industry using four indicators, including the total US dollar value of engineering exports, and the percentage of manufacturing value added by medium and high-tech industries (a proxy for the sophistication of the local engineering sector).

Rwanda: Rebuilding after genocide

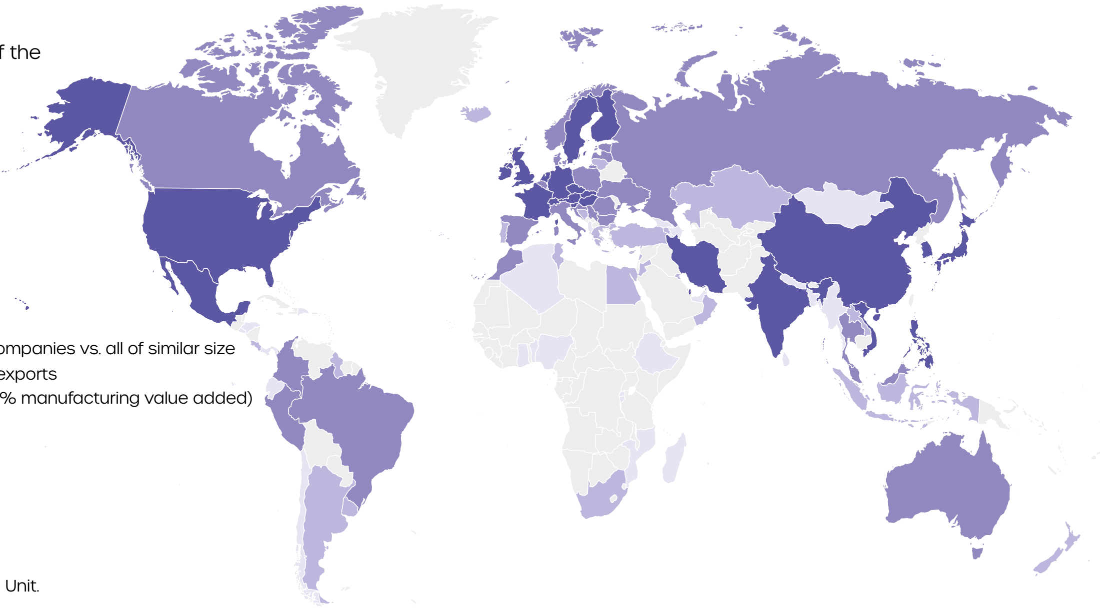
Despite ranking 81st overall in this category, Rwanda is ranked 12th for one indicator: the percentage of medium and large companies in engineering fields as a percentage of all medium and large companies in the country. This reflects concerted efforts to rebuild the country following the 1994 genocide. Rwanda has attracted much international aid, but the government has sought to convert this into investment, focusing on infrastructure projects and offering companies significant tax incentives for doing business in the country.[24]

Indeed, Rwanda ranks second highest in sub-Saharan Africa in terms of ease of doing business,[25] having implemented the largest number of related reforms in the region over the past 15 years. These have included measures to streamline the processes for starting a business, obtaining credit and registering property (in the latter two areas Rwanda ranks among the best in the world). The country has also actively encouraged information and communications technology (ICT) training, seeing this as a facilitator of further investment. There are concerns, however, that two major engineering and construction companies linked to the ruling party and the army have received a disproportionately large number of government contracts.

Engineering industry
Strength and sophistication of the engineering industry

Country ranking
- 1–25
- 26–48
- 49–74
- 75–99

Indicators
- Ratio of medium to large sized companies vs. all of similar size
- Total dollar value of engineering exports
- Medium and high-tech Industry (% manufacturing value added)
- Economic Complexity index



Source: The Economist Intelligence Unit.

24 qz.com/africa/827935/rwanda-is-a-landlocked-country-with-few-natural-resources-so-why-is-china-investing-so-heavily-in-it/
25 www.doingbusiness.org/content/dam/doingBusiness/media/Fact-Sheets/DB18/DB18-FactSheet-SSA.pdf; www.doingbusiness.org/content/dam/doingBusiness/country/r/rwanda/RWA.pdf

Category 4

Infrastructure

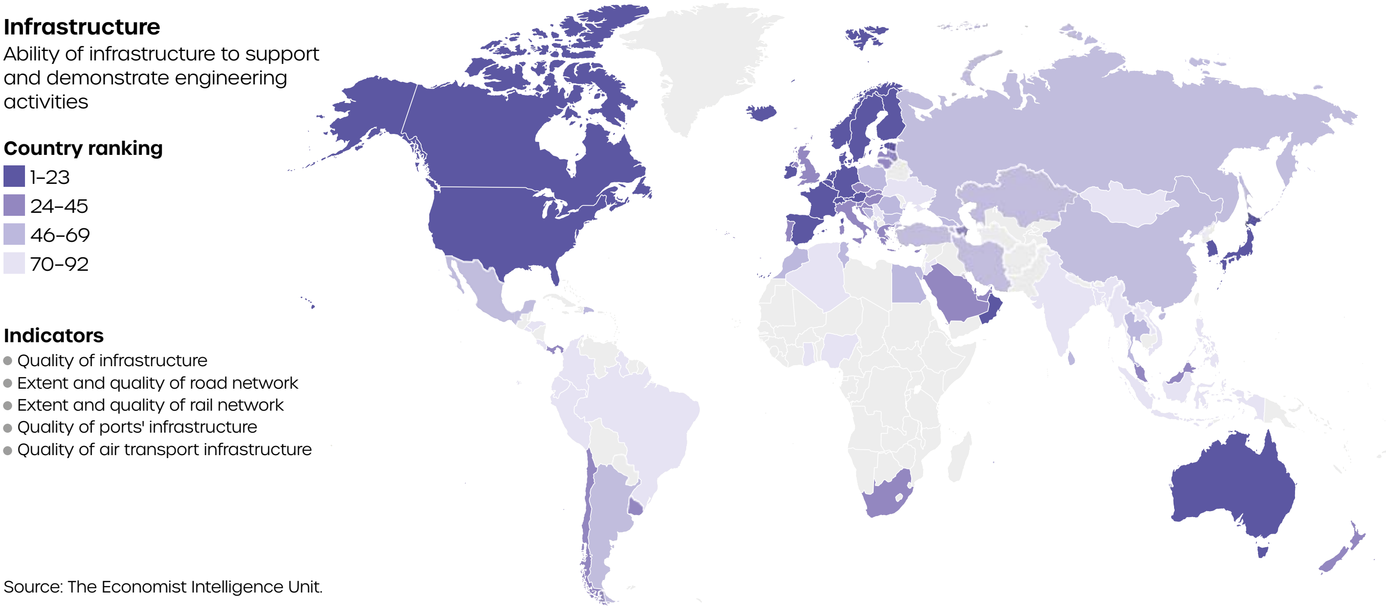
This category measures the ability of a country's infrastructure to support and demonstrate engineering activities using five indicators. These include the extent and quality of road and rail infrastructure, as well as the quality of ports.

Panama: Foreign investment versus domestic capability

Panama ranks 24th in this category but it received a higher ranking (joint 13th) for the quality of port infrastructure. The country's canal contributes to this result, as it enables cargo vessels to cross between the Atlantic and Pacific Oceans – a vital passage for global maritime trade. Given that it accounts for a major part of Panama's GDP, it is in the country's interests to maintain and develop the canal and its related infrastructure, as demonstrated by the recent Panama Canal expansion project. The expansion began in 2007 and was completed in 2016, overcoming budget overruns and labour disputes.[26] The job of digging a new access lane was completed by a European consortium rather than by a Panamanian firm, reflecting the enormity of the task.

Panama's significance for maritime trade has contributed to the enhancement of the country's broader logistics infrastructure, including container ports and the Colón Free Trade Zone.[27] These infrastructure development projects have functioned as catalysts for growth in an economy that has produced an average annual GDP growth rate of 5.6% over the past five years, although the large public debt incurred and the focus on trade leave the economy more exposed to global competition and fluctuations.[28]

The country's prime minister from 2014 to 2019, Juan Carlos Varela, made infrastructure development the keystone of his premiership. Although he inherited several projects, his administration also issued public works contracts worth US$16 billion, representing a major infrastructure push in comparison with the previous administration. Many of these contracts went to foreign companies, however, because the scale of projects was beyond domestic capability.[29] To bolster domestic capability, Panama's largest university added several engineering programmes in 2013, including civil, industrial and airport engineering; and in 2019 it introduced two new engineering courses related to water resources and renewable energy.[30]



Source: The Economist Intelligence Unit.

26 www.pri.org/stories/2014-01-10/after-six-years-and-billions-dollars-panama-canal-expansion-may-grind-halt
27 www.colonfreetradezone.com/freezone-colon.html
28 www.worldbank.org/en/country/panama/overview
29 www.bnamericas.com/en/features/the-infrastructure-legacy-of-panamas-varela-administration
30 www.panamaamerica.com.pa/sociedad/dos-nuevas-ingenierias-tendra-la-universidad-de-panama-1136031

Category 5
Digital infrastructure

This category measures the ability of a country's digital infrastructure to support and demonstrate engineering activities using three indicators, including the number of servers per one million people and local internet speed.

Estonia: Digital revolution

Despite ranking 37th for national internet speed, Estonia's ranking of 9th for both the number of servers and the Digital Adoption Index lift it to 12th place overall in the digital infrastructure category. An early adopter of digital technology, Estonia soon became one of the most internet-connected states in the world. Famously, the country's digital infrastructure was the subject of a Russian attack in 2007, which temporarily disabled its internet and banking systems. Estonia was thus a natural home for the development of the landmark Tallinn Manual between 2009 and 2012, a study on how international law applies to cyber conflicts and cybercrime. The country is still in the vanguard of digital integration, with banking, tax returns and other public services becoming fully digitised.

This focus on ICT development has contributed to Estonia's strong global ranking for ease of doing business.[31] Heavy early investment in digital infrastructure and related systems (including the introduction of digital identity cards in the early 2000s and the recent introduction of e-residency for remote entrepreneurs) showcases Estonia's commitment to developing a robust digital infrastructure and has enhanced the country's business landscape.

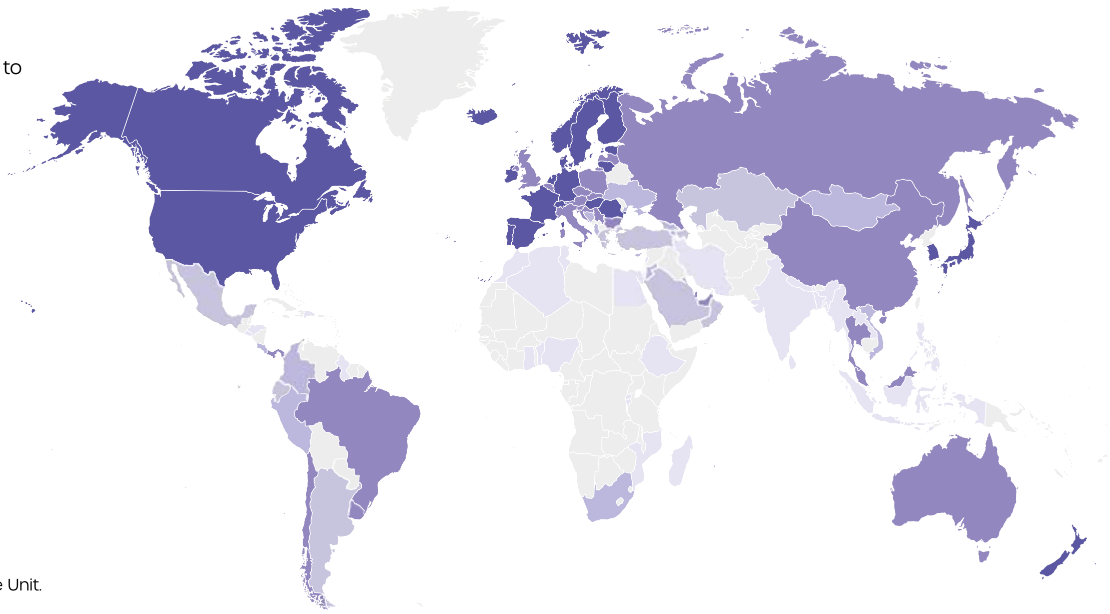
The country has also gone to considerable lengths to nurture engineering talent in computer science, including the decision in 2012 to teach all children how to code. Estonian engineers developed the code behind Skype and TransferWise, and their successes have allowed entrepreneurs to invest in other domestic ventures.[32] In recent years, the rate of growth in the country's information technology (IT) sector – and especially fintech – has increased dramatically (the sector's turnover is valued at €3.6 billion, and Estonia's population is just 1.3 million people), and the government's recruitment drive has been successful in attracting software engineers and data scientists, among others, to the small country.[33]

Digital infrastructure

Ability of digital infrastructure to support and demonstrate engineering activities

Country ranking
- 1–25
- 26–49
- 50–73
- 74–99

Indicators
- Digital adoption index
- Number of servers
- Internet speed



Source: The Economist Intelligence Unit.

31 www.doingbusiness.org/content/dam/doingBusiness/country/e/estonia/EST.pdf
32 www.economist.com/the-economist-explains/2013/07/30/how-did-estonia-become-a-leader-in-technology
33 www.newyorker.com/magazine/2017/12/18/estonia-the-digital-republic; www.computerweekly.com/news/252458004/Estonia-redoubles-efforts-to-attract-global-IT-talent; e-estonia.com/it-sector/

Category 6

Safety standards

This category measures safety in engineering-intensive sectors using two indicators: the number of fatal injuries per 100,000 workers in engineering intensive sectors, and the UL Safety Index.[34]

Singapore: Effective safety regulations, policies and oversight

Singapore boasts a highly impressive record in this category, leading the overall rankings and topping the safety outcomes indicator. A little over half a century since the island state separated from Malaysia and gained its independence, Singapore has undergone remarkable growth to become a leading technological and financial hub. Among the many changes the country has witnessed is the evolution of safety standards, largely the result of state policy.

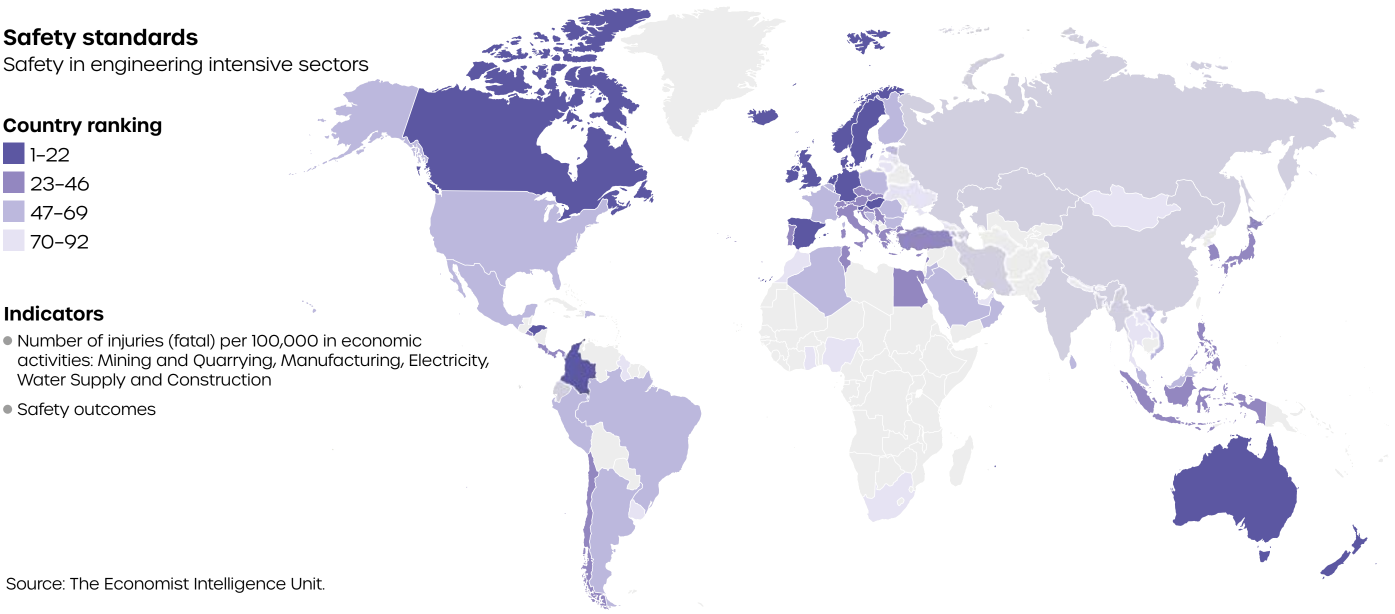
The country's stringent public health and safety standards make companies and individuals liable for safety outcomes through the use of penalties. Regular inspections and education form part of a national strategy that aims to lower workplace injuries and fatality rates to less than one death per 100,000 workers by 2028. (In 2018 the three-year average rate was 1.4 deaths per 100,000 workers.) The 'Vision Zero' movement,[35] launched in 2015 to prevent workplace injuries and fatalities, challenges companies' senior management to make commitments to this goal by providing support and engagement.

Singapore's safety success also reflects the collaboration of different stakeholders: the Ministry of Manpower works in tandem with employer and employee groups to improve these standards. Private companies have developed financial incentive schemes to encourage employees to report incidents and near misses and have introduced more safety checks and training.

Companies are being further incentivised to improve their safety records by a new government requirement to publish rates of workplace deaths and major injuries online. This is likely to influence the selection of contractors and their insurance rates, making company investment in improving safety an even greater priority. This idea was one of several proposed by a committee made up of government, employer and union representatives tasked with finding 10-year strategies for workplace safety and health practices.

Safety standards

Safety in engineering intensive sectors



Source: The Economist Intelligence Unit.

34 ulsafetyindex.org/
35 www.visionzero.global

Engineering capability challenges

Six country case studies

The Engineering Index 2019 provides a review of engineering strength and the extent to which countries can conduct engineering in a safe and innovative way. However, to develop local engineering capability and achieve local economic and social goals, countries also need to identify gaps in their engineering capability. The need for specific engineering capabilities will differ by country, depending on national goals, the quality of local education systems, income level, local environment and economic structure.

The EIU has assessed sectoral growth prospects across 20 countries (see Appendix 2).[36] Expected growth rates vary dramatically across countries and sectors. Supporting sectoral growth requires an analysis of the number of engineers needed by sector, as well as the specific engineering skills required across sectors to conduct engineering in a safe and innovative way. These sectoral growth forecasts can help policymakers identify potential areas to consider when designing policies that enhance domestic engineering capability.

Quantitative measures of engineering capability

Initial research for this report included a quantitative analysis of engineering capability for 20 countries. The purpose of this analysis was to estimate the total number of engineers that will be required in each country by 2023, based on sectoral GDP growth. Data challenges made it difficult to conduct a quantitative analysis of engineering capability. Details on these challenges are provided below.

Data gaps and reporting accuracy. The International Labor Organisation (ILO) is the best source for information on workers by occupation on a global basis. However, the ILO does not receive data on workers by occupation from every country. In the initial quantitative analysis, the ILO could provide data on 15 of 20 countries, requiring us to develop estimates for those countries for which it does not collate data. A lack of data represents a critical barrier to assessing the number of engineers active in today's workforce, as well as needs for the future.

Additionally, the ILO's headline indicators are dependent on national labour force surveys. The methodologies for these surveys may not be directly comparable, based on a number of factors including the country's economic resources. Furthermore, ILO data sometimes contradicts findings from other national sources.

Defining the term 'engineer'. There were challenges identifying a global dataset that defined and categorised workers as engineers. We were able to access data on workers by occupation at the most granular level available from the ILO: 'Science & Engineering Professionals'. However, engineers only make up a small portion of this group, which also includes occupations such as physical and earth science professionals, mathematicians, actuaries and statisticians. We were unable to split out 'engineering professionals' consistently across countries based on the publicly available data, which made assessing the true number of engineers in the current workforce challenging.

36 Countries and case studies were selected at the Royal Academy of Engineering's request, with EIU input.

While an understanding of sectoral growth trends is important, it is equally important to recognise that engineering capability needs are diverse, as are the types of responses required. In some instances, this could mean producing more engineers, but more often it will mean producing higher quality engineers through education, training and professional development. To shed light on these engineering capability challenges and potential responses, we have identified six engineering capability gaps around the world.

Universal challenges, diverse applications

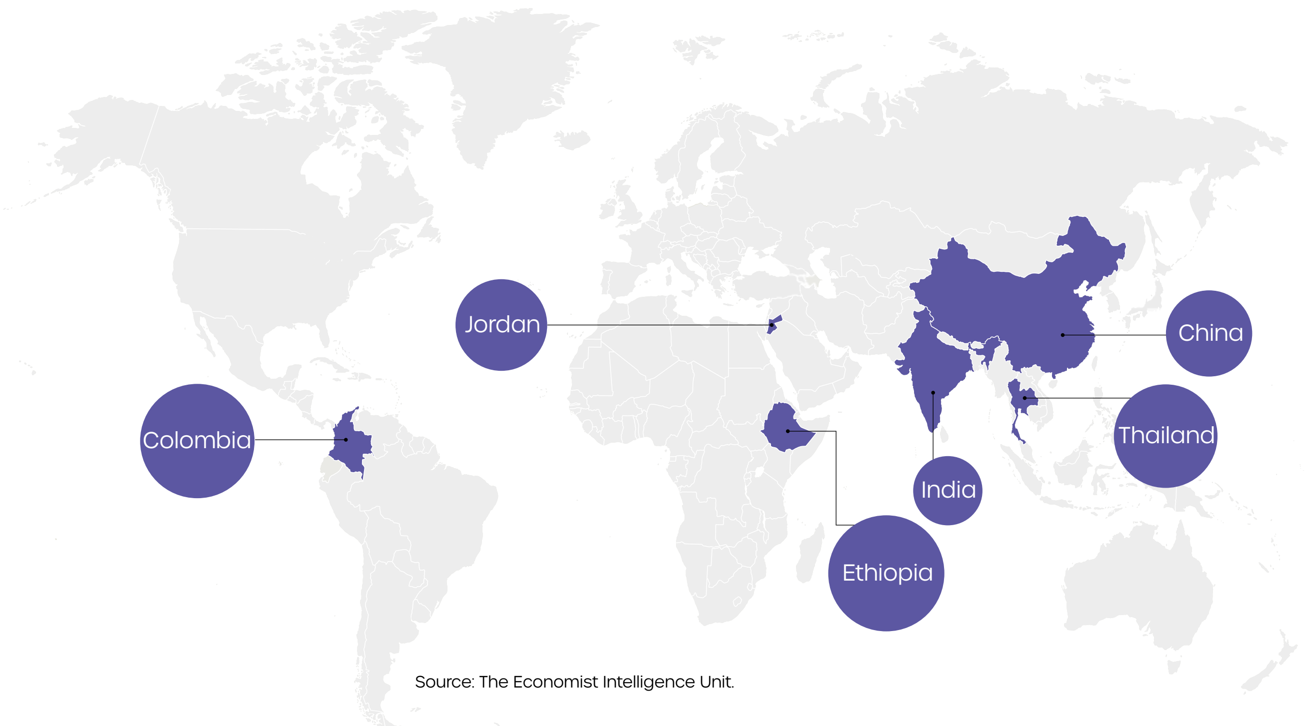
Each country highlighted here faces specific engineering capability challenges that are unique to their environments, education systems and economic structures. However, in the course of this research, we identified three cross-cutting challenges that affected each country, revealing some common barriers to developing engineering capability.

Lack of collaboration between industry and academia. According to experts, professors are out of touch with industry needs in some instances, resulting in coursework or research that does not address relevant challenges. In other instances, students have limited opportunities to gain hands-on work experience through internships that allow them to apply their engineering skills.

Concerns about the quality of engineering education. In some cases, graduates are seen as lacking the basic skills needed to perform the functions of an engineering job. In others, engineering pedagogy is deemed to be out of date, and coursework does not closely mirror the demands of the workplace. Experts also noted that engineering education needs to be more interdisciplinary, providing students with academic experiences in other disciplines (such as the arts, humanities and social sciences) as well as leadership, communication and collaboration skills.

Lack of professional development opportunities and globally recognised standards for engineers who are currently employed. In some instances, recent graduates have not received the required opportunities to learn by doing in their chosen discipline. In other cases, a lack of standards or accreditation means that employers question the quality and consistency of engineering skills, even among seasoned professionals. At the global level, engineers from countries that do not align their training curricula with global or regional standards, such as the Washington Accord,[37] experience limitations to mobility and opportunities.

Country case studies



Source: The Economist Intelligence Unit.

37 www.ieagreements.org/accords/washington/

India

Engineering capabilities to advance 5G

Knowledge = 20th
Labour force = n/a
Engineering industry = 23rd
Infrastructure = 89th
Digital infrastructure = 74th
Safety standards = 82nd

Following the liberalisation of its economy in 1991, India soon became a leading provider of IT services. The digital economy has since become increasingly valuable: a recent McKinsey survey of 600 firms revealed that core digital sectors already constitute a large portion of India's economy and could contribute as much as US$435 billion to the country's GDP by 2025.[38] A government report goes further, suggesting that by 2025 India's digital economy could be worth US$1 trillion, equivalent to 23% of nominal GDP.[39]

As part of its agenda to advance its digital economy, India is striving to become an early adopter of 5G services. 5G is the latest iteration of cellular technology, engineered to increase the speed and responsiveness of wireless networks. 5G will provide significant infrastructure for emerging technologies, such as artificial intelligence (AI) and the IoT, by enabling much larger and faster flows of data. Mobile technology has already emerged as a primary driver of economic growth, stimulating enormous private-sector spending in both R&D and infrastructure. The economic impact of the next wave of cellular technology will be vast.[40]

In 2017 the government hosted the High Level Forum for 5G India 2020 to develop a roadmap for 5G deployment by 2020.[41] The report highlighted three areas for focus:

1. Deployment – to roll out services early in order to maximise the value proposition of 5G
2. Technology – to build domestic industrial and R&D capacity, especially for design and intellectual property
3. Manufacturing – to expand the manufacturing base for 5G technology, including semiconductor fabrication and equipment assembly and testing.[42]

A long road ahead

Becoming an early adopter of 5G is likely to be difficult as India has a poor track record in rolling out new cellular technology. Second- and third-generation technologies were launched six to seven years after they were first available elsewhere, and 4G suffered a four-year delay relative to the first global users. At the end of 2016, 4G represented just 9% of total connections in India.[43]

India's history of sluggish adoption of telecommunications technology is rooted in low investment in infrastructure development, which has made upgrades and enhancements more costly and challenging. The government recently raised import duties on some categories of telecoms equipment by 10%, both in response to the country's current-account deficit and to encourage domestic manufacturing. However, this has added further expense to the procurement of network technology.[44] The country currently imports 90% of critical telecoms equipment, but the government is attempting to reduce this figure by tilting market conditions in favour of domestic manufacturers.[45]

As one expert noted, a large number of Indian engineers are also not equipped to work in the knowledge economy because of insufficient language, problem-solving and technical skills. Although big US technology companies tend to have a strong presence in India because of its reputation for strong (and cheap) engineering talent, there has been negligible change in the employability prospects of Indian engineering graduates in the past decade. Only a small percentage possess the skills required for working on next-generation technologies, with expert interviewees observing a particular shortage in coding.[46] Such skills are inherently multidisciplinary, requiring knowledge of computer science, mathematics, electronics and mechanical design. In order to successfully roll out 5G, India needs a greater depth of talent in two core areas: manufacturing andresearch and development.

Manufacturing: India wants to be able to manufacture semiconductors (a critical component in smartphones and communications technology), and to conduct the equipment assembly and testing necessary to implement 5G networks. There are also security advantages to manufacturing telecoms technology domestically. To do so requires semiconductors capable of sustaining efficient power amplification, as well as advances across hardware manufacturing. The workforce will need to be retrained to manage the various applications of 5G.[47]

Research and development: India also wants to build R&D capacity for 5G and its applications. Limited private-sector involvement and poor support for academic research, as well as a lack of engagement between these two realms, has limited industrial and R&D capacity.[48] Consequently, Indian engineers are not equipped with the right skills or resources to keep up with global competition.[49]

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38 economictimes.indiatimes.com/news/economy/indicators/digital-adoption-may-result-in-strong-economic-growth-in-india-mckinsey-report/articleshow/68600887.cms?from=mdr
39 www.thehindubusinessline.com/info-tech/digital-economy-a-1-trillion-opportunity-for-india/article26323150.ece
40 www.bcgperspectives.com/content/articles/telecommunications_technology_business_transformation_mobile_revolution/
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43 www.gsmaintelligence.com/research/?file=ff6b12ab0f6e04939ea041bf86d299ba&download
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46 aspiringminds.com/sites/default/files/National_Employbility_Report_Engineer_2019.pdf
47 telecom.economictimes.indiatimes.com/news/level-up-or-go-home-india-faces-a-skill-gap-challenge-for-5g-emerging-tech/69889319
48 idsa.in/issuebrief/india-tryst-with-5g-msharma-200319
49 www.businesstoday.in/current/corporate/indian-engineers-tech-jobs-survey-80-per-cent-of-indian-engineers-not-fit-for-jobs-says-survey/story/330869.html

Technical and soft skills will pave the way

To ensure the successful rollout of 5G, India needs to upskill the **current** and **future engineering workforce** in both broad methods and targeted skills in fields specific to 5G.

With regard to the **current workforce**, some firms have recognised the need to upskill and developed strategies to narrow the skills gap. Large telecoms operators, such as Bharti Airtel, are bringing in external consultants from more developed markets to run training programmes on how to deploy these technologies, and are seeking support from outside firms to source equipment and optimise hardware processes. While such practices reflect the fact that India is not a pioneer of 5G technology, they offer scope for improvement.

For the **future workforce**, engineering education needs to adapt. Experts bemoan the fact that present curricula are heavily theory-based, and that less than half of students perform internships in industry or undertake projects beyond their required coursework.[50] Instead, experts recommend that universities incorporate more practical applications and update coursework to emphasise creative thinking and problem-solving. Experts also cited a need for local engineers to develop technical skills in areas such as circuit design and coding.

There is also a need to build up knowledge in **spectrum management**.[51] This refers to the way in which the radio spectrum is deployed in order to minimise interference and ensure the most efficient and beneficial usage. Spectrum management consists of four main areas: planning, engineering, authorisation and monitoring.

The High Level Forum recommended the following measures to develop expertise in this area:

1. **Create spectrum-management skills development programmes**, targeting university faculty, engineering staff and administrators. The programmes should address the upskilling and reskilling of the workforce engaged in the development, manufacturing, deployment and maintenance of 5G technology.

2. **Make programmes geographically and linguistically diverse**. Skills development should address 5G applications, radio and network technologies, deployment and regulatory norms, and entrepreneurship.

3. **Develop learning material for dissemination beyond classroom settings** through hands-on lab projects, pilot and early-deployment field projects, virtual labs, and online tutorials and webinars.[52]

This scheme could also leverage existing government programmes such as the Global Initiative of Academic Networks (GIAN), as well as programmes available through the International Telecommunication Union (ITU) and the UN. A web portal that aggregates information and course material in an easily accessible format is essential to its success.

There is also space for research that identifies which programmes increase employability. Various initiatives could be tested, from massive open online courses and project-based learning to training faculties and internships.

Signs point in the right direction

India's goal of becoming an early adopter of 5G wireless technology could have major economic and social implications for the country. However, achieving this target will be complicated by the limited skills of the current workforce, weaknesses within the engineering education system, and a lack of opportunities for current students and professionals to develop spectrum-management skills. The following steps could be taken to help overcome these barriers: re- and upskilling the existing workforce; curricula reform, including project learning and industry exposure; and the introduction of specific spectrum-management skills development programmes.

50 www.aspiringminds.com/research-reports/national-employability-report-for-engineers-2019/#
51 telecom.economictimes.indiatimes.com/news/level-up-or-go-home-india-faces-a-skill-gap-challenge-for-5g-emerging-tech/69889319
52 dot.gov.in/sites/default/files/5G%20Steering%20Committee%20report%20v%2026.pdf

China

AI surges as production plays catch-up

Knowledge = 2nd
Labour force = 7th
Engineering industry = 4th
Infrastructure = 63rd
Digital infrastructure = 44th
Safety standards = 70th

China is aiming to become a global leader in artificial intelligence. AI is generally defined as "the ability of a machine to perform cognitive functions associated with human minds, such as perceiving, reasoning, and learning".[53] Many AI applications are already used widely, such as virtual assistants built into smartphones and home-management systems, and facial-recognition software used by law enforcement. AI applications vary considerably, but they share a dependence on hardware (notably semiconductors) that enables logic and memory functions.[54]

Although China is ahead of the pack in AI implementation and has invested widely in applications, it does not produce many of the core technologies that power AI, such as operating systems, chips and software. This can be explained by China's relatively late entry into the development of such technology, as a result of a long-standing focus on entry-level manufacturing. In recognition of the value of domestic production, the country is now shifting its attention to creating its own software.

AI: High on the menu

In mid-2017 the State Council (China's chief administrative authority) issued the New Generation Artificial Intelligence Development Plan (AIDP). This document, together with a 2015 plan entitled Made in China 2025, presented the country's AI agenda, making China one of the few countries to have released an AI strategy. The new plan frames AI as a focus of international competition and a strategic technology for future economic growth and national security. China's state and local governments have responded by committing huge sums to investment in AI development. (While the total commitment is not publicly disclosed, at least two regional governments have each committed to investing 100 billion yuan, approximately US$14.7 billion).[55]

In October 2018 China's president, Xi Jinping, held a Politburo study session on AI. Mr Xi's comments echoed the main conclusions of both the AIDP and Made in China 2025, namely that China should "achieve world-leading levels" in AI technology and reduce its vulnerable "external [foreign] dependence for key technologies and advanced equipment".[56] A Tsinghua University report published in 2018 found that "China has secured a leading position in the top echelon in both technology development and market applications and is in a race of 'two giants' with the US." It ranked China as the top producer of AI patents, the highest-placed country for AI venture-capital investment, and second for the number of AI companies and the size of its AI talent pool.[57]

China's latest action plan for implementing its strategy presents four major tasks for 2018-2020:

1. Identifying targets for the development of "smart products", such as networked vehicles, intelligent service robots and video image identification systems
2. Pursuing technological breakthroughs in "core foundations", such as neural-network chips
3. Nurturing the development of "intelligent manufacturing"
4. Building a public support system by accelerating the development of an "intelligent next-generation internet".[58]

Getting hungry: China's demand for semiconductor chips

Trade tensions between the US and China highlight the latter's institutional weakness in developing the core technologies and semiconductors that power AI. The experience of Chinese telecom giant ZTE is revealing. The company's business ground to a halt when the US government prevented it from buying American-made chips in early 2018. The US later offered a concession, but at no small cost to ZTE, which was compelled to restructure its management team and pay a US$1 billion fine. A computer scientist at Tsinghua University put ZTE's woes down to "inadequate 'core technology' and weak innovation".[59]

Chips are at the heart of this issue. China accounts for more than 50% of global demand for chips but produces only 8% of those that it uses, according to a Chinese newspaper, Yicai. In 2016 the country imported US$227 billion worth of semiconductors – almost double the amount spent on crude oil shipments.[60] China's weakness in developing chips stems primarily from its late start in semiconductor manufacturing. This is compounded by the low profit margins for chip businesses and the country's poor previous investment in R&D, especially compared with Japan and South Korea.

53 blog.worximity.com/en/industry-4_0/mckinsey-an-executives-guide-to-ai
54 www.mckinsey.com/industries/semiconductors/our-insights/artificial-intelligence-hardware-new-opportunities-for-semiconductor-companies
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58 futureoflife.org/ai-policy-china/?cn-reloaded=1&cn-reloaded=1
59 www.techinasia.com/zte-saga-illustrates-crisis-looming-chinas-semiconductor-industry
60 www.techinasia.com/zte-saga-illustrates-crisis-looming-chinas-semiconductor-industry

Crucially, the labour force is also lacking in terms of both skills and scale. In 2017 fewer than 300,000 people worked in the domestic chipmaking industry in China, and reaching the government's goal of increasing the industry's size fivefold by 2030 will require an estimated 400,000 additional employees. This gap is linked to limited educational resources and career prospects, as well as poor salaries.[61] Although Chinese engineers tend to be very well trained, developing the core technologies for AI requires a different set of industry skills and deep research knowledge. Additionally, many of China's engineers who are educated abroad tend to seek employment in the West, and large Chinese companies can lose their best talent to foreign competitors.

Finally, the emergence of several vast companies in China over the past decade, such as Huawei, Alibaba and Tencent, has signalled a change in the way in which industrial R&D is carried out. As an expert noted, companies would previously contract universities to develop new equipment. Today, universities are less well funded and big firms have the resources to do much of their own R&D, resulting in lower rates of collaboration between the two realms.

R&D: The secret sauce for China's semiconductor sector

China is seeking to reduce its dependence on semiconductor imports by strengthening its domestic semiconductor sector. The country has launched a fund focused on semiconductor development (the China National Integrated Circuit Industry Investment Fund), which in mid-2019 raised around US$29 billion in its second round of financing. The ongoing US-China trade war has certainly made greater self-reliance in this sector more of a priority.[62] Other measures to encourage domestic production include tax breaks for up to five years for local chipmakers.[63]

Investment in R&D will need to be coupled with the development of a talented labour force. Even if China invests substantially in its semiconductor sector, it will be forced to compete with established US giants such as Intel, which spends more than US$10 billion annually on R&D. For the investment to succeed, China will need to cultivate and retain a talent pool to lead innovations in AI. China can also strengthen career services for graduates, and improve benefits for engineers doing research in electronic engineering and computer science, in order to reduce the number of graduates leaving to work abroad.[64]

Letting the chips fall

China is implementing AI at a rapid pace but lacks the domestic capability to develop the core technologies it requires. This is a major concern for the country, especially in light of the trade war with the US, and its resolution could lead to various economic and security benefits. To try to wean industry off its reliance on imports, China has begun various investments and provided incentives to encourage domestic production. However, the success of this approach may be limited without the parallel adoption of a more interdisciplinary learning model (in place of the current insular approach). The sector would also benefit from more collaboration between universities and industry, improved funding for science professors, and measures to improve English language proficiency. Given that the payoff for R&D investment in AI can take time to materialise, this will be a long-term project.

61 www.chinadaily.com.cn/a/201805/09/WS5af23633a3105cdcf651cbf1.html
62 technode.com/2019/07/26/chinas-big-fund-raises-rmb-200-billion-to-fuel-chip-industry/
63 www.scmp.com/business/article/3011377/china-offers-five-year-tax-breaks-chip-makers-software-developers-bolster
64 www.chinadaily.com.cn/a/201805/09/WS5af23633a3105cdcf651cbf1.html; www.techrepublic.com/article/how-china-tried-and-failed-to-win-the-ai-race-the-inside-story/

Colombia

Transitioning to green energy

Knowledge = 62nd
Labour force = 54th
Engineering industry = 35th
Infrastructure = 70th
Digital infrastructure = 63rd
Safety standards = 19th

At first glance, Colombia appears to have little to worry about with regard to energy production: it exports about three times more than it consumes, and it is home to a rich array of natural and fossil-fuel resources. However, the country remains largely dependent on hydropower to produce electricity, domestic energy demand is growing quickly, and the country is very vulnerable to the effects of climate change. The use of non-conventional energy sources (NCES) is still very low, but solar, wind and biomass hold great potential. The use of NCES would alleviate Colombia's reliance on hydropower and its exposure to fluctuating prices for fossil fuels and their damaging environmental impact, improving the country's energy security and efficiency in the process.[65]

Colombia's energy sector has undergone various structural adjustments towards full liberalisation. Its privatisation in the 1990s saw the unbundling of electricity generation and infrastructure maintenance, marking a broader shift to stimulate competition between regional utilities and eliminate barriers to entry for private investors. Colombia was the first Latin American state to introduce a bidding system in its electricity market, and the increased competition in the sector has improved distribution efficiency and led to higher foreign investment. However, the network remains vulnerable: an increased threat of drought threatens its viability, and in the past few years oil infrastructure has been the target of guerrilla attacks. As a result, interest in alternative energy sources is growing. A regasification plant has already been developed on the north coast to facilitate imports of liquefied natural gas (LNG), and legislation has been passed to promote coal-based power production and bioenergy.[66]

Growing green

The imperative to achieve greater sustainability in energy production led to the launch of the Long-Term Green Growth Policy in 2018. This document contains sustainable development targets for 2030, including expanding the installed capacity of renewable energies to 15% of total energy production.[67] An earlier law (Law 1715), passed in 2014, set out to diversify the energy system by incentivising private capital investment in renewable energy integration. It provided fiscal incentives, a dedicated fund and the legal basis for the development of renewable energy initiatives, allowing further policy and regulatory action.[68]

With close to half of Colombia's land area and approximately 4% of its population not connected to the electricity grid, expanding access is another priority. The World Bank has deemed essential the development of non-conventional energies in remote areas to enable local communities to access basic services and development opportunities.[69] To this end, the government has created a National Rural Electrification Plan (Plan Nacional de Electrificación Rural, PNER), which "prioritises the use of non-conventional and preferably renewable energies for the promotion and use of appropriate technological solutions for power generation", in keeping with widespread support for a greener system.[70]

Making it easy: Incentivising investment in green energy

There are a number of barriers to Colombia's investment in NCES. Perhaps most importantly, the country has vast resources of unexploited fossil fuels, as well as existing infrastructure that supports their extraction and use. This is likely to put off investment in renewable energies, particularly as Colombia does not have a strong record of incentivising green energy investment through subsidies, grants or other means. Energy production has also seen a sixfold increase since the early 1980s, with most of this growth due to the expansion of coal mining activity and oil exploration and production.[71] In addition, there is insufficient infrastructure to supply renewables from the energy-rich north-east of the country to centres of demand.[72]

There is also a huge skills gap across Latin America, which makes it hard for countries like Colombia to adjust to new sources of growth after reaching middle-income status.[73] Broadly speaking, 50% of Colombian firms report difficulty finding workers with the right skills.[74] Data also shows that 40% of young Latin Americans are neither studying nor working, and that 55% of employees are working in the informal economy.[75] With the involvement of the Inter-American Development Bank and the World Bank, the Colombian government launched the Colombia Científica programme in 2016 to strengthen research and teaching in higher education. This has resulted in improvements to the provision of high-quality educational and vocational programming up to the tertiary level.[76]

65 www3.weforum.org/docs/WEF_Bridging_Skills_Innovation_Gaps_Latin_America; www.nortonrosefulbright.com/en/knowledge/publications/b09be352/renewable-energy-in-latin-america-colombia; www.geni.org/globalenergy/library/national_energy_grid/colombia/index.shtml
66 www.clingendael.org/sites/default/files/pdfs/Country_study_Colombia.pdf
67 gggi.org/colombia-presents-a-2030-green-growth-roadmap/
68 www.iea.org/policiesandmeasures/pams/colombia/name-161773-en.php
69 http://documents.worldbank.org/curated/en/165821513479626035/pdf/PD-Revised-11-20-2017-11202017.pdf
70 http://documents.worldbank.org/curated/en/165821513479626035/pdf/PD-Revised-11-20-2017-11202017.pdf
71 www.clingendael.org/sites/default/files/pdfs/Country_study_Colombia.pdf
72 www.edc.ca/en/blog/clean-energy-colombias-untapped-potential.html
73 www.oecd-ilibrary.org/development/no-sympathy-for-the-devil_26b78724-en
74 www.weforum.org/agenda/2018/03/latin-america-has-the-biggest-skills-gap-in-the-world-here-s-how-to-bridge-it/
75 www.weforum.org/agenda/2017/03/in-latin-america-companies-still-can-t-find-the-skilled-workers-they-need/
76 theglobalamericans.org/2017/04/skilled-workers-latin-america/

¡La Reforma! Education reform and upskilling

University engineering programmes in Colombia are generally well regarded. In recent years the curricula of engineering faculties have begun to incorporate sustainability, and this has proved popular with students. While comprehensive theory is taught in university programmes, several experts criticise the limited project work and industry exposure. Professors often have limited industry experience, and classroom lessons do not always translate well to real-world applications. The government could address this by pushing curriculum reform to create a more application-focused approach to engineering. Engineering education also remains out of reach for many because of its high cost, and more could be done to improve access. Finally, universities and industry could increase their collaboration. As one expert noted, universities could observe the way in which doctoral students in British universities gain experience working on industry projects.

Colombia has the natural resources to operate lucrative renewable energy projects, but the labour force needs the right mix of skills to support growth. Current expertise in NCES is largely limited to solar energy, rather than biomass or other forms of bio-energy. This situation could be improved through the transfer of knowledge from countries like the UK, facilitated by university partnerships, organisational programmes, exchanges and workshops. Colombia remains an emerging-market economy, and many companies do not have the resources to invest in the tools necessary for green development. The country also levies heavy taxes on imports of foreign equipment, which limits access. The industry should also seek community input – especially from indigenous populations – in developing renewable energy systems that align with local needs.

Practical remedies to boost renewable energy usage involve closing both the labour and technology gaps. To manufacture, install and maintain solar panels requires both training and electrical batteries. An expert notes that alkaline batteries are hugely important to manage the fluctuating electricity supply that emerging renewable methods will provide in the medium term, so addressing the skills gap in their manufacture would be of great use.

Down a renewable road

Colombia is reliant on hydropower and fossil fuels for its energy, and it is highly vulnerable to climate change and fluctuations in energy prices. The country has rich resources that would allow it to develop NCESs and diversify its power model, but the current market structure is tilted against this: existing infrastructure favours fossil fuels, heavy taxes on imports restrict access to the technology required, and current economic conditions discourage risk. In addition, a skills gap in the labour force constrains ambitions. Nonetheless, the government has made green growth a priority and has set out plans to make this a reality. The commercial and industrial sectors are increasingly aware of the benefits of installing solar panels on roofs, and residential interest is growing. There is also scope for large foreign companies to collaborate with smaller Colombian firms in developing renewable projects.

Ethiopia

An emerging manufacturing centre

Knowledge = 64th
Labour force = n/a
Engineering industry = 84th
Infrastructure = n/a
Digital infrastructure = 95th
Safety standards = n/a

Ethiopia's political and economic landscape is in the midst of a remarkable transformation. Since coming to power in early 2018, the prime minister, Abiy Ahmed, has overseen rapid political liberalisation, brokering peace with neighbouring Eritrea, liberating tens of thousands of prisoners (including all detained journalists) and filling half of his cabinet with women. He has pledged to hold free elections in 2020 and has appointed a prominent opposition activist to lead the electoral commission. The Norwegian Nobel Committee decided to honour him with the Nobel Peace Prize in December 2019. However, he has been censured for his silence following incidences of ethnic tension, and for shutting down internet access in times of public protest.[77]

In the past decade Ethiopia has generated the fastest GDP growth in Africa. Although this has brought greater levels of prosperity to the country, it may result in wider inequality. In seeking to maintain rapid growth, the government has begun to open up the economy to foreign investment, and to allow private-sector-led liberalisation, initially in manufacturing, telecoms and logistics. This programme is being conducted cautiously and in stages, beginning with regulatory reform and a larger role for business in job creation. Mr Abiy has also moved the country away from its state-led development model. Most notably, he has sought to combat the country's ongoing debt and currency weaknesses by renegotiating Chinese loans and has requested financial and technical support from the World Bank.[78]

Making the move

Ethiopia's growth model revolves around transitioning from an agrarian to a manufacturing economy. The government is investing over US$1 billion in 30 industrial parks by 2025 that it hopes will position it at the forefront of manufacturing in Africa.[79] Foreign direct investment has also been channelled to these parks, and various state-owned businesses have been sold to foreign investors, including Chinese firms. The country is further encouraging foreign investment in its manufacturing sector by offering lower labour costs than current manufacturing hubs such as India, Bangladesh and China. This has already borne fruit in garment manufacturing, with clothing companies including H&M, Guess and J Crew establishing manufacturing centres. The government also seeks to benefit from the technology transfer that foreign businesses bring to industrial parks and has introduced tax relief programmes to attract such investment to the country. In theory, this would help Ethiopian engineers to learn transferable skills, although many industries that process raw materials are largely automated.

Ethiopia has also improved its road and rail infrastructure to match the country's good flight connectivity, prompting a recent research paper to predict that Ethiopia could become the manufacturing hub of Africa.[80] Underpinning this effort is the administration's emphasis on manufacturing as a central part of its growth strategy. As a means of incentivising manufacturing and import substitution, attention has been particularly focused on producing the inputs required for industrial processes.

Local workers, foreign companies

Ethiopia's emergence as a manufacturing powerhouse requires advancements in R&D and industrial production. The recent boom has largely been led by foreign firms, and there is a particular need to develop local skills in industrial and chemical engineering. Quite apart from the value of Ethiopian projects to the national economy, foreign firms still need local skilled workers. However, skills develop in part from training on the job, and such considerations may need to be factored into the negotiation of contracts.

As the country's economy has grown, the chemicals industry has increased in importance as a supplier for other domestic industries such as textiles, leather, food and agriculture. Although Ethiopia has made progress in this area, the chemicals industry remains underdeveloped, constrained by a shortage of financial support and skilled labour, as well as by antiquated technology.[81] The manufacturing sector has a number of problems of its own, including power shortages, foreign-exchange constraints, irregular supply of domestic raw materials due to weak industrial links, poor internet services, and weak logistical support that leads to high transaction costs. Ethiopia needs to boost capability in industrial engineering to mitigate these issues.[82]

Some of our expert interviewees characterise the recent boom in manufacturing as rushed. Corners have been cut, and standards have not risen at the same pace as economic activity. The government has tried to create sectoral institutes with the aim of identifying and plugging skills gaps, but the education system tends to focus on quantity rather than quality. Our expert interviewees criticised the engineering curriculum, which does not provide opportunities for hands-on application of theoretical concepts or internship opportunities, suggesting that it fails to provide adequate work experience.

77 www.washingtonpost.com/world/africa/ethiopias-abiy-ahmed-wont-be-answering-any-questions-when-he-receives-his-nobel-prize/2019/12/09/5277fe12-1871-11ea-80d6-d0ca7007273f_story.html
78 www.chathamhouse.org/expert/comment/can-abiy-ahmed-continue-remodel-ethiopia; www.ft.com/content/abe678b6-346f-11e9-bb0c-42459962a812
79 www.xinhuanet.com/english/2019-01/03/c_137717546.htm
80 www.weforum.org/agenda/2018/05/ethiopia-africa-fastest-growing-economy/
81 open.unido.org/api/documents/14100685/download/UNIDO-Publication-2019-14100685
82 www.et.undp.org/content/dam/ethiopia/docs/Understanding%20African%20experiences%20in%20formulating%20and%20implementing%20plans%20for%20emergence%20Growing%20Manufacturing%20Industry.pdf

Cut from the finest cloth

Developing a skilled labour force is critical to strengthening the country's engineering and fabrication capability, productivity and quality. Progress, along with a better investment climate, will facilitate stronger competitiveness and structural transformation. The skills gap may be narrowed by developing and implementing more effective training programmes. The manufacturing sector's success will depend on such changes, along with improved access to finance, land, and infrastructure for firms.[83]

Ethiopia's Federal Technical and Vocational Education and Training (TVET) Agency is tasked with strengthening the labour force. Its overall objective is "to create a competent, motivated, adaptable and innovative workforce", along with technology accumulation and transfer in order to promote economic growth.[84] Its challenge is to meet labour market demand for skilled workers, which requires overcoming a record of poor-quality training. A current project seeks to develop the skills needed to strengthen international trade, and to improve the quality of and promote inclusion in the education system.[85] However, there are challenges to delivering a quality education both at the technical level (which TVET supports) and at the university level, where engineering graduate quality is often called into question by employers. As an expert noted, university graduates often compete with technical graduates for jobs in Ethiopia's manufacturing centres, raising questions about workplace preparedness.

Times are changing

Ethiopia is undergoing dramatic political and economic change. Alongside a programme of political liberalisation, the government is advancing the transition from an agrarian to a manufacturing economy. The light manufacturing industry is surging, in part thanks to the development of numerous industrial parks around the country, where industries such as textiles, leather processing and cosmetics are clustered based on the availability of natural resources. Foreign investment has held up well in the face of political uncertainty, taking advantage of Ethiopia's supply of cheap labour and good transport links. However, some areas of infrastructure, such as electricity and internet supply, remain poor. A domestic skills gap also hampers local projects and engineering employment. Ethiopia's engineering training needs to do more to give graduates practical expertise.

83 www.worldbank.org/en/news/press-release/2015/07/08/transforming-ethiopia-into-a-manufacturing-powerhouse-requires-skills-development-and-improved-investment-climate
84 www.unesco.org/education/edurights/media/docs/c93aa57e340844f8e8e4c3868c68fb3b8054ac61.pdf
85 www.ilo.org/africa/countries-covered/ethiopia/WCMS_702158/lang--en/index.htm

Thailand

Sustainable concrete in a construction quagmire

Knowledge = 37th
Labour force = 55th
Engineering industry = 34th
Infrastructure = 65th
Digital infrastructure = 45th
Safety standards = 92nd

As building activity remains buoyant worldwide, Thailand has become a key producer of concrete and one of its core components, sand. Manufacturing concrete requires large quantities of coarse and fine aggregate made up of stone and sand, which is mined from lakes, rivers and the ocean floor. International demand for sand is rising, particularly in emerging economies that are in the midst of major construction and infrastructure development. (Sand is also widely used in the manufacturing of asphalt and glass, and in land reclamation and fracking.)[86] The Organisation for Economic Co-operation and Development estimates that 27 billion tonnes of sand and stone are used in construction every year, and that this will double by 2060.[87]

However, unchecked sand extraction destroys the habitats of river and marine life, weakens the barriers and reefs that protect coastal communities, lowers the water table and pollutes drinking water.[88] Furthermore, while sand might appear to be an abundant resource, desert sand is mostly unusable in concrete because its grains are too rounded to bind well. Certain types of sand are particularly sought after, such as riverbed sand (targeted for its angular shape and gritty texture) and desalinated sand from the seabed. Thailand also has a sizable cement manufacturing sector that is both energy and carbon intensive. Developing sustainable solutions is necessary to balance economic and environmental needs.

Finding an alternative solution

To successfully manage the growing demand for concrete, Thailand will need to address the effects of producing this material in the conventional manner. The current process has significant impacts on the environment (through the destruction of river habitats and ecosystems, the pollution of potable drinking water, high energy consumption and CO_2 emissions), on health (through the increased risk of water-borne diseases) and on society (through illegal extraction by criminal enterprises). The government will need to consider ways to curb the environmental effects, and to train future generations of engineers and labourers in more sustainable production methods.

Various alternatives to riverbed sand are being tested but are currently more expensive and less accessible to businesses. Waste or recycled materials can be substituted to reduce the use of sand and other materials, but this may carry additional transportation costs.[89] The introduction of alternative materials also requires making investments against a well-established product and will likely require changes to the existing supply chain.[90] Nonetheless, recent research may provide breakthroughs in the long term. Studies have found that up to 10% of sand in concrete can be replaced by recycled plastic without significantly affecting the structural integrity of the concrete, and researchers at the University of Exeter are using nano-engineering technology to develop new types of concrete that cut the use of raw materials by 50%.[91]

Thailand also needs to address the lack of English proficiency within the labour force, which can prevent professional advancement and employment. An inability to communicate in English makes it difficult to collaborate and to compete for research grants or jobs with international employers.

Going green

Growing environmental awareness is helping to foster the use of more environmentally friendly materials and production processes. This trend is also being driven by tighter environmental legislation. The construction materials sector is particularly resource intensive, with cement production alone accounting for around one-third of the country's energy consumption. Recognising the drain on national resources that this represents, the government adopted the Energy Conservation Plan in 2015, with the aim of reducing energy consumption by 37% by 2036 (against a 2010 baseline).[92] For the cement industry, practical methods to achieve this could include changing the ratio of sand in concrete production and employing recycled materials.

Identifying the skills gaps in developing alternative forms of concrete, sand and cement (or ways of using them more efficiently) is vital to solving the construction materials conundrum. The government's Thailand 4.0 initiative aims to enhance infrastructure development and the national skills base, particularly through technological development. It has a lot of ground to cover as Thailand faces a shortage of skilled, young labour, in part because of its ageing population and low birth rate. Thai students also tend to underperform compared with their regional peers in STEM subjects in secondary school, and a recent study of engineers working in Thai companies found that less than 1% of those surveyed were certified to work as an engineer in other Association of Southeast Asian Nations (ASEAN) countries.[93] There is a consensus that Thailand needs to invest in training, with as many as 90% of the firms surveyed reporting that training is important to them in addressing performance gaps and improving productivity.[94]

86 e360.yale.edu/features/the-hidden-environmental-toll-of-mining-the-worlds-sand
87 www.oecd.org/environment/raw-materials-use-to-double-by-2060-with-severe-environmental-consequences.htm
88 www.theguardian.com/global/2018/jul/01/riddle-of-the-sands-the-truth-behind-stolen-beaches-and-dredged-islands
89 www.bbc.co.uk/news/business-45893549
90 lib.dr.iastate.edu/cgi/viewcontent.cgi?article=15529&context=rtd; www.theguardian.com/global/2018/jul/01/riddle-of-the-sands-the-truth-behind-stolen-beaches-and-dredged-islands
91 www.bbc.co.uk/news/business-45893549; www.newscientist.com/article/2230263-living-concrete-made-from-bacteria-used-to-create-replicating-bricks/
92 www.sciencedirect.com/science/article/pii/S1876610218310907
93 www.doingbusiness.org/content/dam/doingBusiness/country/t/thailand/THA.pdf; journals.sagepub.com/doi/pdf/10.1177/2158244017745346; http://acpecc.net/v2/index.php
94 journals.sagepub.com/doi/pdf/10.1177/2158244017745346

Universities and industry can also help to close the skills gap. Research efforts are currently concentrated in a small number of universities and should be promoted across other institutions. Producing concrete's constituent parts is a capital-heavy endeavour, and improved research and development capacity is necessary to create solutions. These must then be covered by concrete and cement technology courses so that future generations are trained in more sustainable processes. Although universities have made progress in the last 10 years in co-operative learning and industry placements, the number of graduates who are able to take up skilled, STEM-related roles falls short of industry needs.[95] Increased government investment in STEM courses, including engineering, can help to remedy the shortage. Curricula should integrate a sustainability-specific component, building on initiatives such as the Master's degree programme in Industrial Engineering for Thailand Sustainable Smart Industry (MSIE4), which seeks to implement technology and university partnerships for a sustainable engineering industry.[96]

The adoption of sustainable materials also depends on consumer behaviour, given that current building decisions are based largely on price. As capital outlay tends to be low and costs remain a concern, it is important to educate consumers about the value of sustainable processes. Government policy can encourage developers and consumers to use innovative materials by providing incentives such as tax breaks, and the state can pave the way to best practice by using more sustainable materials in its own infrastructure projects.

International collaboration is an additional avenue for advancing a green agenda. Two agreements in particular help to enable closer work within ASEAN: the Mutual Recognition Arrangement on Engineering Services (MRA), and the free flow of skilled labour agreement under ASEAN Economic Community rules. Engineering trade exhibitions, such as the Manufacturing Expo 2018, also provide opportunities for collaboration, particularly in new and more sustainable technology and production processes. International certifications and private-sector engagement can facilitate rising standards. The Concrete Sustainability Council Certification, for example, originated as a joint international initiative between industry associations.[97]

Change on the horizon

Thailand has a thriving construction materials industry for international and domestic markets, but the associated extraction of sand and conventional production processes have significant environmental ramifications. Alternative materials and methods are required, but innovation in the sector is hampered by poor secondary-level education in STEM subjects and an engineering curriculum at the university level that provides limited opportunities for practical training. Although current students have more options for industry exposure than their predecessors, they would benefit from forward-thinking courses that address practical skills and capabilities. The labour force lacks the accreditation and English language proficiency that would allow it to compete for global contracts and research awards, and it requires investment in training. Increased research capacity will in turn lead to greater commercialisation and can be achieved through seed funding and international collaboration.

95 www.peoplemattersglobal.com/news/global-perspective/thailand-faces-shortage-of-skills-and-young-workers-20757
96 msie4.ait.ac.th/
97 www.eepcindia.org/download/DoingBusinessinThailand2018-171212123109.pdf; www.heidelbergcement.com/en/cement-sustainability-initiative

Jordan

Water provision for one of the world's driest countries

Knowledge = 51st
Labour force = 47th
Engineering industry = 71st
Infrastructure = 74th
Digital infrastructure = 68th
Safety standards = 61st

With one of the world's lowest levels of water availability per head, Jordan is verging on a water crisis. In 2015, 94% of the population had access to safely managed water and 80% of the population had access to safely managed sanitation. However, multiple factors threaten the future water supply.[98] The climate is naturally arid, receiving less than 200 millimetres of rainfall each year (and even less in its desert areas), compared to 818 millimetres in the United States.[99] The country is also particularly vulnerable to the effects of climate change, with summer temperatures predicted to rise by 2.5 °C to 3.7 °C over the next 50 to 70 years.[100]

Against this backdrop, the country's existing water, sanitation and hygiene system has a long way to go to ensure access to sustainably managed water and sanitation resources for all. Only one-third of schools have basic sanitation services, and the country's waste-management practices are poor.[101] The sewage system connects only 58% of households, and just 6% of households in rural areas.[102] Jordan draws almost two-thirds of its water supply from aquifers (bodies of rock containing groundwater), which are dependent on reserves of underground water being replenished by rain. The rate of extraction already exceeds the speed at which these aquifers are refilled, and lower rainfall in the future will only exacerbate this disparity. Existing water constraints mean that Jordan is able to provide only 150 cubic metres of water per person annually, well below the 500 cubic metres that the UN uses to indicate water scarcity.[103] It is clear that Jordan faces substantial challenges in water provision, sanitation and wastewater management.

Expanding the water network

In 2016 the Ministry of Water and Irrigation announced a new national strategy covering the next decade. It targets five areas for improvement:

1. Integrated water resources management
2. Water, sewage and sanitation services
3. Water for irrigation, energy and other uses
4. Institutional reform
5. Sector information management and monitoring.

The strategy seeks to revise existing frameworks, streamline management and administration, and introduce new procedures to measure the sector's performance.

More specifically, the strategy aims to expand wastewater service coverage to 80% of the country by 2025, up from 63% in 2014; improve hygiene and hygiene awareness in all schools; and increase access to available water resources from 832 cubic meters in 2014 to 1,341 in 2025. It acknowledges that these targets present an urgent need for technical expertise in sector management, including developing engineering capability. However, the strategy does not identify specific measures to help meet this need.[104]

Under stress

Jordan's water challenge is compounded by the global refugee crisis. In 2019 the number of refugees hosted by Jordan reached 2.9 million, making it the 10th-largest refugee-hosting country in the world and the second largest relative to national population, with 72 refugees per 1,000 residents. Although the majority of these refugees (2.2 million) originated from Palestine and have lived in Jordan for several decades, displacement triggered by the civil war in Syria has led to the arrival of 676,000 Syrians in the past few years. Most Syrian refugees in Jordan live in urban areas, and over 80% live below the poverty line.[105]

This influx of refugees, coupled with overall population growth, has placed additional stress on Jordan's water infrastructure, particularly in the northern governorates.[106] The water and sanitation conditions in refugee camps are dire; at the largest camp in the region, Za'atari, water is so scarce that each person is allotted only 30 litres per day.[107] This water scarcity results in deteriorating sanitation, with multiple families forced to share bathwater and avoid washing clothes. The water management in Za'atari and other camps is largely coordinated by UNICEF and most of the sanitation infrastructure is communal, which can cause issues for camp residents with cultural preferences for household-level sanitation over communal facilities. This tension has been exacerbated by concerns about the safety and privacy of the communal facilities. Some households have built their own makeshift private bathrooms, leading to uncontrolled and unhygienic wastewater management. Although the Za'atari camp has yet to face a major disease outbreak, waterborne diseases remain a critical risk in refugee camps due to poor sanitation.[108]

98 washdata.org/data/household#!/jor
99 www.ncdc.noaa.gov/sotc/national/201713
100 harvardpolitics.com/world/no-shortage-of-challenges-jordans-water-crisis/; http://www.jordantimes.com/news/local/us-water-strategy-aims-aid-jordan-stopping-desertification
101 www.unicef.org/jordan/water-sanitation-and-hygiene
102 www.unicef.org/jordan/water-sanitation-and-hygiene
103 www.oxfam.ca/blog/syrian-refugee-influx-adding-to-jordans-water-worries/
104 www.mwi.gov.jo/sites/en-us/Hot%20Issues/Strategic%20Documents%20of%20%20The%20Water%20Sector/National%20Water%20Strategy(%202016-2025)-25.2.2016.pdf
105 www.amnesty.org/en/what-we-do/refugees-asylum-seekers-and-migrants/global-refugee-crisis-statistics-and-facts/; www.unhcr.org/uk/statistics/unhcrstats/5d08d7ee7/unhcr-global-trends-2018.html; reliefweb.int/sites/reliefweb.int/files/resources/FactSheetJordanFebruary2018-FINAL_0.pdf
106 www.globalwaters.org/WhereWeWork/MiddleEast/Jordan
107 harvardpolitics.com/world/no-shortage-of-challenges-jordans-water-crisis/
108 www.unhcr.org/7steps/en-uk/water/

Addressing the water problem

Jordan's water and sanitation challenges are manifold, but robust engineering responses can help. To support these responses, engineering education must better prepare graduates to meet the country's needs. This starts with developing multidisciplinary skills instead of focusing on technical skills. Experts critique the education system at both the school and university level for its focus on memorisation and conventional scenarios, and for its failure to give sufficient attention to critical thinking.

Improving the national water and sanitation infrastructure requires an understanding of the link between design and operation. The first stage of a project tends to involve an engineering team modelling and constructing a system in accordance with best practices and standards. In the operation stage the same standards may not be implemented, however, due to ad hoc management styles or a misunderstanding of best practices. Experts suggest that operational decisions often lead to problems in sustaining water and sanitation services. Improving the water system's durability would be a long-term project and would require changes to current delivery methods. Decentralised water and wastewater services could ease the strain on the network, allowing local management of smaller systems. This would also reduce construction costs and water losses.

Water and sanitation systems in refugee camps require a separate approach, as these facilities are not connected to the national network. Although the national water strategy identifies refugee camps as contributing to the country's water crisis and outlines measures to improve conditions, the camps are managed by the UN Refugee Agency (UNHCR) and UNICEF rather than by the government, with UNICEF responsible for water and sanitation services.[109] Having previously organised water provision as part of an emergency response, UNICEF, supported by the Jordanian Ministry of Water and Irrigation, completed a new water and wastewater network at the Za'atari camp in 2019, improving access and sanitation and reducing operating costs.[110] Now, every house has an in-built toilet as well as direct access to safe drinking water. Questions remain about the long-term management of the camp's water and sanitation system, as UNICEF is not well suited to carry out the functions of a utility company. However, the government is unwilling to assume responsibility for its management because of the associated political and financial costs.

A 2017 study highlighted the need for a shift away from a humanitarian relief approach and towards a more structured and planned approach to the provision of sanitation facilities in Jordan's refugee camps, using the Za'atari camp as an example.[111] This could include synchronising the construction of centralised water and sanitation infrastructures (which are vital in densely populated areas), as well as conducting public engagements, social assessments and communications to facilitate goodwill between stakeholders.

Universities could help by teaching engineering students more about camp systems, as these differ from conventional models. Operating a decentralised sanitation system for a small number of shelters requires a degree of maintenance, ideally by a resident with sufficient understanding to monitor the system. Local expectations of water supply should also be taken into consideration, as the successful sharing of limited resources requires community engagement and awareness. Camp systems depend on external funding, and it can be challenging to convince donors of the merits of particular technologies in a field that can be hard to understand.

Reducing the strain

Jordan's water and sanitation struggles have been exacerbated by inefficient supply within the national network, and by heightened demand owing to the arrival of large numbers of refugees. The country's arid climate is likely to become even drier in the coming decades as a result of climate change, and its water resources must be carefully managed as a result. The impact of water scarcity is already visible in the challenges the country is facing in providing sanitation facilities in refugee camps, where safety and privacy

have become additional concerns. There is the potential to mitigate the water and sanitation crisis by attending to systemic faults and by supporting engineering capability. This includes preventing water leakage, adopting an urban-planning approach to redesign refugee camps, shifting away from a method of emergency response to one grounded in sustainability, and improving sanitation knowledge. Engineering education could also become more multidisciplinary, and management practices could be better synchronised with engineering best practices. The proper operation of water and sanitation systems requires a combination of engineering acumen, local understanding and strong communication.

109 www.mwi.gov.jo/sites/en-us/Hot%20Issues/Strategic%20Documents%20of%20%20The%20Water%20Sector/National%20Water%20Strategy(%202016-2025)-25.2.2016.pdf
110 www.jordantimes.com/news/local/unicef-completes-construction-water-sanitation-network-zaatari-camp
111 iwaponline.com/washdev/article-pdf/7/3/521/159425/washdev0070521.pdf

Recommendations

Strengthen the evidence base and focus on quality not quantity

This report shows the breadth and diversity of engineering strengths and weaknesses around the world, highlighting that each country will have to identify its own priority engineering capability gaps and develop nuanced responses. This does not mean merely increasing the number of engineers, but also investigating the barriers that inhibit safe and innovative engineering practice. Interventions could look similar to those already outlined, but this will depend on the specific needs of each country.

We have identified several common challenges faced by countries as they work to enhance their engineering capacity. In this section, we outline these challenges as well as solutions that governments, the private sector, international funders and the global engineering community could implement to address them.

Strengthen the evidence base

Many countries struggle to collect and report accurate data on a variety of indicators that could support safe and innovative engineering.

1. **Enhance data collection and reporting accuracy**
   Few low-income countries have accurate data from a singular, reliable source that identifies their total number of engineers. When labour force surveys are conducted, some countries struggle to report an accurate representation of their workforce due to a number of factors, including resource constraints. *Governments can improve their data collection and reporting techniques to get a more accurate understanding of their engineering workforce by*:

   - **Engaging with international organisations to implement best practices**. International organisations like the ILO can provide guidance to national governments on how to develop, administer and analyse labour force surveys based on international best-practice. In 2015 the ILO launched a Labour Force Survey Pilot Programme in collaboration with the national statistical offices of 10 countries around the world, including lower-income countries such as Namibia and Cameroon.[112] The Pilot Programme provided assistance and training to the personnel designing and conducting the surveys and sought to encourage participating countries to adopt best practices in methodology to enhance the quality and global comparability of their statistics.[113]

   - **Leveraging technology to increase efficacy and reach**. National governments can invest in new technologies to improve their data collection capabilities in labour force surveys. The Danish Labour Force Survey collects data on individuals rather than households, in contrast to the majority of countries in Europe.[114] In 2016 the survey's methodology was updated to incorporate the option of data collection through online interviews.[115] This shift towards the use of digital technologies boosts efficiency and enables more comprehensive surveying of the population and country as a whole.

2. **Address alignment issues**
   Currently, there is misalignment within and across countries on how to categorise an 'engineer'. As the role of an engineer continues to expand and diversify, it is becoming increasingly important to

112 www.ilo.org/stat/Areasofwork/Standards/lfs/WCMS_627815/lang--en/index.htm
113 www.ilo.org/stat/Areasofwork/Standards/lfs/lang--en/index.htm
114 www.dst.dk/en/Statistik/dokumentation/documentationofstatistics/labour-force-survey/accuracy-and-reliability
115 www.dst.dk/en/Statistik/dokumentation/documentationofstatistics/labour-force-survey

develop a more robust categorisation of the term 'engineer' and the skills this role requires.
Governments and international organisations can do this by:

- **Using labour force surveys to disaggregate data on engineers**. Countries can design labour force surveys to collect more granular data by occupation, for example by differentiating by 'type' of engineer (civil, chemical, mechanical etc.) According to a report on agriculture in the UK by the Department for Environment, Food and Rural Affairs, the definition of an 'operator' in the UK farming industry was reworked in 2018 and the occupation reclassified. Previously, many operators had been inaccurately recorded as processors, however this change allows for the more accurate categorisation of operators as wholesalers, traders or retailers.[116]

- **Developing a global engineering skills taxonomy**. Using the most current definitions of engineering activities / skills, the engineering community can leverage technology to assess which engineering skills are needed in specific industries and roles. Nesta – a UK-based organisation that seeks to promote innovation through programmes, investment and partnerships – developed the first publicly available, data-driven skills taxonomy for the UK.[117] The taxonomy illustrates the skills needed by workers in each profession in the UK, including multiple types of engineer, and provides a framework to measure skills shortages. Nesta identified 10,500 skills that featured in 41 million job adverts between 2012 and 2017 and used machine-learning technology to examine them and establish the skills needed for each job. The more frequently a pair of skills featured in the same job advert, the more likely they were to end up in the same branch of the taxonomy and thus to be associated with a particular profession. As the work of engineers continues to expand into new industries, a skills taxonomy can be used to identify the skills needed in each field of work.

Focus on quality, not quantity

Countries often face problems not in producing engineers (in many instances there are plenty of unemployed or underemployed engineers) but in producing high-quality engineers who are able to conduct the work required of them.

1. **Provide opportunities for collaboration**
   A lack of integration between academia and the private sector has been consistently cited as a challenge to delivering effective and relevant engineering education from the perspective of professors, students and industry organisations.
   International funders, private-sector organisations and the engineering community can provide more opportunities for collaboration by:

- **Developing working partnerships that benefit both parties**. Large organisations can collaborate with academic institutions to develop academic research that addresses challenges within the industry or supports organisational goals. In 2018 the Faculty of Electronics and the Faculty of Computer Science at the Universiti Tun Hussein Onn Malaysia (UTM) collaborated with Sena Traffic Systems (STS), an industry player in the smart traffic systems market. The partnership focused on bringing together university students and industry employees to work collaboratively on a real-world problem and to exchange ideas in order to develop practical traffic solutions. Both the university and STS are keen to expand the scope of their collaboration to engage UTM professors with STS engineers.[118]

- **Sponsoring programmes for academics to gain work experience in the private sector**. Organisations in the engineering sector can develop work-shadowing and internship programmes for engineering students to provide them with real-world industry exposure. The main funding body for engineering and physical sciences research in the United Kingdom – the Engineering and Physical Sciences Research Council (EPSRC) – offers Industrial Cooperative Awards in Science & Technology (CASE) studentships. These programmes involve a PhD student undertaking research training experience in an industrial organisation.[119]

2. **Develop a more hands-on and interdisciplinary engineering curriculum**
   In many countries, engineering students have few opportunities to apply theoretical concepts learned in the classroom. Similarly, they often do not take courses outside of their engineering degree, limiting opportunities to develop other important skills.
   The global engineering community can help governments develop engineering curricula focused on project-based learning and provide opportunities for students to take classes outside of their major by:

- **Developing and sharing engineering education best practices**. The global engineering community can provide guidance on how to develop and implement effective engineering curricula. In 2000 the Massachusetts Institute of Technology (MIT) partnered with three Swedish universities to form the Conceive Design Implement Operate (CDIO) Initiative.[120] CDIO is an international scheme to reform engineering education, with over 120 other institutions participating.[121] The CDIO syllabus maintains the traditional focus on technical engineering knowledge, while also incorporating the development of personal and professional skills, and product- and system-building skills, into the framework.[122]

- **Creating alternative education models**. National governments can invest in new engineering or technical colleges that emphasise a novel hands-on approach to engineering education. The Olin College of Engineering, founded in 1997 in Needham, Massachusetts, offers an alternative engineering curriculum, focused primarily on experiential learning and multidisciplinary education.[123] There is a focus on practical work and project-based learning, both in the university

116 assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/848641/AUK_2018_09jul19a.pdf
117 data-viz.nesta.org.uk/skills-taxonomy/index.html
118 www.nst.com.my/education/2019/01/453582/importance-academia-industry-linkages
119 epsrc.ukri.org/skills/students/industrial-case/intro/
120 web.mit.edu/edtech/casestudies/cdio.html
121 www.cdio.org/cdio-organization
122 www.cdio.org/cdio-history
123 www.olin.edu/academics/curriculum/

setting and in industry, with students witnessing real-world applications of engineering concepts before being formally introduced to the underlying theory. Olin's hands-on approach is catching on, with new schools adopting its experiential method, such as NMITE in the UK.[124]

3. **Enhance on-the-job training opportunities**.
Experts consistently noted that organisations will have to provide greater training and development opportunities for employed engineers to supplement their education.
Private-sector organisations and governments can work together to develop the skills of both recent graduates and more experienced engineers by:

- **Creating opportunities for ongoing professional development**. National engineering associations can offer engineers programmes designed to enhance the technical and soft skills needed for career progression. The Engineers Training Center of the Jordan Engineers Association offers over 250 training programmes to enhance professional development.[125] These programmes cover topics from specialised engineering to contracts, administration and accounting.

- **Offering graduate schemes to those with little experience**. Industry-specific organisations can develop graduate schemes that enhance the skills of recent graduates through real-world experience. Mott MacDonald is an engineering and development consultancy that offers engineering graduate placements to those with less than 12 months of work experience.[126] Recent graduates are offered jobs in civil, electrical and software engineering and are enrolled in a three-year Accelerate Your Future programme to enhance their professional development and skill sets.

4. **Develop professional certifications and standards**.
Many countries still lack professional certifications and standards for engineers. This acts as an impediment to hiring and can lead to increased competition for jobs (for example, engineers competing with technicians for the same job). Similarly, a lack of standards can raise questions about the efficacy and safety of engineering practices.
Governments, international organisations and the global engineering community can work together to develop a set of national professional certifications or standards by:

- **Encouraging transnational collaboration to develop accreditations of engineering qualifications**. The engineering community can support regional and international efforts to establish transboundary accreditation schemes of engineering qualifications. Across Africa, there are various sub-regional initiatives and bodies established for co-operation in engineering regulation and the accreditation of engineering qualifications. For example, the African and Malagasy Council for Higher Education (CAMES) recognises and accredits degrees awarded in all Francophone African countries, and the Engineering Regulation Boards of Kenya, Tanzania and Uganda signed a Mutual Recognition Agreement in which each country agreed to recognise all engineering degrees accredited in the others.[127] These initiatives enable greater labour mobility among engineers within the continent and can be expanded to incorporate other African countries.

- **Enhancing safety standards in engineering-intensive industries**. National governments can implement stricter regulations on safety standards in engineering intensive industries. In Saudi Arabia, the National Strategic Program for Occupational Safety and Health requires that businesses implement an occupational safety and health strategy. However, an official from the Ministry of Labour and Social Development noted an absence of health and safety precaution implementation across businesses.[128] As a result, the Ministry introduced a resolution in 2018 detailing prescriptive safety measures to which employers must adhere. Employers operating in medium- and high-risk environments, such as construction, building and manufacturing, must comply with a greater number of safety requirements.[129]

124 nmite.ac.uk/study-at-nmite/why-study-with-us/
125 www.jea.org.jo/portal/en/training-center-2/
126 www.mottmac.com/
127 http://documents.worldbank.org/curated/en/773831468007776683/pdf/860620BRI0WB0H00Box382147B00PUBLIC0.pdf
128 http://saudigazette.com.sa/article/538111/SAUDI-ARABIA/Occupational-safety-plan-must-for-firms-with-more-than-49-workers
129 www.shrm.org/resourcesandtools/legal-and-compliance/employment-law/pages/global-saudi-arabia-safety-resolution.aspx

Appendix

Appendix 1

Full Engineering Index 2019 Results

For detailed information on the methodology used in this research programme please review the *Global Engineering Capability Review: Methodology* document.
www.raeng.org.uk/capability-review-methodology

	KNOWLEDGE
1	United States
2	China
3	Japan
4	Republic of Korea
5	Germany
6	United Kingdom
7	France
7	Switzerland
9	Sweden
10	Denmark
11	Australia
12	Canada
13	Austria
14	Belgium
14	Italy
16	Finland
17	Netherlands
17	Singapore
19	Spain
20	India
21	Brazil
22	Hong Kong
23	Norway
24	Russian Federation
25	Czech Republic
26	Turkey
27	Iceland
27	Portugal
29	Malaysia
30	Slovenia
31	Greece
32	Ireland
32	New Zealand
34	Hungary
35	Poland
36	Iran
37	Thailand
38	South Africa
39	Egypt
39	Estonia
41	Saudi Arabia
42	Luxembourg
43	Mexico
44	UAE
45	Serbia
46	Slovakia
47	Croatia
48	Lithuania
49	Bulgaria
50	Algeria
51	Argentina
51	Jordan
53	Chile

	LABOUR FORCE
1	Singapore
2	Finland
3	Germany
4	Hong Kong
4	Portugal
6	Republic of Korea
7	China
8	Japan
9	Estonia
10	Sweden
10	Viet Nam
12	Canada
13	Poland
14	Russian Federation
15	Switzerland
16	Malaysia
17	Austria
18	Norway
19	Iceland
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21	France
22	Italy
23	Slovenia
24	Denmark
24	Netherlands
26	Spain
27	New Zealand
28	Belgium
29	United Kingdom
30	United States
31	Australia
31	Czech Republic
33	Ireland
34	UAE
35	Lithuania
36	Kazakhstan
37	Croatia
38	Qatar
39	Hungary
40	Romania
41	Argentina
42	Latvia
43	Chile
44	Mexico
45	Cyprus
46	Slovakia
47	Jordan
48	Malta
49	Luxembourg
50	Tunisia
51	Bulgaria
52	Lebanon
53	Turkey

	ENGINEERING INDUSTRY
1	Japan
2	Germany
3	Singapore
4	China
5	Republic of Korea
6	Iran
6	Switzerland
8	United States
9	Qatar
10	Hungary
11	Sweden
12	Slovenia
13	France
14	Czech Republic
15	Viet Nam
16	Finland
17	Netherlands
18	Ireland
19	Mexico
20	United Kingdom
21	Austria
22	Hong Kong
23	India
23	Slovakia
25	Philippines
26	Denmark
27	Morocco
28	Norway
29	Italy
30	Belgium
31	Poland
32	Malaysia
33	Romania
34	Thailand
35	Colombia
35	Spain
37	Croatia
38	Peru
39	Canada
40	Estonia
41	Russian Federation
42	Ukraine
43	Saudi Arabia
44	Brazil
45	Serbia
46	Latvia
47	Australia
48	Bulgaria
49	Lithuania
49	South Africa
51	Bahrain
51	Egypt
53	Turkey

	INFRASTRUCTURE
1	Switzerland
2	Finland
3	France
4	Denmark
5	Sweden
6	Singapore
7	United States
8	Canada
9	Norway
10	Hong Kong
11	Netherlands
12	Japan
13	Austria
14	Germany
15	Belgium
16	Australia
17	Spain
18	Ireland
19	Luxembourg
20	Iceland
21	Republic of Korea
22	Estonia
23	Oman
24	Panama
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39	Slovakia
40	South Africa
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45	Cyprus
47	Poland
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49	Kuwait
50	Mexico
51	Egypt
52	Russian Federation
53	Kazakhstan

	DIGITAL INFRASTRUCTURE
1	Singapore
2	Denmark
3	Netherlands
4	Switzerland
5	United States
6	Hong Kong
7	Luxembourg
8	Germany
9	Republic of Korea
10	Iceland
11	Sweden
12	Estonia
13	Norway
14	Ireland
15	France
16	Malta
17	Canada
18	Japan
19	Spain
20	Finland
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22	Lithuania
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25	New Zealand
26	Czech Republic
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35	Italy
35	Poland
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37	Slovakia
39	Bulgaria
40	Russian Federation
41	Qatar
42	Bahrain
43	Uruguay
44	China
45	Thailand
46	Serbia
47	Croatia
48	Panama
49	Brazil
50	Kazakhstan
51	Cyprus
52	Argentina
52	Saudi Arabia

	SAFETY STANDARDS
1	Singapore
2	Bahrain
3	Australia
4	Ireland
5	Netherlands
6	Iceland
7	Kuwait
8	Honduras
9	United Kingdom
10	New Zealand
11	Denmark
12	Sweden
13	Malta
14	Spain
15	Canada
16	Luxembourg
16	Norway
16	Slovenia
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19	Mauritius
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22	Germany
23	Croatia
23	Greece
25	Costa Rica
26	Portugal
27	Italy
28	Switzerland
29	Tunisia
30	Cyprus
31	Czech Republic
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34	El Salvador
35	Republic of Korea
36	Philippines
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37	Japan
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43	Serbia
44	Chile
44	Slovakia
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47	Bulgaria
48	Mexico
49	Sri Lanka
50	Poland
51	Belgium
52	Finland
53	Bosnia and Herzegovina

	KNOWLEDGE		LABOUR FORCE		ENGINEERING INDUSTRY		INFRASTRUCTURE		DIGITAL INFRASTRUCTURE		SAFETY STANDARDS
54	Romania	54	Colombia	54	Iceland	54	Bulgaria	54	South Africa	54	France
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56	Cyprus	55	Thailand	56	Argentina	56	Bahrain	56	Mauritius	56	Saudi Arabia
57	Ukraine	55	Uruguay	57	Cyprus	57	Turkey	57	Turkey	57	Oman
58	Lebanon	58	Albania	57	Portugal	58	Argentina	57	Ukraine	58	Romania
59	Qatar	59	Algeria	59	Malta	58	Mauritius	59	Kuwait	59	United States
59	Viet Nam	60	Brazil	60	Oman	60	Armenia	60	Oman	60	Estonia
61	Morocco	61	Peru	61	Indonesia	61	Albania	61	Greece	61	Dominican Republic
62	Colombia	62	Indonesia	62	Kazakhstan	62	Morocco	62	Albania	61	Jordan
63	Latvia	63	Georgia	62	New Zealand	63	China	63	Colombia	63	Armenia
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65	Malta	n/a	Azerbaijan	66	Kuwait	66	Iran	66	Bosnia and Herzegovina	66	Peru
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68	Nigeria	n/a	Benin	69	Costa Rica	69	Romania	69	Peru	69	Algeria
70	Dominican Republic	n/a	Bosnia and Herzegovina	70	Guyana	70	Colombia	70	Azerbaijan	70	China
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98	Honduras	n/a	Sri Lanka	98	Madagascar	n/a	Nepal	98	Mozambique	n/a	Nepal
98	Madagascar	n/a	Ukraine	99	Burundi	n/a	Rwanda	99	Benin	n/a	Rwanda

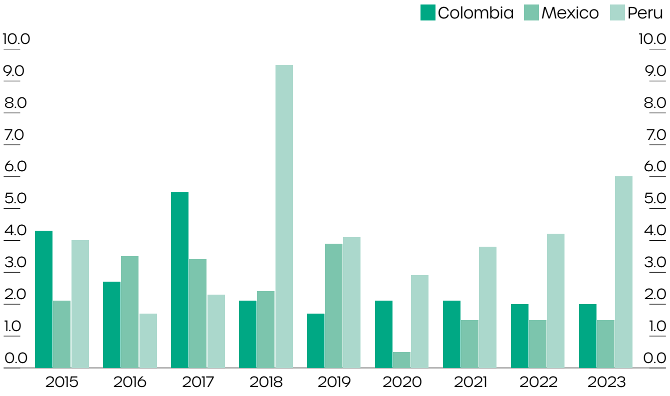
Appendix 2

Sectoral GDP growth forecasts by region

Americas

Agriculture

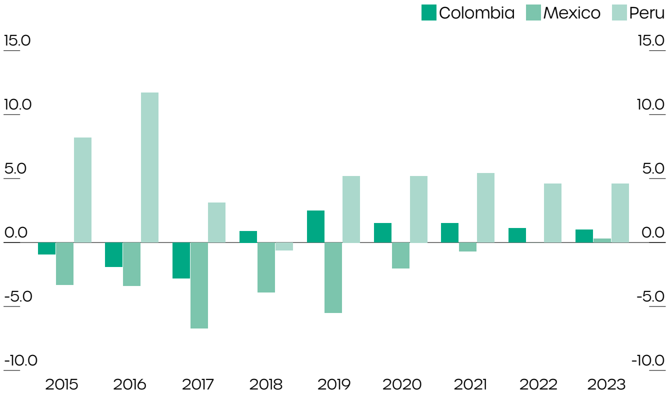
GDP growth rate (%) for Colombia, Mexico and Peru



Source: The Economist Intelligence Unit.

Mining and utilities

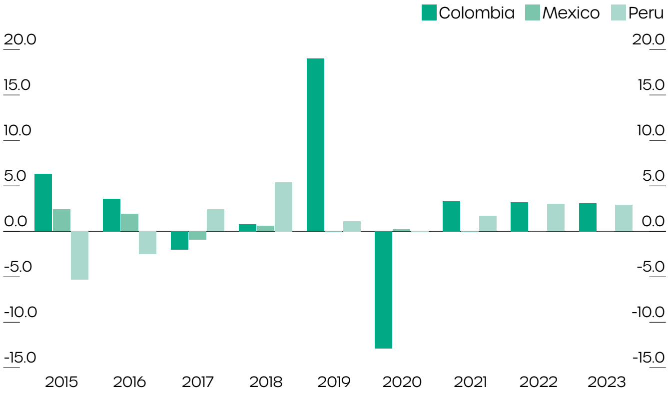
GDP growth rate (%) for Colombia, Mexico and Peru



Source: The Economist Intelligence Unit.

Construction

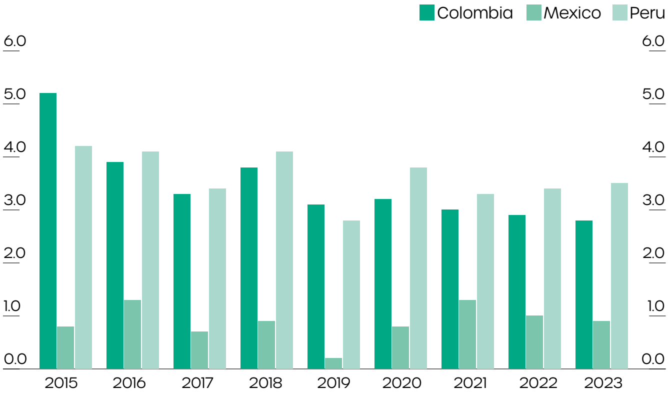
GDP growth rate (%) for Colombia, Mexico and Peru



Source: The Economist Intelligence Unit.

Public administration and other services

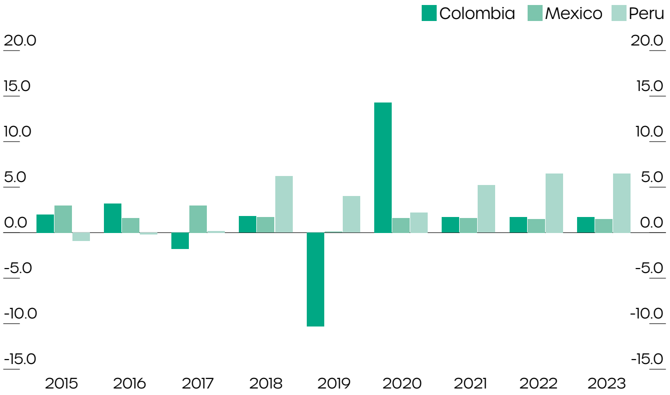
GDP growth rate (%) for Colombia, Mexico and Peru



Source: The Economist Intelligence Unit.

Manufacturing

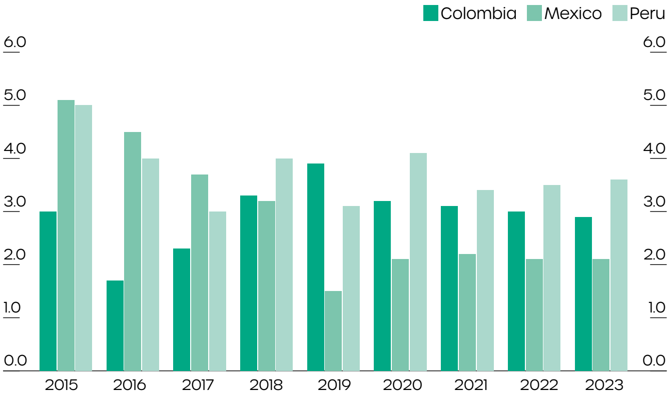
GDP growth rate (%) for Colombia, Mexico and Peru



Source: The Economist Intelligence Unit.

Trade, transportation and business administration

GDP growth rate (%) for Colombia, Mexico and Peru

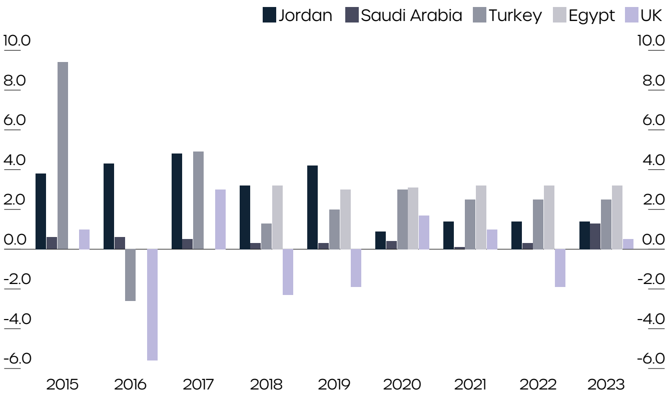


Source: The Economist Intelligence Unit.

Europe and the Middle East

Agriculture

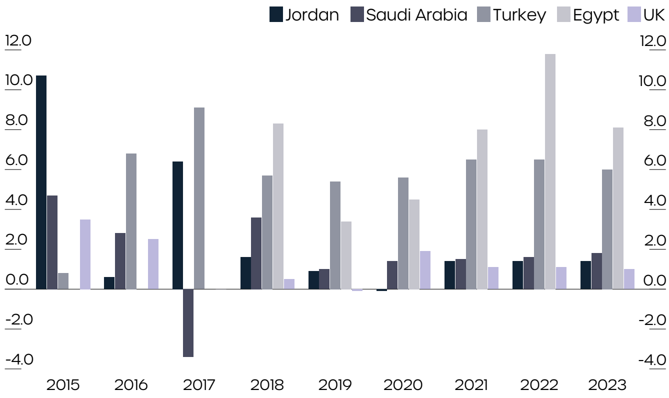
GDP growth rate (%) for Jordan, Saudi Arabia, Turkey, Egypt and the UK



Source: The Economist Intelligence Unit.

Mining and utilities

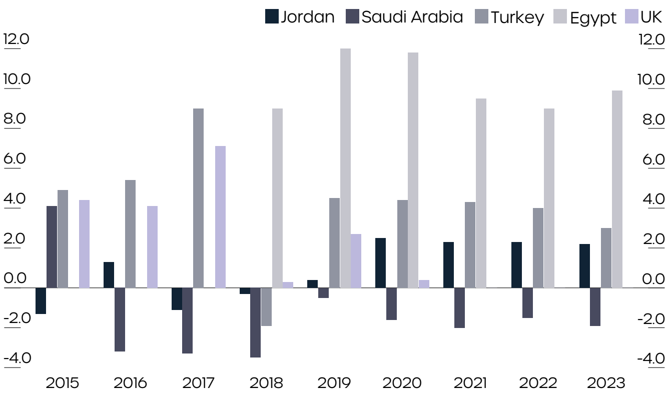
GDP growth rate (%) for Jordan, Saudi Arabia, Turkey, Egypt and the UK



Source: The Economist Intelligence Unit.

Construction

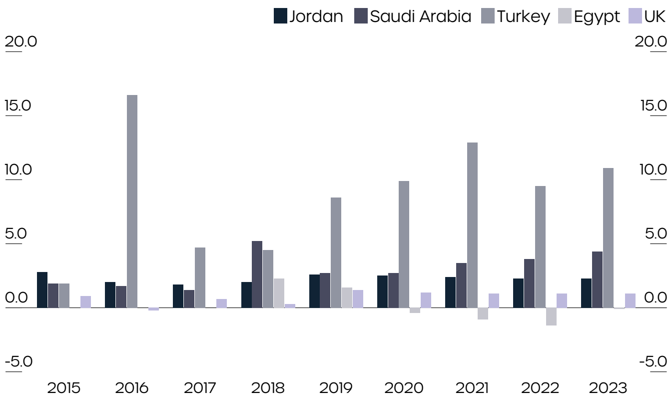
GDP growth rate (%) for Jordan, Saudi Arabia, Turkey, Egypt and the UK



Source: The Economist Intelligence Unit.

Public administration and other services

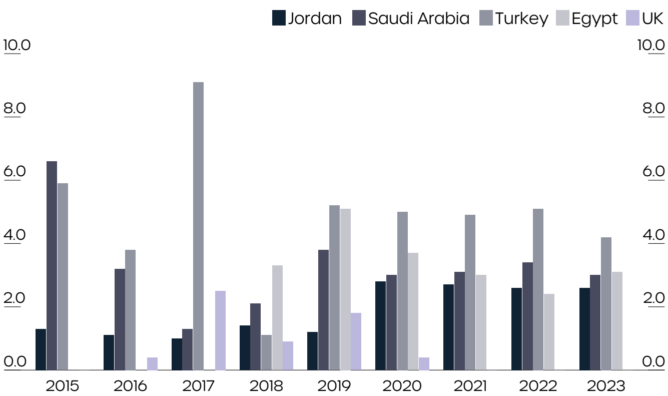
GDP growth rate (%) for Jordan, Saudi Arabia, Turkey, Egypt and the UK



Source: The Economist Intelligence Unit.

Manufacturing

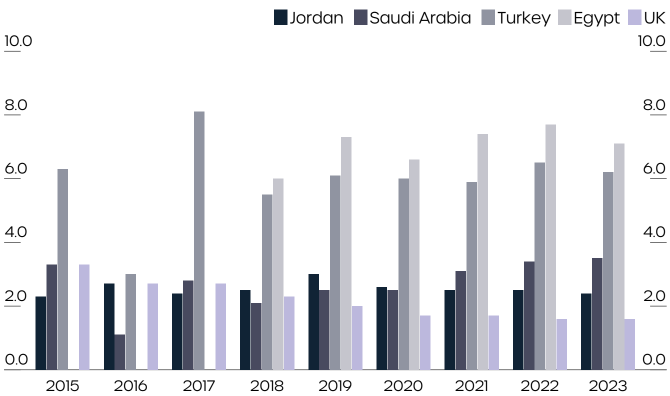
GDP growth rate (%) for Jordan, Saudi Arabia, Turkey, Egypt and the UK



Source: The Economist Intelligence Unit.

Trade, transportation and business administration

GDP growth rate (%) for Jordan, Saudi Arabia, Turkey, Egypt and the UK

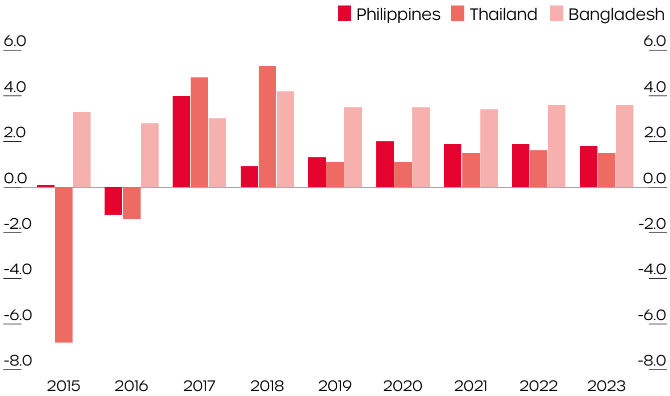


Source: The Economist Intelligence Unit.

Asia

Agriculture

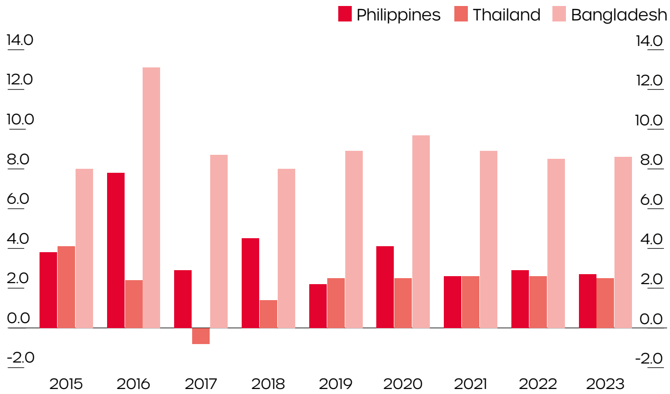
GDP growth rate (%) for the Philippines, Thailand and Bangladesh



Source: The Economist Intelligence Unit.

Mining and utilities

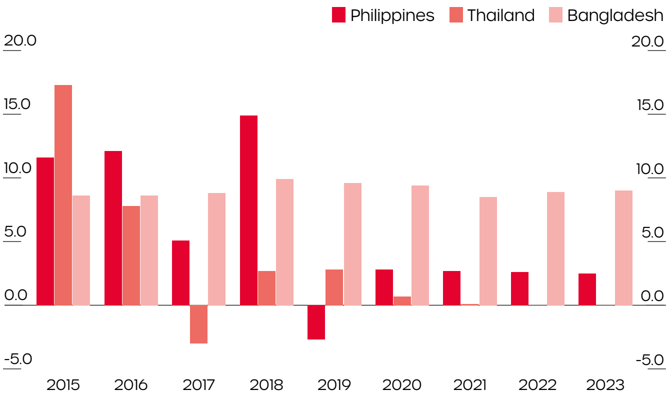
GDP growth rate (%) for the Philippines, Thailand and Bangladesh



Source: The Economist Intelligence Unit.

Construction

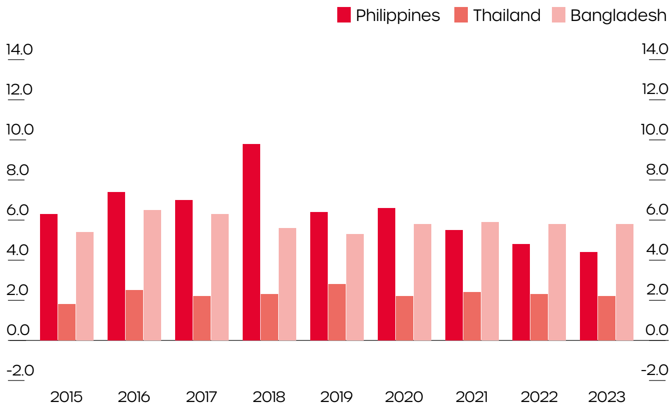
GDP growth rate (%) for the Philippines, Thailand and Bangladesh



Source: The Economist Intelligence Unit.

Public administration and other services

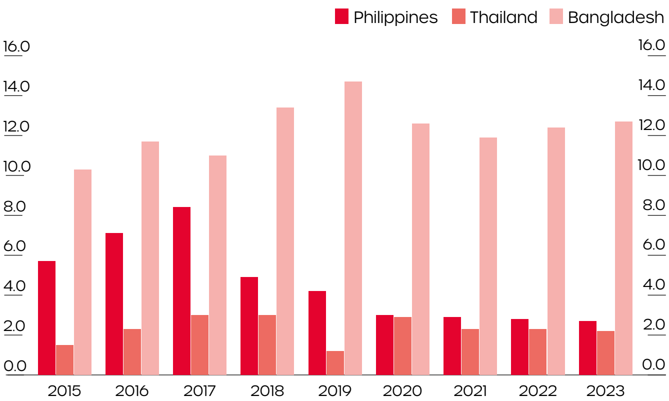
GDP growth rate (%) for the Philippines, Thailand and Bangladesh



Source: The Economist Intelligence Unit.

Manufacturing

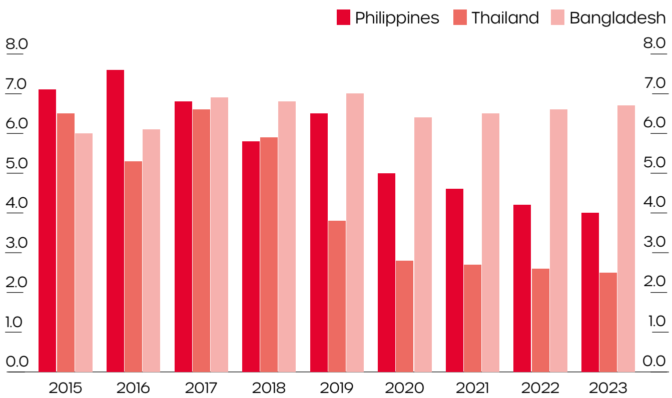
GDP growth rate (%) for the Philippines, Thailand and Bangladesh



Source: The Economist Intelligence Unit.

Trade, transportation and business administration

GDP growth rate (%) for the Philippines, Thailand and Bangladesh

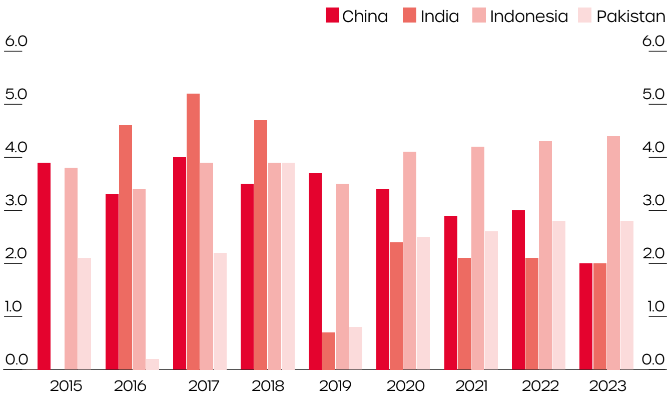


Source: The Economist Intelligence Unit.

Asia *continued*

Agriculture

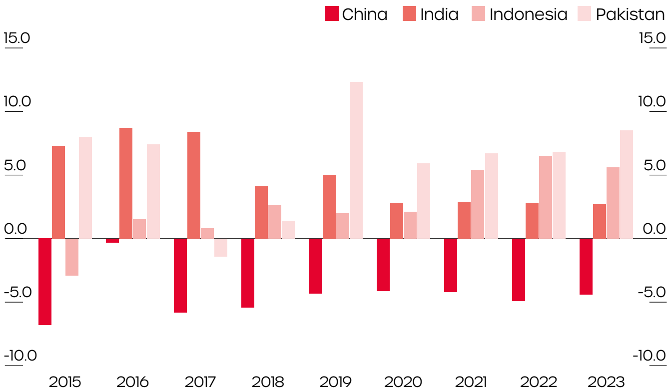
GDP growth rate (%) for China, India, Indonesia and Pakistan



Source: The Economist Intelligence Unit.

Mining and utilities

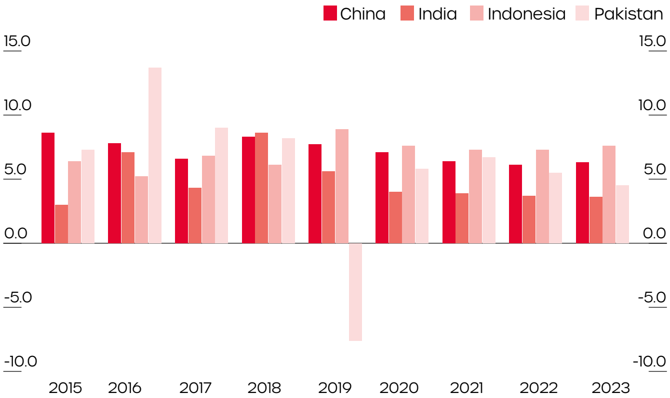
GDP growth rate (%) for China, India, Indonesia and Pakistan



Source: The Economist Intelligence Unit.

Construction

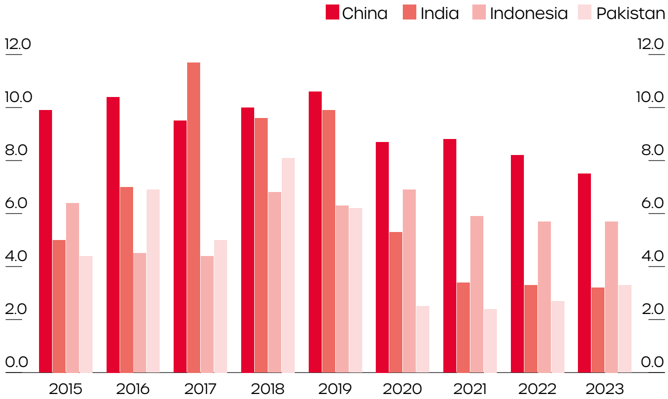
GDP growth rate (%) for China, India, Indonesia and Pakistan



Source: The Economist Intelligence Unit.

Public administration and other services

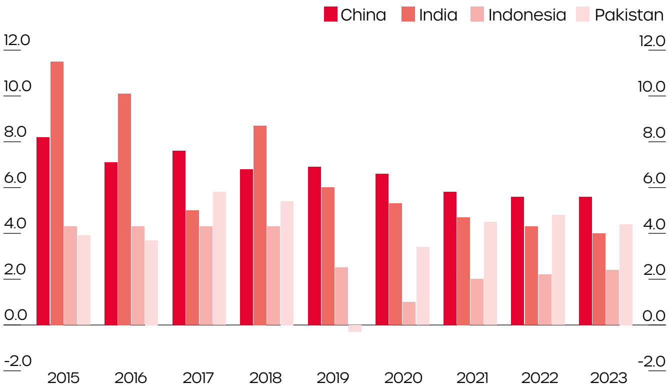
GDP growth rate (%) for China, India, Indonesia and Pakistan



Source: The Economist Intelligence Unit.

Manufacturing

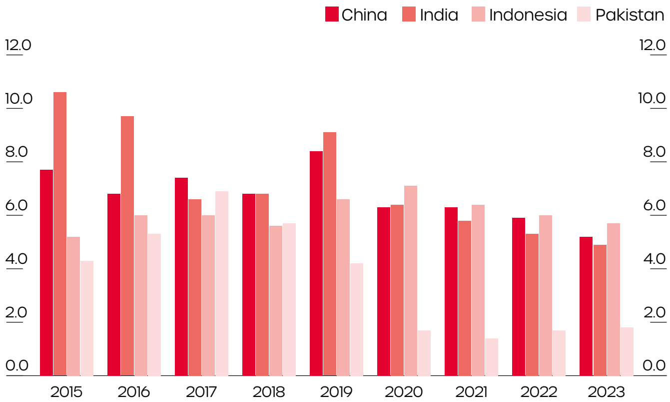
GDP growth rate (%) for China, India, Indonesia and Pakistan



Source: The Economist Intelligence Unit.

Trade, transportation and business administration

GDP growth rate (%) for China, India, Indonesia and Pakistan

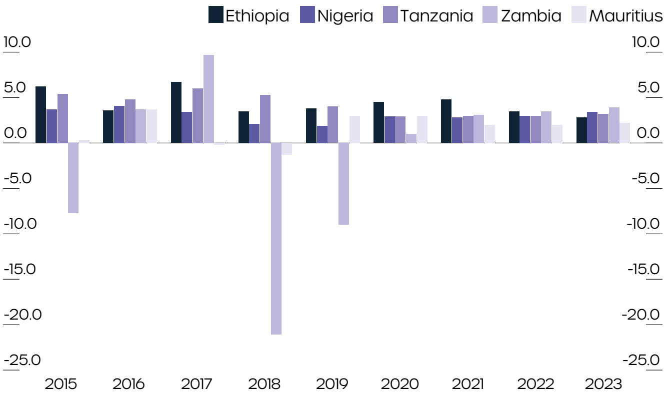


Source: The Economist Intelligence Unit.

Africa

Agriculture

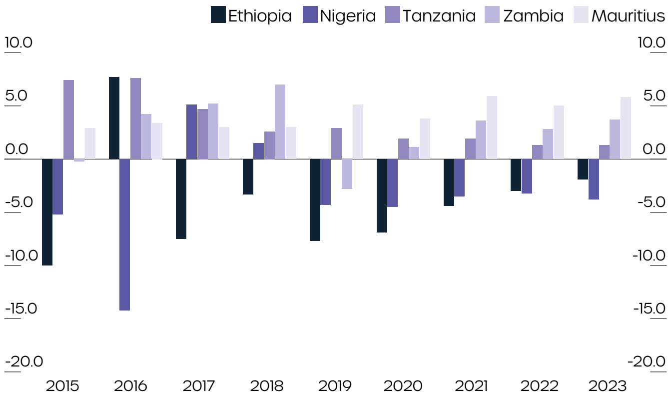
GDP growth rate (%) for Ethiopia, Nigeria, Tanzania, Zambia and Mauritius



Source: The Economist Intelligence Unit.

Mining and utilities

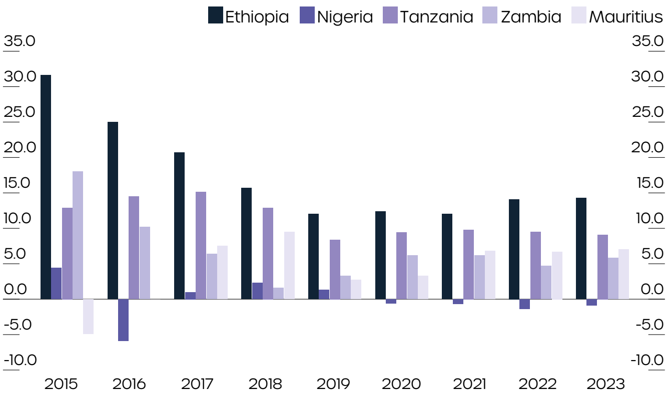
GDP growth rate (%) for Ethiopia, Nigeria, Tanzania, Zambia and Mauritius



Source: The Economist Intelligence Unit.

Construction

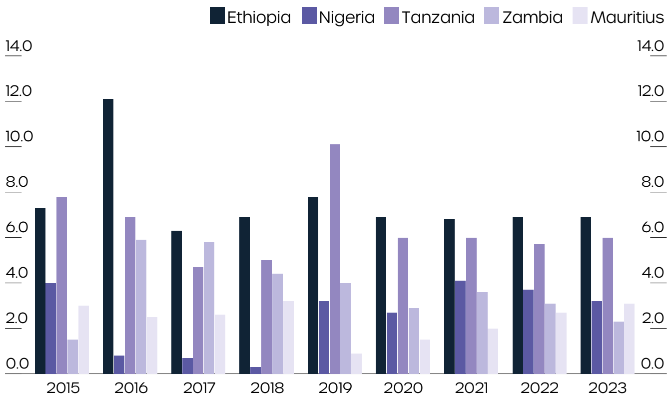
GDP growth rate (%) for Ethiopia, Nigeria, Tanzania, Zambia and Mauritius



Source: The Economist Intelligence Unit.

Public administration and other services

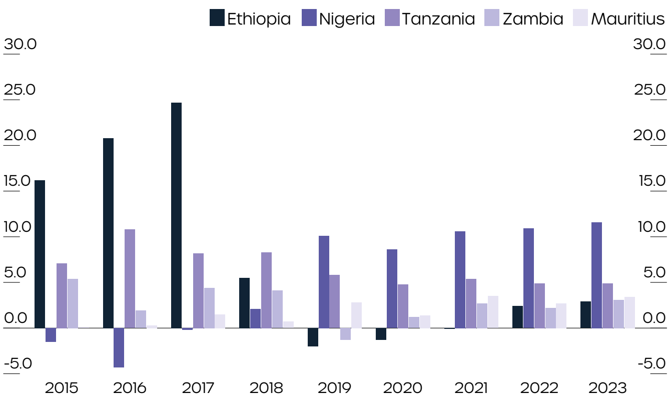
GDP growth rate (%) for Ethiopia, Nigeria, Tanzania, Zambia and Mauritius



Source: The Economist Intelligence Unit.

Manufacturing

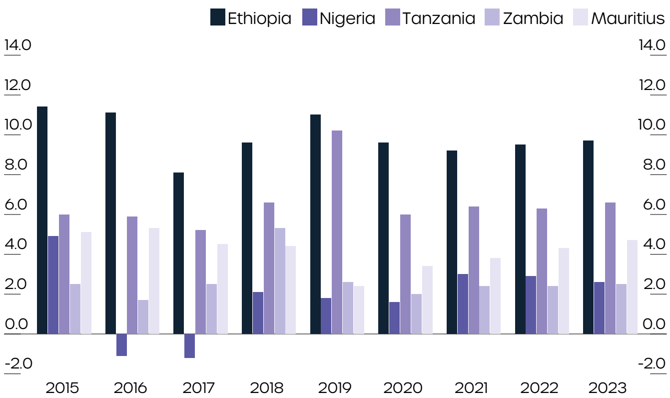
GDP growth rate (%) for Ethiopia, Nigeria, Tanzania, Zambia and Mauritius



Source: The Economist Intelligence Unit.

Trade, transportation and business administration

GDP growth rate (%) for Ethiopia, Nigeria, Tanzania, Zambia and Mauritius



Source: The Economist Intelligence Unit.

Lloyd's Register Foundation

Our vision

Our vision is to be known worldwide as a leading supporter of engineering-related research, training and education, which makes a real difference in improving the safety of the critical infrastructure on which modern society relies. In support of this, we promote scientific excellence and act as a catalyst working with others to achieve maximum impact.

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• To secure for the benefit of the community high technical standards of design, manufacture, construction, maintenance, operation and performance for the purpose of enhancing the safety of life and property at sea, on land and in the air.

• The advancement of public education including within the transportation industries and any other engineering and technological disciplines.

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We have three strategic priorities:

- Make the UK the leading nation for engineering innovation and businesses
- Address the engineering skills and diversity challenge
- Position engineering at the heart of society

We bring together engineers, policymakers, entrepreneurs, business leaders, academics, educators and the public in pursuit of these goals.

Engineering is a global profession, so we work with partners across the world to advance engineering's contribution to society on an international, as well as a national scale.

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